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EFFECT OF IRRIGATION SYSTEMS UNDER DIFFERENT NITROGEN AND ORGANIC MANURE LEVELS ON POTATO PRODUCTIVITY

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Abstract

Field studies were conducted in the two successive winter seasons of 2016/17 and 2017/18 at Nubaria district, Behaira Governorate, Egypt (84 Km Alexandria / Cairo Desert Road) in calcareous coarse sandy soil. The trials aimed to study the effect of nitrogen level *i.e.*; 0, 75, 90, 105 and 120 kg N fd^{-1}* and compost 10, 20, 30 and 40 m^3 fd^{-1} under two irrigation types (flood and sprinkler) on potato yield and yield components. The results showed significant main effects of fertilizer and compost application on no. of tubers $plant^{-1}$ and overall tuber yield. Tuber yield significantly increased with increasing the rate of compost addition for each 10 m^3 increase in application rate, demonstrating the responsiveness of potato to organic matter addition. Compost applied at 40 m^3 surpassed the yield at 10 m^3 by 45%. The untreated control yields 4.6 t and yields were progressively increased by fertilizer addition to 9.0 t with 120 kg N. There were no significant differences overall between flood and sprinkler irrigation although there is a small trend (5% increase) for higher yields under flood irrigation but the amount of irrigation water used was less about 10% in sprinkler system than flood irrigation system. All fertilizer treatments under flood irrigation gave lower water productivity than that those under sprinkler irrigation system Successive increments were reported in water productivity as N level increased and the highest water productivity was reported when the plants were fertilized with 105 or 120 kg N fed^{-1} without significant difference between these two treatments. All compost application levels resulted in significant increases in water productivity (kg m^{-3}) compared with the normal farmer practice (FYM 20 m^3 + 90 kg N) and the highest water productivity recorded when the plants were fertilized with 40 m^3 fed^{-1}. The results of fertilizer equivalency suggested that the compost has N fertilizer equivalency value of 50%. A statistically significant interaction with the rate of N application ($P = 0.037^*$) and irrigation method on tuber yield (P = 0.035) for compost – amended soil. These results indicate the high potentiality for improving potato yield and higher water productivity per water unit in such poor soil through manuring with compost and rationalizing the irrigation water using sprinkler irrigation system.

Key words : Potato, Compost, Nitrogen, Yield.

* fd = feddan = 4200 m^2

Introduction

The newly reclaimed soils in Egypt are desert soils and characterized by low fertility and poor moisture retention. Since animal manure is no longer readily available, other materials such as composted should be tested and used to meet soil nutrient and organic matter requirements. Compost use in agriculture is widely regarded as good source of organic fertilizer. Organic fertilizer has beneficial effects including the increases of hydraulic conductivity, raises the water holding capacity and soil micro-organism biological characteristics, changes the improved soil structure and soil pH where increases or decreases, depending on the soil contents and type and characteristics of organic fertilizer, elevates the soil aggregation and water infiltration and reduces the frequency of plant diseases (Olson and Papworth, 2006 and Tagoe *et al.*, 2008). Using of animal manure such as cattle manure has positively beneficial effects on vegetative growth, yield and tuber quality (Kolay, 2007;

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White *et al.,* 2007; Najm *et al.,* 2010; Balemi *et al.,* 2012 and Najm *et al.,* 2013). It is well known that organic manure improved the structure of the soil and this consequently encourage the plant to have a good growth. Moreover, the slow released nutrients from organic manure are beneficial to plants. All these reasons resulted in improve plant growth. Such results were illustrated by Filip and Muller (1984), Kadhim (1986), Borin *et al*., (1987) and Moustafa (1994). The value of organic fertilizers as a source of nutrients for potato plants has been revived by several investigators such as Striban *et al*., (1984); Tashkhodzhaev (1985); Borin *et al.,* (1987); Reichbuch *et al*., (1989); Grewal (1990) and Blecharczyk and Shrzyczak (1996). Studies were also made by several researchers on the effects of organic and inorganic fertilizers on vegetative growth, yield, and chemical compositions of potato, such as Eiecharczyk and Malecka (2000); Danilchenko *et al*., (2005) and Singh and Kushwah (2006). Najm *et al.,* (2010, 2013) indicated that nitrogen fertilizer, cattle manure and their combination had highly significant effects on tubers yield. The maximum tubers yield (36.8 tons ha^{-1}) was obtained by the utilization of 150 kg nitrogen per hectare + 20 tons cattle manure. Such *et al.,* (2015) they observed that potato yield was increased by the combined use of animal manure such as cow dung and NPK (20 : 10 : 10) compared with sole application of cow dung or NPK mineral fertilizer. It has been reported that, combined application of both organic and inorganic give higher yield than is obtained from applying either of them (Najm *et al*., 2010).

In Egypt, national yield and variety trials data over several locations on different crop species clearly indicated that soil nutrient stress is the most significant factor controlling crop yield. Farmers should tackle this problem through the application of both organic and inorganic fertilizers, which amends the soil environment Shahein *et al*., (2014).

Irrigation of crops that sensitive to water stress such as potato requires a systematic approach to irrigation scheduling (Ayas, 2013). This involves preventing the soil water deficit from falling below threshold level for a particular crop and soil condition. Increasing potato irrigation efficiency by modern systems cause a significant increase in the growth parameters, yield of tubers **(**Badr *et al.,* 2012). Potato is an essential crop in Egypt and the cultivated area of potato in 2016 reached about 376631 feddans, which yielded 4113441 tons of tubers with an average of about 10.921 tons per feddan (Agricultural Economics of Egypt, 2018). It demands a great quantity of organic manure and nitrogen; however, due to some environmental problems like nitrate leaching in the desert lands and the lack of organic manure, it is important to find alternative organic resources. Shahein *et al*., (2014) showed that integrated use in different proportion of the combined use of organic manure with inorganic fertilizer application was recognized as the most suitable way for ensuring high quantity and quality crop yield and reducing the harmful effects of using nitrogenous chemical fertilizers and for sustaining soil fertility status.

Therefore, the objective of the study was to investigate the effect of organic manure and nitrogen on potato yield and yield components under two irrigation types (flood and sprinkler). Another objective was to evaluate the fertilizer equivalency value of the organic manure.

Materials and Methods

Field studies were conducted in the winter seasons of 2016/2017 and 2017/2018 on a private farm, Nubaria District, Behaira Governorate, Egypt (84 km Alex-Cairo desert road), in a newly reclaimed desert soil. The experimental area was 0.25 ha (0.59 feddan), the physical and chemical analysis of the soil was sandy gravelly (sand 67.4 %, gravels 29.3 % and clay + silt 3.3 %) with (pH 8.5; EC 0.24 dsm^{-1}; OM 0.73 %; $CaCO_3$ 5.0 %, N 1400 ppm; P 132 ppm; K 826 ppm; Fe 3694 ppm; Mn 56.8 ppm; Zn 17.8 ppm; Cu 3.78 ppm; Cd 0.02 ppm; pb 1.36 ppm; Ni 2.9 ppm). The experiment included 20 treatments which were the combination of two irrigation types (flood and sprinkler) and 10 fertilizer treatments included 5 nitrogen fertilizer levels *i.e.*; 0, 75, 90, 105 and 120 kg fd^{-1} and 4 compost levels *i.e.*; 10, 20, 30 and 40 m^3 fd^{-1}. as well as the conventical farm practice treatment (FYM 20 m^3 + 90 kg N fd^{-1}). The experimental design was split-plot with 4 replicates where the irrigation system treatments occupied the main plots and the fertilizer treatments were allocated in the sub-plots. The experimental area was ploughed twice, ridged and divided to experimental unites each of 21 m^2 = 1/200 fd. Both types of organic manures were applied and manually calibrated on volumetric basis to the assigned plots. The Chemical of compost and livestock manure are presented in (Table 1).

In order to secure homogenous incorporation with the soil surface layer, a rotary cultivator was used. During the soil preparation all plots were fertilised with calcium super phosphate at 31 kg fd^{-1} P_2O_5. Potato cultivar Spunta was sown in hills 25 cm apart on November 17*th* and 23*th* in 2016 and 2017 at rate of 1 ton by hand in ridges. Nitrogen fertilizer as ammonium sulphate (20.6 % N) levels were applied 30 and 45 days from sowing as well

Table 1: Chemical properties (mean values and 95% confidence limit) of compost and livestock manure (Units: density as t m^3; ds, N, P, K and Fe as %, other elements as mg kg^{-1}).

Manure	Density	ds	N	P	N	P	K	Fe	Mn	Zn	Cu
FYM	0.6 ±0.2	90.9 ±5.3	0.9 ±0.3	0.7 ±0.3	0.9 ±0.3	0.7 ±0.3	0.7 ±0.2	1.3 ±0.5	264.0 ±13.6	99.0 ±23.0	88.0 ±25.0
Compost	0.6±0.2	79.2 ±9.5	2.5 ±1.4	1.4 ±2.1	2.5 ±1.4	1.4 ±2.1	0.8 ±0.9	0.3 ±0.2	196.0 ±9.2	174.0 ±29.3	125.0 ±21.5

as a potassium sulphate (48 % K_2O) was applied at 72 kg K_2O fd^{-1}. Irrigation was carried out as followed in the district. Weeds were controlled by manual cultivation after 21 and 35 days from sowing. Harvest was done at early April. Five plants were pulled gently to determine number of tubers per plants, tuber weight and tuber yield per plant. Tuber yield per feddan was determined from a central area of 10.5 m^2 = 1/400 fd at each plot.

Chemical analyses for soil (0 - 30 cm depth) and manure were carried out according to the methods described by A.O.A.C. (1990), Chapman and Pratt (1961) and Jackson (1969).

The water use efficiency (WUE) was calculated according to FAO (1998) as follows: The ratio of crop yield (y) to the total amount of irrigation water use in the field for the growth season (IR); WUE (Kg m^{-3}) = Y (kg) / IR (m^3). The average weekly irrigation requirements (m^3 fd^{-1}).

The N equivalency value was estimated according to Colwell (1994) by the following equation:

$$\text{N equivalency (\%)} = \frac{1/b(y-a)}{N} \times 100$$

Where a is the regression intercept value), b is the regression coefficient, y is the mean tuber yield recorded for the plots supplied with compost at a rate of 10 m^3 fd^{-1} and N is the rate of N application at 10 m^3 fd^{-1} of compost.

The analysis of variance of split plot experiment was carried out using MSTAT-C Computer Software (MSTAT-C, 1988), after testing the homogeneity of the error according to Bartlett's test, combined analysis for both seasons were done. Means of the different treatments were compared using the least significant difference (LSD) test at P<0.05.

Results

Data presented in table 2 show the effect of irrigation system. It is clear that there were no significant differences between flood and sprinkler irrigation, although there is a small trend (5 % increase) for higher yields under flood irrigation, which may be expected as the greater quantity of water applied compared to sprinkler irrigation. There was no significant difference due to irrigation system on water productivity of potato per one m^3 of irrigated water although greater marginal water productivity was evident for sprinkler irrigation than flood irrigation.

The data of the effect of fertilizer treatments on yield characteristics of potato show that there were significant main effects of fertilizer and compost on number of tubers per plant and overall tuber yield, but not on tuber weight (Table 3). The untreated control yielded 4.6 ton fd^{-1}. and yields were progressively increased by fertilizer addition to 9.1 ton with 120 kg N (Fig. 1). The number of tubers also increased from 6 to 10 per plant. The number of tubers per plant and tuber yield increased with increasing rate of compost addition. For each 10 m^3 increase in application rate, the increase in yield was significant, demonstrating the responsiveness of potato to organic matter addition. Compost applied at 40 m^3 had a yield 45 % greater than that from 10 m^3, and was also significantly greater than the yield from the highest rate of fertilizer. Farmyard manure (20 m^3) plus fertilizer (90 kg N) represented farmer practice. The yield from this treatment was not significantly different to compost at 10 m^3 or fertilizer applied on its own at 90 kg N.

Concerning fertilizer treatment effects on water productivity regardless irrigation system, data presented in Table 3 and Fig. (2) show successive increments in water productivity as N level increased and the highest water productivity was reported when the plants were fertilized with 105 or 120 kg N fd^{-1} without significant difference between these two treatments. All compost application levels resulted in significant increases in water productivity (kg m^{-3}) compared with the normal farmer practice (FYM 20 m^3 + 90 kg N fd^{-1}) and the highest water productivity recorded when the plants were fertilized with 40 m^3 fd^{-1}.

Data presented in table 4 show the interaction effect of irrigation system and fertilizer treatments. There were highly significant interactive effects were detected for all parameters with the exception of mean tuber weight. This effect was due to the significantly greater yields from compost applied at 10 m^3 under flood irrigation, compared with the equivalent rate under sprinkler irrigation. Yields from the higher levels of compost application did not show the same effect and the lack of an overall effect of irrigation method is confirmed by the analysis of main effects (Table 1). Data in Table 3 and Fig. (2) show significant differences resulted from the

Table 2: Effect of irrigation system on yield characteristics of potato.

Irrigation system	No. of tubers plant^{-1}	Tuber weight (g)	Tuber yield plant^{-1} (g)	Tuber yield fd^{-1} (ton)	Water productivity kg m^{-3}
Flood	9.1	59.9	543	7.83	2.237
Sprinkler	8.8	59.8	519	7.45	2.40
Probability	0.363	0.431	0.115	0.117	0.850
LSD at 0.05	ns	ns	ns	ns	ns

Table 3: Effect of fertilizer treatments on yield characteristics of potato.

Treatment	No. of tubers plant^{-1}	Tuber weight (g)	Tuber yield plant^{-1} (g)	Tuber yield fd^{-1} (ton)	Water productivity kg m^{-3}
Control	6.0	54.2	321	4.63	1.232
75 kg N	8.0	57.8	462	6.65	2.056
90 kg N	8.0	60.4	478	6.83	2.013
105 kg N	9.0	65.6	576	8.30	2.819
120 kg N	10.0	65.5	635	9.13	2.889
Compost 10 m^3	8.0	60.1	476	6.86	2.348
Compost 20 m^3	10.0	57.3	566	8.16	2.537
Compost 30 m^3	10.5	60.3	620	8.93	2.649
Compost 40 m^3	12.0	57.5	660	9.93	3.084
FYM 20 m^3 + F	8.1	59.8	484	6.96	2.032
Probability	<0.001***	0.08	<0.001***	<0.001***	<0.001***
LSD at 0.05	1.19	ns	46.9	0.21	0.063

interaction between irrigation system and fertilizer treatments on water productivity (kg m^{-3}). Generally, application of 120 kg N fd^{-1} or compost at 40 m^3 fd^{-1} gave the highest water productivity values under flood or sprinkler irrigation systems.

The relationship between tuber yield and mineral N application to potato expressed as Fertilizer Equivalent Ratio. Data shown in Fig. (3a) for potato and the crop response to compost application on the basis of total N addition is presented in Fig. (3b). Statistical tests by ANOVA of tuber production from plots amended with inorganic N or with compost showed subtle effects of irrigation method were apparent on yield performance. The main effect of irrigation type with mineral N was not statistically significant (P = 0.224), but a significant interaction with the rate of inorganic fertilizer application (P = 0.004**) suggested that there were slightly different patterns of response to mineral N under the different irrigation regimes. Indeed, the linear regression models showed that flooding was marginally more effective than sprinkler irrigation with increasing rate of inorganic N addition (Fig. 2a). A statistically significant interaction with the rate of N application (P = 0.037*) and a significant main effect of irrigation method on tuber yield (P = 0.035*) was observed for compost-amended soil (Fig. 3b). However, again, the general effects of irrigation system on tuber yield were small with overall mean values for flood and sprinkler irrigation of 7.83 ton and 7.57 ton fd^{-1}, respectively. The fertilizer equivalency of compost is calculated relative to inorganic N fertilizer in table 5 by comparing the linear regression coefficients describing the yield responses to mineral N and compost in Fig. (2). The mean value obtained for both types of irrigation method suggests that compost has an N fertilizer equivalency value of 44 and 63 %under flood and sprinkler irrigation systems, respectively.

Discussion

The abovementioned results clear that there was no significant difference due to irrigation system on water productivity of potato per 1 m^3 of irrigated water although greater marginal water productivity was evident for sprinkler irrigation than flood irrigation. Such effect may be due to the lower water duty of sprinkler irrigation (3100 m^3 fd^{-1}) compared with (3500 m^3 fd^{-1}) for flood irrigation systems. In this respect, Zhong *et al*., (2003) found that tuber total and marketable yield increased with increasing amount of irrigation water and the highest yield was obtained at the 1.25 times regime. Kumar *et al*., (2007 and 2009) found that the highest tuber yield was obtained in the irrigation regime of 1.20 of pan evaporation and the preferable grade of tuber decreased with the decrease in irrigation level from 1.20 to 0.60 of pan evaporation. The higher yield production under 100% IR may be due to proper balance of moisture in plants, which creates favourable conditions for nutrients uptake, photosynthesis and metabolites translocation (Kar and Kumar, 2007). On contrast excessive irrigation, have been reported to lower the WUE due to deep percolation and leaching (Dalla Costa and Giovanardi, 2000).

The results of organic manuring showed that all compost application levels resulted in significant increases in water productivity (kg m^{-3}) compared with the normal farmer practice (FYM 20 m^3 + 90 kg N) and the highest water productivity recorded when the plants were fertilized with 40 m^3 fd^{-1}. Such high-water productivity values when potato was fertilized with different compost levels could be attributed the greater water retention due to the high organic matter content in the compost. Adugna (2016) pointed out that application of compost to the soil improve the chemical, physical and biological

Table 4: Interaction effects between fertilizer and irrigation from ANOVA of yield characteristics of potato.

Treatment	No. of tubers plant^{-1}	Tuber weight (g)	Tuber yield plant^{-1} (g)	Tuber yield fd^{-1} (ton)	Water productivity kg m^{-3}
Flood					
Control	6.0	52.9	312	4.05	1.157
75 kg N	8.0	58.8	470	6.76	1.931
90 kg N	8.0	57.7	460	6.62	1.891
105 kg N	9.0	73.2	644	9.27	2.649
120 kg N	10.0	67.4	660	9.50	2.714
Compost 10 m^3	9.0	59.4	535	7.72	2.206
Compost 20 m^3	10.0	59.0	579	8.34	2.383
Compost 30 m3	11.0	55.5	605	8.71	2.489
Compost 40 m^3	12.0	58.7	704	10.14	2.897
FYM 20 m^3 + F	8.2	56.8	464	6.68	1.909
Sprinkler					
Control	6.0	55.4	330	4.75	1.306
75 kg N	8.0	56.7	454	6.54	2.181
90 kg N	8.0	63.1	497	7.04	2.135
105 kg N	9.0	58.0	509	7.33	2.990
120 kg N	10.0	63.6	610	8.76	3.065
Compost 10 m^3	7.0	60.7	418	6.00	2.490
Compost 20 m^3	10.0	55.6	554	7.98	2.690
Compost 30 m^3	10.0	65.2	636	9.16	2.810
Compost 40 m3	12.0	56.6	675	9.72	3.271
FYM 20 m^3 + F	8.0	62.7	503	7.24	2.155
Probability	<0.001***	0.102	0.0015**	0.0015**	<0.001***
LSD at 0.05	1.68	ns	66.4	0.57	0.172
CV %	14.9	13.9	9.9	9.9	

Note: Numbers in each column followed by different letters are significantly different at $P < 0.05$

Table 5: Nitrogen equivalency of composted sewage sludge for potato production by flood or sprinkler irrigation on reclaimed desert soil.

Item	Flood	Sprinkler
Regression coefficient for compost N (a)	0.018	0.019
Regression coefficient for inorganic N (b)	0.041	0.030
% N efficiency (a / b x 100)	44	63

characteristics of soils. It improves water retention and soil structure by increasing the stability of soil aggregates. Moreover, Abd El-Hady and Eldardiry (2016) reported that the effects of the organic matter applied to the soil in compost are seen in increased efficiency of mineral fertilizer utilization by crops and improved performance. Also, Sriom (2017) reported that nitrogen application up to 200 kg N ha^{-1} produced taller plant which ultimately resulted in the production of a greater number of leaves per plant. Successive increase in nitrogen levels produce significantly more number of leaves per plant (51.21 at 75 DAP) over its lower levels. Nitrogen affects the rate and extent of protein synthesis. Therefore, it increases the plant height and number of leaves per plant. The highest water productivity among all treatments was obtained when potato was fertilized with compost at 40 m^3 fd^{-1}. It is worthy to note that all fertilizer treatments under flood irrigation gave lower water productivity than that those under sprinkler irrigation system. Such effect may be due to the lower water duty of sprinkler irrigation (3100 m^3 fd^{-1}) compared with (3500 m^3 fd^{-1}) for flood irrigation systems.

El-Sayed *et al.*, (2015) reported that there were significant increases in the total and marketable yield of potato crops from plots that received compost at the rate of 35.7 t ha^{-1}, compared with plots treated with full dose of mineral fertilizer plus 11.9 t ha^{-1} compost (control). Benefits of compost amendments to soil include correcting Fe deficiency; increasing the uptake of Fe, Zn, Cu, and Mn; pH stabilization; and faster water infiltration rate due to enhanced soil aggregation (Stamatoados *et al.,* 1999). Soils supplied with compost initially had a lower soil pH than those supplied with synthetic fertilizers (Bulluck *et al.*, 2002). Many studies showed that yields of potato, pepper, and soybean provided by conventional and organic cultures are comparable (Volterrani *et al.*, 1996; Delate *et al.,* 2003 and Lang, 2005). Shahein *et al*. (2014) found that integrated use in different proportion

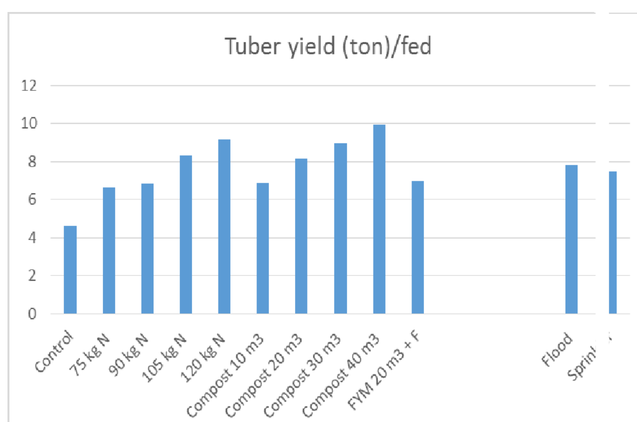

Fig. 1: Effect of fertilizer treatment and irrigation system on potato tuber yields.

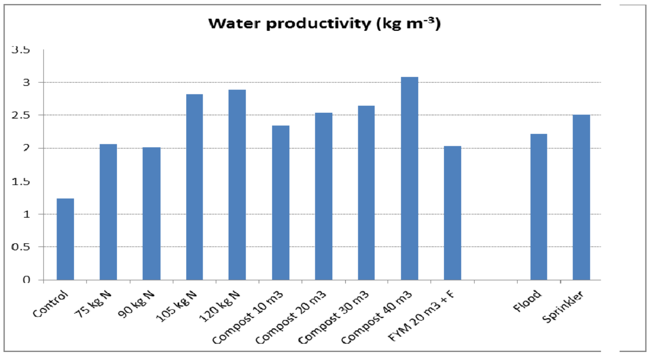

Fig. 2: Effect of fertilizer treatment and irrigation system on water productivity.

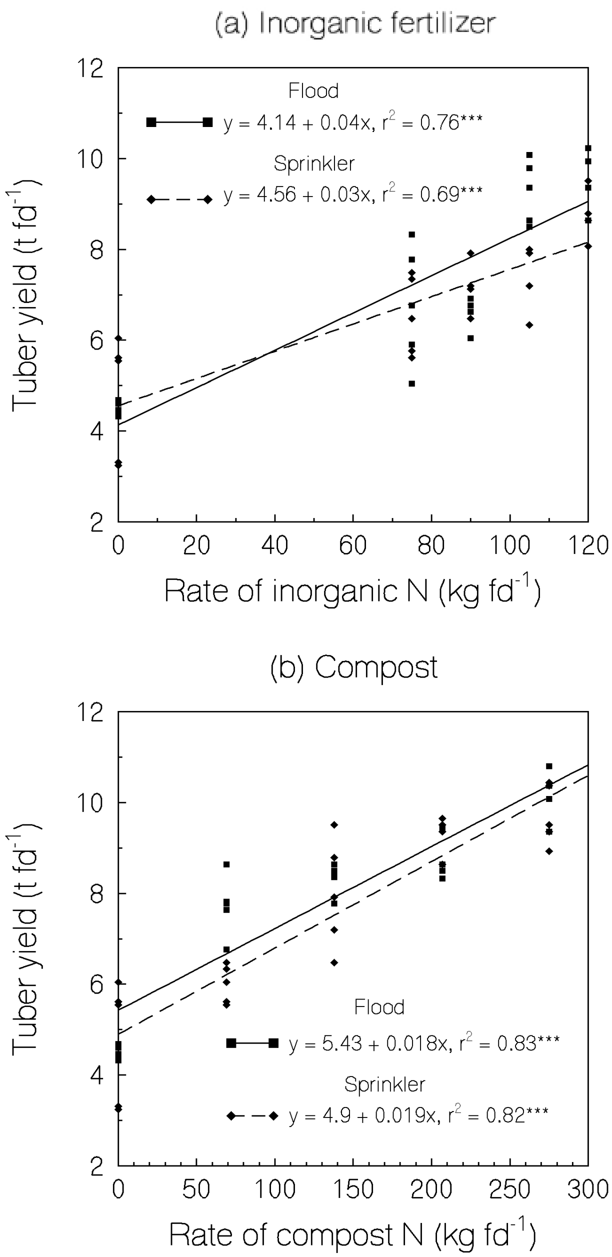

Fig. 3: Yield of potato tubers in relation to the rate of N application in (a) inorganic fertilizer and (b) compost.

increased the plant height, number of stems, total chlorophyll, nitrogen concentration in potato tubers and protein content, but mineral nitrogen fertilizer individually gave higher values compared with the integrated organic and mineral nitrogen fertilizers. However, the maximum and minimum values of potato yield were obtained by application of poultry manure combined with mineral nitrogen fertilizer and organic nitrogen individually, respectively. They added that organic matter content in soil was increased in all treatments compared with sole mineral nitrogen fertilizer and contrary, the values of bulk density (BD) decreased generally.

The results of the mean value obtained for both types of irrigation method suggest that compost has an N fertilizer equivalency value of 44 and 63% under flood and sprinkler irrigation systems, respectively. Similar results of the fertilizer equivalent ratio were obtained on different crops were reported by Abd El Lateef *et al*. (2018) on cowpea, they reported that organic manures have significant N fertilizer replacement value for cowpea on reclaimed desert soils. Farm yard manure is more effective as a soil amendment at increasing crop yield compared with pant compost product. On the basis of equivalent rates of N application in plant compost, the crop yield response to the farm yard manure material was 37 % higher compared to the compost product.

Conclusion

It could be concluded from this study that there is high potentiality for improving potato yield and higher water productivity per water unit in similar sandy soils through organic manuring with compost and maximizing water productivity under sprinkler irrigation system.

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