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Effect of Pressured Irrigation Systems, Deficit Irrigation and Fertigation Rates on Yield, Quality and Water use Efficiency of Groundnut

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Abstract: Application of modern irrigation systems which have high efficiency is an important concept should be followed in Egypt for saving part of the irrigation water due to the limited water resources. Two field experiments were conducted at the Research and Production Station, National Research Centre, El-Nubaria Province, El-Behira Governorate, Egypt, during the two successive summer seasons of 2012 and 2013, to study the effect of irrigation systems, water irrigation deficit and fertigation rates on yield, yield attributes, irrigation deficit and irrigation water use efficiency of groundnut grown under water limitation conditions in sandy soils of Egypt. The results show that drip irrigation significantly surpassed sprinkler irrigation in most of the studied characters except, 100-pod weight. Significant difference between irrigation deficit as well as fertigation rates in most of studied characters. The study indicted the possibility of reducing irrigation duty under drip irrigation up to 80 % of the recommended water quantity. The combined fertigation with reduced irrigation duty up to 80 % could effectively produce similar yields with good quality to 100% irrigation quantity plus full rate of NPK. The treatment drip irrigation + 100% irrigation deficit recorded the highest values of most of studied characters while, drip irrigation+ 80% irrigation deficit was the highest in seed oil and protein contents, oil and protein yield/ha. The treatment drip irrigation+100% NPK significantly surpassed the other treatments in most of the studied characters. No significant differences between drip irrigation+80% NPK and sprinkler irrigation+100% NPK in seed yield/ha and pods yield/ha was recorded.
Key words: Groundnut, Drip irrigation, Sprinkler irrigation, Fertigation, Irrigation water use efficiency.

Introduction

With the fast decline of irrigation water potential and continued expansion of population and economic activity in most of the countries located in arid and semi-arid regions, the problems of water scarcity is expected to be aggravated further[1,2]. One of the main reasons for the low coverage of irrigation is the predominant use of flood (conventional) method of irrigation, where water use efficiency is very low due to various reasons. Available estimates indicate that water use efficiency under flood method of irrigation is only about 35-40% because of huge conveyance and distribution losses[3]. While the various strategies introduced to improve the water use efficiency have been continuing through application modern irrigation systems like sprinkler and drip irrigation. Maximizing irrigation water use efficiency is a common concept used by irrigation project managers. In recent years, however, growing competition for scarce water resources has led to applying modified techniques for maximizing water use efficiency and improving crop yields and quality, particularly in arid regions like Egypt[4]. Drip irrigation is highly efficient because only the immediate root zone of each plant is wetted. This system also allows precise application of water-soluble fertilizers and other agricultural chemicals.

This system also allows precise application of water-soluble fertilizers and other agricultural chemicals. It helps to achieve yield gains of up to 100%, water savings of up to 40-80%, and associated fertilizer, pesticide, and labor savings over conventional irrigation systems[5]. Apart from reducing water consumption, drip irrigation also helps in reducing cost of cultivation and improving productivity of crops as compared to the same crops cultivated under flood method of irrigation. In sprinkler irrigation method, water saving is relatively low (up to 70 %) as compared to drip irrigation since SIM supplies water over the entire field of the crop[6,7]. About 17% improvement in groundnut yield and a like amount of water saving owing to use of sprinkler instead of surface irrigation, but a 40% improvement in water use efficiency[8]. Use of sprinkler and drip irrigation methods are becoming popular since water requirement in these methods is about half and water use efficiency is high. A yield advantage of 32% over the check basin method was realized with sprinkler irrigation system[9]. Besides saving of 24.7% irrigated water, yield of groundnut under sprinkler irrigation was 18.8% higher than yield obtained under surface irrigation (CPRWM, 1984). Sprinkler irrigation increased the pod yields by 20.8% and saved 33% irrigation water compared to the check basin method[10].

The application efficiency is estimated to be relatively lower under sprinkler irrigation as compared to drip method because of two reasons. First, sprinkler irrigation is often affected by wind interference which ultimately reduces the efficiency. Second, unlike drip method, sprinkler supplies water to whole of cropped area and therefore, water losses would obviously be higher. Drip method of irrigation does not allow water to spread beyond the root zone of the crop and therefore, the water moisture evaporation is very less in drip irrigation. Because of very high level of conveyance and application efficiency and low water moisture evaporation, the overall water use efficiency is very high under drip method of irrigation as compared to sprinkler and surface method of irrigation. Therefore, drip irrigation appears to be the most efficient method of irrigation in terms of absolute use of water for crop cultivation. Among sprinkler and drip method of irrigation, drip method appears to be more efficient in terms of producing output per unit of water.

Fertigation through sprinkler irrigation recorded higher water use efficiency than soil application under sprinkler irrigation or surface irrigation. The beneficial effects of combining fertigation with sprinkler irrigation on pod yield, and hence on water use efficiency, might perhaps largely stem from the constant soil moisture content at field capacity leading to proper proportion of water and air in the active root zone and also reduction of nutrient leaching losses due to the restriction of wetting area to active root zone[11,12].

Groundnut (*Arachis hypogaea,* L.) is one of the oilseed crops, is due to the high nutritive value of its seeds which considered rich in protein (22–30%) and fats (44–56%) and one of the richest sources of vitamin E, niacin, falacin, calcium, phosphorus, magnesium, zinc, iron, riboflavin, thiamine and potassium[13]. Groundnuts are consumed as peanut butter or crushed and used for the groundnut oil or simply consumed as a confectionary snack roasted, salted or in sweets. Moreover, the peanut green leafy organs (contain more than 10% protein) is another advantage characterized the crop as a good fodder for livestock (oil pressings, seeds, green material and straw) and industrial raw material (oil cakes and fertilizer). These multiple uses of groundnut, it makes an excellent cash crop for domestic markets as well as for foreign trade in several developing and developed countries. In addition, the crop has a good ability for growing in lightly soil, and thrives in improving the characteristics of the newly reclaimed sandy soils which commonly suffer from some constraints such as poor physical properties and nutrients deficiency. The specific objective of this investigation was to study the effect of irrigation system, water irrigation deficit and fertigation rates on yield, yield attributes irrigation deficit and irrigation water use efficiency of groundnut grown under water limitation conditions in sandy soils of Egypt.

Materials and Methods

Two field experiments were conducted at the Research and Production Station, National Research Centre, El-Nubaria Province, El-Behira Governorate, Egypt, during the two successive summer seasons of 2012 and 2013, to study the effect of irrigation system, water irrigation deficit and fertigation rates on yield, yield attributes, irrigation deficit and irrigation water use efficiency of groundnut grown under water limitation conditions in sandy soils of Egypt. Some physical and chemical properties of the experimental soil are shown in (Table 1) according to[14]. Irrigation water was obtained from an irrigation channel going through the experimental area, with pH 7.35 and an average electrical conductivity of 0.41 dS m^{-1}.

Table (1): Soil physical characteristics of experimental site

Soil depth (cm)	Particle size distribution			Texture Class	Saturated point (%)	F.C. (%)	W.P. (%)	OM (%)	EC (dSm^{-1})	$CaCO_3$ (%)
	Coarse Sand	Fine sand	Clay + Silt							
0-20	47.76	49.75	2.49	Sandy	21.0	10.1	4.7	0.65	0.35	7.02
20-40	56.72	39.56	3.72	Sandy	19.0	13.5	5.6	0.40	0.32	2.34
40-60	36.76	59.40	3.84	Sandy	22.0	12.5	4.6	0.25	0.44	4.68

This experiment was conducted in strip-split plot design with three replicates, where the irrigation systems (sprinkle and drip irrigation) were arranged in the vertical plots while water deficit (100, 80, 60 and 40% of the recommended water duty) were arranged in the horizontal plots and fertigation rates (100, 80 and 60 % of the recommended dose NPK) were distributed in the subplot factors.

1- Layout of Experimental Design:

Irrigation system components consisted of control head, pumping and filtration unit. It consists of submersible pump with 45 m^3/h discharge and it was driven by electrical engine and screen filter and back flow prevention device, pressure regulator, pressure gauges, flow-meter, control valves. Main line was of PVC pipes with 110 mm in diameter (OD) to convey the water from the source to the main control points in the field. Sub-main lines were of PVC pipes with 75 mm diameter (OD) was connected to the main line. Manifold lines: PE pipes was of 63 mm in diameter (OD) were connected to the sub main line through control valve 2`` and discharge gauge. Layouts of experiment design consist of two irrigation systems. Sprinkler is a metal impact sprinkler 3/4" diameter with a discharge of 1.17 m^3/h, wetted radius of 12 m, and working pressure of 250 KPa. Emitters, built in laterals tubes of PE with 16 mm diameter (OD) and 30 m in long (emitter discharge was 4 l/h at 1.0 bar operating pressure and 30 cm spacing between emitters and all details about the experiment design as shown in Fig. 1.

All irrigation treatments were done in separate blocks as well as, the amount of irrigation water was estimated and added according to the recommended doses and intervals for each treatment during the growing season. Seeds were sown on May 12^{th} and 15^{th} in the first and second seasons, respectively. The seeds (Giza 6 c.v.) were coated just before sowing with the bacteria inoculants, using Arabic gum (40 %) as adhesive agent and were sown in hills 10 cm apart. Phosphorus (calcium superphosphate, 15.5 % P_2O_5) at level 75 kg P_2O_5/ha was added during the seed bed preparation and potassium (potassium sulfate (48.52 % K_2 O) was applied at the rate of 125 kg ha^{-1} before the first and third irrigations in two equal doses, while nitrogen fertilizer was added at level of 100 kg N/ha as ammonium sulfate, 20.6 % in four equal doses weekly starting from 15 days after sowing. The proceeding winter crop was faba bean and wheat in the first and the second season, respectively. Groundnut was manually harvested on September 15^{th} and 19^{th} in the first and second season, respectively.

Evaluation parameters

Yield and yield attributes: At harvest, a random sample of 10 plants was taken from each plot to determine number and weight of pods/plant, number and weight of seeds/plant, 100-seed weight, 100-pod weight. Plants in the all plots were harvested and their pods were air dried to calculate, pods, seed and biological yield/ha.

Irrigation water-use efficiency (IWUE) value was calculated according to[15].

$$IWUE = (\frac{E_y}{I_r}) \times 100$$

Where IWUE is the irrigation water use efficiency (kg $_{seed}$/$m^3$$_{water}$), Ey is the economical yield (kg $_{seed}$/ha), I_r is the amount of applied irrigation water (m^3 $_{water}$ ha^{-1}/season).

Chemical traits: Oil % and N in seed was determined according to the method described by[16] and the seed protein content was calculated by multiplying total nitrogen concentration by 6.25. Oil and protein yields/ha were calculated by multiplying seed yield by seed oil and protein percentage.

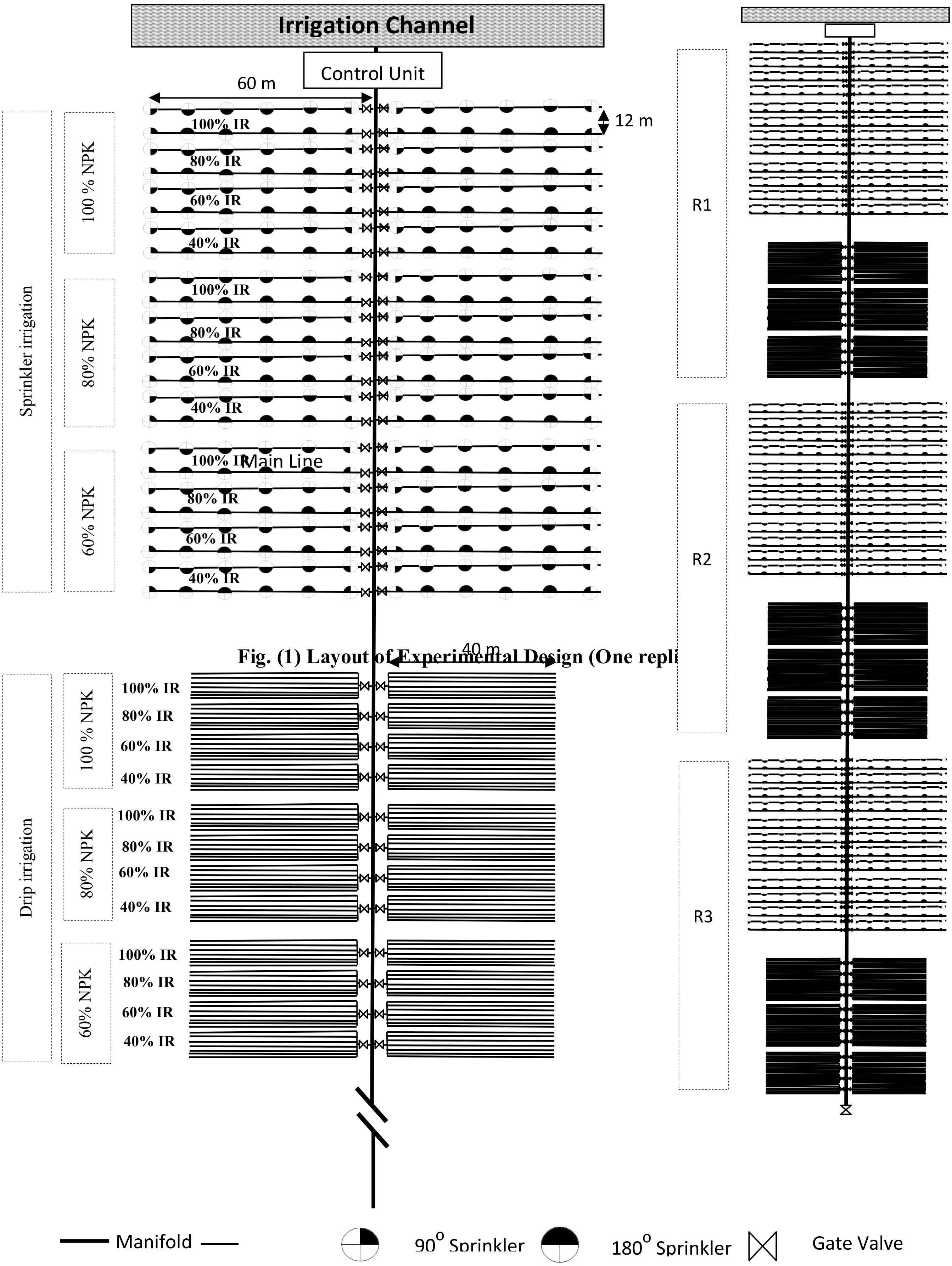

Fig. (1) Layout of Experimental Design (One repli

Statistical analysis: The obtained data were statistically analyzed according to[17] and the combined analysis of two seasons was done according to[18] while, the values of least significant differences (L.S.D. at 5 % level) were calculated to compare the means of different treatments.

Results and Discussion

1- Effect of irrigation systems, irrigation water deficit and fertigation rates

Data presented in Tables (2 and 2 cont.) show the effect of irrigation systems (sprinkler and drip irrigations) irrigation deficit and irrigation water use efficiency (IWUE) on some yield, yield attributes. Drip irrigation significantly surpassed sprinkler irrigation in most of the studied characters except 100-pod weight. The use of drip irrigation recorded increases in seed yield/ha (11.15%), pod yield/ha(24.16%), biological yield/ha (6.25%), IWUE for seed (49.52%) and for pod (59.37%) over sprinkler irrigation system, while irrigation water deficit of sprinkler irrigation increased over irrigation water deficit by 12.48%. Drip irrigation recorded higher water use efficiency as compared to sprinkler irrigation. It was mainly due to higher pod yield and maximum saving in irrigation water. The low water use efficiency in sprinkler irrigation might be the result of higher irrigation water use with comparatively less yield. Among the different irrigation systems, drip irrigation system exhibited yield increase of 21 and 11 % over conventional and sprinkler irrigation systems, respectively[19]. Typical irrigation in peanut production is applied overhead with a lateral or pivot sprinkler system; while another technique receiving some grower acceptance is the use of drip irrigation. Drip irrigation is purported to maximize water-use efficiency (WUE) by reducing soil evaporation, percolation, and runoff[20,21]. However, DI systems, through the nature of their underground water application, may impede peg soil penetration due to drier soil surfaces and possibly elevated soil surface temperatures[22,23]. Sprinkler irrigation increased the pod yields by 20.8% and saved 33% irrigation water compared to the check basin method (Kakde et al., 1989).

Table (2) : Effect of irrigation systems, irrigation water deficit and fertigation rates on some yield and yield components (combined data of two seasons)

		No. pod/ plant	Wt. pod/ plant (g)	No. of seeds/ plant	Wt. of seeds/ plant (g)	100-pod weight	100-seed weight	Seed yield (kg/ha)	Pods yield (kg/ha)	Biological yield (kg/ha)
Irrigation systems	Drip irrigation	31.88	39.76	53.65	32.55	112.57	62.95	1505.12	3109.24	6630.15
	Sprinkler irrigation	30.60	32.34	51.50	29.18	113.21	61.15	1354.04	2504.12	6223.25
LSD 5%		0.14	0.13	1.22	0.16	NS	1.19	33.05	61.25	64.19
Irrigation water deficit	100%	36.63	41.16	61.98	36.95	122.18	65.58	1825.58	3518.41	7627.29
	80%	34.73	37.62	58.83	34.22	119.95	64.48	1792.51	3468.24	7282.27
	60%	29.12	30.68	51.02	28.47	108.58	61.57	1309.35	2614.24	6644.29
	40%	24.47	22.74	38.47	19.84	100.85	56.56	939.98	2139.54	5153.21
LSD 5%		3.21	2.30	4.39	4.29	2.39	2.15	78.95	69.39	142.25
Fertigation rates	100% NPK	33.67	36.15	55.39	32.12	115.54	63.06	1979.25	3609.54	7890.29
	80 % NPK	32.55	33.32	53.06	30.15	112.46	62.30	1465.03	2874.85	6679.48
	60 % NPK	28.05	29.67	49.27	27.34	110.67	60.78	1159.97	2385.52	5461.21
LSD 5%		1.15	3.17	2.17	2.13	1.16	2.08	98.95	73.58	234.25

Regarding irrigation water deficit, significant differences between irrigation deficit treatments was observed by increasing irrigation deficit from 100% to 40% from recommended amount in the studied characters, while increasing irrigation deficit from 100% to 80% did not show significant differences in number of pods/plant, number and weight of seed /plant, 100-seed weight, seed and pod yields/ha, IWUE for pods and seed. Increasing irrigation deficit from 100 to 40 % from recommended amount tended to reduce seed, pods and biological yield/ha, Water stress interferes with both the production of photo assimilates and the import of assimilated material into the developing seeds. Yield potential is apparently limited by the capacities of both the sink[24] and the assimilatory source[25]. Drip irrigation systems may increase water use efficiency due to reduced soil and plant surface evaporation and because only the root zone or the partial root zone is irrigated as opposed to sprinkler irrigation where the entire field area is wetted. Surface irrigation recorded 70 per cent water efficient, but drip irrigation to be only 42 to 56 per cent efficient. The efficiency of water use can be physically improved by reducing the amount of water used per unit of crop yield[26]. Use of sprinkler and drip irrigation methods are becoming popular since water requirement in these methods is about half and water use efficiency is high. A yield advantage of 32% over the check basin method was realized with sprinkler irrigation system[9]. Besides saving of 24.7% irrigated water, yield of groundnut under sprinkler irrigation was 18.8% higher than yield (1.67 ton/ha) obtained under surface irrigation[27].

Table (2 cont.): Effect of irrigation systems, irrigation water deficit and fertigation rates on some chemical characters, irrigation deficit and IWUE for pods and seeds (combined data of two seasons)

		Oil (%)	Oil yield (kg/ha)	Protein (%)	Protein yield (kg/ha)	Irrigation deficit, m^3/ha/season	IWUE (kg pods/m^3 water)	IWUE (kg seed/m^3 water)
Irrigation systems	Drip irrigation	37.06	557.79	23.05	349.94	3539.20	1.079	0.537
	Sprinkler irrigation	36.64	469.03	22.75	280.96	3981.60	0.677	0.359
LSD 5%		NS	10.34	NS	17.05	12.25	0.430	NS
Irrigation water deficit	100%	36.57	667.61	23.20	423.53	5372.00	0.655	0.345
	80%	43.54	780.45	25.91	464.43	4297.60	0.902	0.515
	60%	35.48	464.55	20.94	274.17	3223.20	0.878	0.435
	40%	21.80	204.91	17.96	168.82	2148.80	1.077	0.497
LSD 5%		2.95	11.21	0.93	9.34	17.25	NS	NS
Fertigation rates	100% NPK	39.81	787.93	24.48	484.52	3760.40	1.034	0.550
	80% NPK	37.65	551.58	21.66	317.32	3760.40	0.876	0.441
	60 % NPK	34.58	401.11	19.86	230.37	3760.40	0.723	0.353
LSD 5%		1.66	25.24	1.54	17.12	NS	0.138	NS

Regarding fertigation treatments, significant differences among fertigation treatments was observed by reduction of fertilizer treatments from 100 to 60 % of the recommended doses in the studied characters, while reduction of fertilizer treatments from 100 to 80 % of the recommended doses show significant differences in most of studied characters except, number and weight of seed/plant, 100-seed weight, irrigation deficit and IWUE for seed. Reduction of fertilizer treatments from 100 to 60 % of the recommended doses tended to reduce seed, pods and biological yield/ha. The increase in groundnut seed and biological yields with fertigation rates may be due to producing higher number of pods and heavier seed weight which resulted from improved nitrogen use efficiency as a major component in chlorophyll and other cellular constituents of plant. Such increase in biological yield was obtained by improved nitrogen use efficiency.

2-Effect of interaction between irrigation systems and irrigation water deficit

Data presented in Table (3 and 3 cont.) show the effect of interaction between irrigation systems and water deficit on studied characters where significant differences between treatments were observed in most studied characters except, 100-seed weight, biological yield/ha, protein percentage and IWUE for pods and seed. The treatment drip irrigation + 100% irrigation deficit recorded the highest values of most of studied characters with significant difference with the other treatments, while drip irrigation+ 80% irrigation deficit was the best in seed oil (44.16%) and protein (26.49%) contents and oil (799.43 kg/ha) and protein yield/ha (479.55 kg/ha). The treatments of drip irrigation + 100% irrigation deficit and sprinkler irrigation+100% irrigation deficit were similar. The decline in the pod yield is due to the reduction in the seed yield, as expressed by the decrease in weight ratio of the seeds and the pods[28]. Drip method of irrigation appeared to be more efficient in terms of producing output per unit of water. Since the application efficiency of water is much higher in drip irrigation method, the water use efficiency in terms of productivity is also substantially higher in drip method.

Table (3): Effect of interaction between irrigation systems and irrigation water deficit on some yield and yield components (combined data of two seasons)

Irrigation systems	Irrigation water deficit	No. pod/ plant	Wt. pod/ plant (g)	No. of seeds/ plant	Wt. of seeds/ plant (g)	100-pod weight	100-seed weight	Seed yield (kg/ha)	Pods yield (kg/ha)	Biological yield (kg/ha)
Drip irrigation	100%	37.38	42.01	63.25	37.71	123.99	66.73	1949.28	4301.21	7893.25
	80%	35.44	38.39	60.03	34.92	121.07	65.47	1810.32	3814.21	7369.95
	60%	29.72	31.43	52.06	29.34	105.17	62.02	1449.98	3194.29	6372.25
	40%	24.97	23.20	39.26	20.25	100.04	57.59	1054.97	2285.21	4887.18
Sprinkler irrigation	100%	35.88	40.31	60.71	36.19	121.37	64.43	1881.21	3049.35	7360.54
	80%	34.02	36.84	57.62	33.52	118.83	63.50	1589.97	2956.32	7196.57
	60%	28.53	29.92	49.98	27.59	112.00	61.13	1159.24	2037.27	6916.12
	40%	23.97	22.27	37.68	19.43	101.65	55.53	808.75	1988.32	5420.27
LSD 5%		2.29	3.43	1.56	2.41	3.55	NS	119.12	105.21	NS

Regarding drip irrigation, increase irrigation deficit from 100 % to 40 % significantly decreased most of studied characters where drip irrigation + 100% irrigation water deficit recorded the highest values of most studied characters except, oil %, oil yield, protein %, protein yield, IWUE for pods and IWUE for seed where, drip irrigation + 80% irrigation water deficit records the highest values. Increase irrigation deficit from 100% to 80 % decrease seed, pod and biological/yield by -7.12,-11.32 and -6.62%, respectively but IWUE for pods and seed increased by 47.80% and 48.78%, respectively. Increase of irrigation deficit from 100% to 60 % decrease seed, pod and biological /yield by -25.61, -25.73 and -19.26%, respectively, but IWUE for pods and seed increased by 46.39% and 29.26%, respectively. Increase of irrigation deficit from 100% to 40 % decrease seed, pod and biological/yield by -45.87, -46.87 and -38.10%, respectively, but IWUE for pods and seed increased by 61.85% and 45.85%, respectively. Typical irrigation in peanut production is applied overhead with sprinkler system; while another technique receiving some grower acceptance is the use of drip irrigation. Drip irrigation is purported to maximize water-use efficiency (WUE) by reducing soil evaporation, percolation, and runoff[21]. However, drip irrigation system, through the nature of their underground water application, may impede peg soil penetration due to drier soil surfaces and possibly elevated soil surface temperatures[22,23].

Table (3 cont.): Effect of interaction between irrigation systems and irrigation water deficit on some chemical characters, irrigation deficit and IWUE for pods and seeds (combined data of two seasons)

Irrigation systems	Irrigation water deficit	Oil (%)	Oil yield (kg/ha)	Protein (%)	Protein yield (kg/ha)	Irrigation deficit, m^3/ha/season	IWUE (kg pods/m^3 water)	IWUE (kg seed/m^3 water)
Drip irrigation	100%	40.04	780.49	24.10	469.77	5056.00	0.776	0.410
	80%	44.16	799.43	26.49	479.55	4044.80	1.147	0.610
	60%	40.38	585.50	22.46	325.66	3033.60	1.136	0.530
	40%	23.66	249.60	19.94	210.36	2022.40	1.256	0.598
Sprinkler Irrigation	100%	39.10	736.49	22.30	354.56	5688.00	0.534	0.280
	80%	42.92	682.05	25.32	476.32	4550.40	0.657	0.420
	60%	37.58	435.64	19.42	225.12	3412.80	0.620	0.341
	40%	29.94	242.13	15.97	129.15	2275.20	0.897	0.396
LSD 5%		1.35	12.05	NS	10.40	47.35	NS	NS

Regarding sprinkler irrigation, increase irrigation deficit from 100 % to 40 % significantly decreased most of studied characters. Increasing irrigation deficit from 100% to 60 % reduced seed, pod and biological /yield by -38.37, -33.19 and -11.47, respectively but IWUE for pods and seed increased by 16.10% and 21.78%, respectively. Increasing irrigation deficit from 100% to 40 % decreased seed, pod and biological/yield by -57.00, -34.79 and -26.36%, respectively, but IWUE for pods and seed increased by 67.97% and 41.42%, respectively. In sprinkler irrigation method, water saving is relatively low (up to 70 %) as compared to drip irrigation[7].

3-Effect of interaction between irrigation systems and fertigation rates

Data in Table (4 and 4 cont.) show the effect of interaction between irrigation systems (drip and sprinkler irrigations) and reduce fertigation rates from 100% to 60% of NPK recommended doses on studied characters. Significant differences among treatments were observed in most studied characters except, weight of pods/plant, 100-seed weight, 100-seed weight, seed protein content, irrigation deficit, IWUE for pods and seed. The treatment drip irrigation + 100% NPK significantly surpassed the other treatments in most of the studied characters. No significant differences between drip irrigation +80% NPK and sprinkler irrigation+ 100% NPK in seed yield/ha and pods yield/ha was recorded. Fertigation through drip irrigation recorded higher water use efficiency than under sprinkler irrigation. Irrigation water, a costly input in crop production is scarce and expensive. Efficient use of this input can be achieved through judicious fertilizer and water management practices. High frequency irrigation aims at applying small quantities of water in each irrigation for maintaining optimum available moisture in the root zone depth for plant growth. Increase in yields was attributed to increase in available soil moisture, which increased the availability of nutrients, especially, nitrogen and phosphorus. The beneficial effects of combining fertigation with drip irrigation on pod yield, and hence on water use efficiency, might perhaps largely stem from the constant soil moisture content at field capacity leading to proper proportion of water and air in the active root zone and also reduction of nutrient leaching losses due to the restriction of wetting area to active root zone. These results are agreement with those obtained by[11,12].

Table (4) Effect of interaction between irrigation systems and fertigation rates on some yield and yield components (combined data of two seasons)

Irrigation systems	Fertigation rates	No. pod/ plant	Wt. pod/ plant (g)	No. of seeds/ plant	Wt. of seeds/ plant (g)	100-pod weight	100-seed weight	Seed yield (kg/ha)	Pods Yield (kg/ha)	Biological yield (kg/ha)
Drip irrigation	100% NPK	34.36	36.89	56.52	32.78	114.80	63.88	2186.24	4085.15	7880.25
	80% NPK	32.65	34.10	54.15	30.98	112.01	63.38	1654.27	3314.05	6496.24
	60% NPK	28.62	30.28	50.28	27.89	110.89	61.59	1308.15	2808.09	5115.09
Sprinkler irrigation	100% NPK	32.98	35.40	54.25	31.46	116.28	62.24	1764.21	3127.01	7508.28
	80 % NPK	31.34	32.55	51.98	29.31	112.90	61.22	1319.35	2426.50	6862.27
	60 % NPK	27.48	29.06	48.27	26.78	110.45	59.97	998.15	1968.95	5807.39
LSD 5%		2.11	3.42	2.02	NS	NS	NS	117.21	201.02	184.25

Regarding drip irrigation, the reduction of fertigation rates from 100 % to 60 % NPK significantly decreased most of studied characters where drip irrigation + 100 % NPK recorded the highest values of all studied characters. Reduction the fertigation rates from 100 % to 80 % NPK decreased seed, pod and biological/yields by -24.33,-18.87 and -17.56%, respectively also, IWUE for pods and seeds decreased by -17.18% and -22.83%, respectively. Reduction the fertigation rates from 100 % to 60 % NPK decreased seed, pod and biological/yield by -40.16, -31.26 and -35.08%, respectively, also IWUE for pods and seed deceased by -29.92% and -36.71%, respectively. These differences may be due to changes in photosynthesis process, which is the most significant process influence crop production, and is also inhibited by drought stress. Some photosynthesis process studies have shown that the photosynthetic rate of leaves decreases as relative water content and water potential decrease[29]. Limitation of net photosynthetic rate in low moisture stressed plant is mainly through stomatal closure[30] and/or by metabolic impairment[31].

Table (4 cont.) Effect of interaction between irrigation systems and fertigation rates on some chemical characters, irrigation deficit and IWUE for pods and seeds (combined data of two seasons)

Irrigation systems	Fertigation rates	Oil (%)	Oil yield (kg/ha)	Protein (%)	Protein yield (kg/ha)	Irrigation deficit, m^3/ha/season	IWUE (kg pods/m^3 water)	IWUE (kg seed/m^3 water)
Drip irrigation	100% NPK	42.83	936.36	25.25	552.02	3539.20	1.280	0.670
	80% NPK	37.73	609.06	22.94	370.31	3539.20	1.060	0.517
	60% NPK	30.62	400.55	21.55	281.90	3539.20	0.897	0.424
Sprinkler Irrigation	100 % NPK	36.80	649.25	23.71	418.30	3981.60	0.788	0.430
	80 % NPK	31.57	416.51	20.38	268.88	3981.60	0.693	0.365
	60 % NPK	26.54	264.90	18.18	181.46	3981.60	0.549	0.283
LSD 5%		4.04	1.09	NS	5.27	NS	NS	NS

Regarding sprinkler irrigation, decrease the fertigation rates from 100 % to 60 % of NPK significantly decrease most of studied character. Reduction the fertigation rates from 100 % to 80 % of NPK decrease seed, pod and biological/yield by -25.21,-22.40 and -8.60%, respectively, also, IWUE for pods and seed decreased by -12.05% and -15.11%, respectively. Reduction the fertigation rates from 100 % to 60 % of NPK decrease seed, pod and biological/yield by -43.42, -37.03 and -22.65%, respectively, also, IWUE for pods and seed deceased by -30.33% and -34.18%, respectively. Efficient irrigation management helps not only maintain farm profitability in a scenario of limited, higher cost water supplies but also result in water saving to meet future water requirements. Sprinkler irrigation, which is the pressurized and low volume irrigation system, is recognized as an efficient irrigation technology to get more crop yield per drop[32]. Fertigation is an appropriate method of fertilizer application from the fertilizer use efficiency angle[33].

4-Effect of interaction between irrigation water deficit and fertigation rates

Data in Table (5 and 5 cont.) show the effect of interaction between irrigation water deficit from 100% to 40 % of the recommended irrigation amount and reduce fertigation rates from 100% to 60% of NPK on studied characters however, significant differences between treatments were observed in weight of pods/plant, number of seed/plant, seed, pods and biological yield/ha, oil percentage, oil yield/ha and protein yield/ha. The treatment 100% irrigation water deficit+100% of NPK surpassed in number and weight of pods/plant, number and weight of seed/plant, 100-seed weight, seed yield/ha, pods yield/ha, oil yield/ha, protein percentage and protein yield/ha, while treatment 80% irrigation water deficit + 100% of NPK surpassed in 100-pod weight and biological yield/ha compared to other treatments. The treatment 80% irrigation water deficit+80% of NPK surpassed in oil percentage, while treatment 40% irrigation water deficit+100% of NPK surpassed in irrigation water use efficiency for pods and seed. No significance differences between the treatments 100% irrigation water deficit+100% of NPK, 100% irrigation deficit + 80% of NPK and 80% irrigation deficit + 100% of NPK in weight of pods/plant, number of seed/plant and biological yield/ha. The data presented illustrate that the use of fertigation practice could save better circumstances for nutrient release especially under low irrigation levels, consequently greater water use efficiency to produce better biomass so the reduction of irrigation requirements from 100 % to 80 % offset the impact of the shortage in irrigation requirements in the studied characters. Water availability mostly affects accumulation of some organic compatible solutes such as sugars, betaines and proline which adjusts the intercellular osmotic potential is also early reaction of plants to water stress. Proline accumulation of plants could be only useful as a possible drought injury sensor instead of its role in stress tolerance mechanism[34]. Proline is involved in tolerance mechanisms against oxidative stress and this was the main strategy of plants to avoid detrimental effects of water stress[35].

Table (5) Effect of interaction between irrigation water deficit and fertigation rates on some yield and yield components (combined data of two seasons)

Irrigation water deficit	Fertigation rates	No. pod/ plant	Wt. pod/ plant (g)	No. of seeds/ plant	Wt. of seeds/ plant (g)	100-pod weight	100-seed weight	Seed yield (kg/ha)	Pods yield (kg/ha)	Biological yield (kg/ha)
100%	100% NPK	39.03	44.08	63.58	37.74	122.35	68.18	2721.24	4321.21	7240.15
	80% NPK	37.30	42.91	62.48	37.06	123.18	64.30	1564.25	3284.12	7180.24
	60% NPK	33.56	37.49	59.89	36.05	121.00	64.26	1098.21	2484.35	6160.05
80%	100% NPK	36.38	42.44	61.69	37.24	123.37	65.21	2443.12	4120.12	7380.09
	80 % NPK	35.61	36.63	58.49	33.92	119.44	65.40	2054.21	3580.25	7147.94
	60 % NPK	32.21	34.79	56.30	31.50	117.04	62.83	1774.25	3184.12	5800.75
60%	100% NPK	33.08	32.36	53.24	30.47	111.00	61.63	1563.24	3084.12	7280.07
	80 % NPK	28.66	32.11	52.18	29.77	107.79	62.01	1324.02	2604.12	6885.21
	60 % NPK	25.63	27.55	47.64	25.16	106.96	61.08	1024.32	2154.12	5567.24
40%	100% NPK	26.19	26.70	43.05	23.04	105.45	57.22	1164.28	2480.14	6160.47
	80 % NPK	26.42	22.65	39.10	19.84	99.41	57.50	907.74	2201.02	4983.94
	60 % NPK	20.80	18.85	33.27	16.64	97.68	54.97	724.29	1707.09	4317.08
LSD 5%		NS	2.12	4.32	NS	NS	NS	71.21	134.05	285.21

Regarding 100% irrigation water deficit, reduction of fertigation rates from 100% to 80% of NPK decreased seed, pod and biological yield/ha, irrigation water use efficiency for pods and irrigation water use efficiency for seed by -42.51,- 23.99,- 0.88, -30.17 and -40.40 %, respectively. Reduction of fertigation rates from 100% to 60% of NPK decreased seed, pod and biological yield/ha, irrigation water use efficiency for pods and irrigation water use efficiency for seed by -59.63, -42.50, -14.91, -69.02 and -50.30%, respectively.

Regarding 80% irrigation water deficit, reduction of fertigation rates from 100% to 80% of NPK decreased seed, pod and biological yield/ha, irrigation water use efficiency for pods and irrigation water use efficiency for seed by -15.92,- 13.10,-3.14, -15.79 and -15.26%, respectively. Reduction of fertigation rates from 100% to 60% of NPK decreased seed, pod and biological yield/ha, irrigation water use efficiency for pods and irrigation water use efficiency for seed by -27.37, -22.71, -21.40, -26.73 and -25.33%, respectively.

Table (5 cont.) Effect of interaction between irrigation water deficit and fertigation rates on some chemical characters, irrigation deficit and IWUE for pods and seeds (combined data of two seasons)

Irrigation water deficit	Fertigation rates	Oil (%)	Oil yield (ton/ha)	Protein (%)	Protein yield (kg/ha)	Irrigation deficit, m^3/ha/season	IWUE (kg pods/m^3 water)	IWUE (kg seed/m^3 water)
100%	100%	42.15	1147.00	23.72	645.47	5372.00	0.875	0.495
	80%	38.07	595.51	22.63	353.98	5372.00	0.611	0.295
	60%	23.50	258.07	19.25	211.40	5372.00	0.479	0.246
80%	100%	41.77	1020.49	23.32	569.73	4297.60	1.051	0.596
	80 %	43.43	892.14	22.43	460.75	4297.60	0.885	0.505
	60 %	37.42	663.92	22.97	407.54	4297.60	0.770	0.445
60%	100%	38.07	595.12	22.63	353.76	3223.20	1.020	0.491
	80 %	35.13	465.12	20.75	274.73	3223.20	0.885	0.470
	60 %	33.23	340.38	19.43	199.02	3223.20	0.730	0.345
40%	100%	23.27	270.92	19.25	224.12	2148.80	1.191	0.620
	80 %	21.97	199.43	17.82	161.75	2148.80	1.125	0.495
	60 %	20.17	146.08	16.80	121.68	2148.80	0.914	0.376
LSD 5%		1.17	14.27	NS	21.25	NS	NS	NS

Regarding 60% irrigation water deficit, reduction of fertigation rates from 100% to 80% of NPK decreased seed, pod and biological yield/ha, irrigation water use efficiency for pods and irrigation water use efficiency for seed by -15.30,- 15.56,-5.42, -13.23 and -4.27%, respectively. Reduction of fertigation rates from 100% to 60% of NPK decreased seed, pod and biological yield/ha, irrigation water use efficiency for pods and irrigation water use efficiency for seed by -34.47, -30.15, -23.52, -28.43 and -29.73%, respectively.

Regarding 40% irrigation water deficit, reduction of fertigation rates from 100% to 80% of NPK decreased seed, pod and biological yield/ha, irrigation water use efficiency for pods and irrigation water use efficiency for seed by -22.03,- 11.25,-19.09, -5.54 and -20.16 %, respectively. Reduction of fertigation rates from 100% to 60% of NPK decreased seed, pod and biological yield/ha, irrigation water use efficiency for pods and irrigation water use efficiency for seed by -37.79, -31.17, -29.92, -23.25 and -39.35%, respectively.

5-**Effect of interaction between irrigation systems, irrigation water deficit and fertigation rates**

Data presented in Fig (2) shows the effect of interaction between irrigation systems (drip and sprinkler irrigations), irrigation water deficit and fertigation rates on seed yield/ha where, the treatment drip irrigation+100% irrigation deficit+100% fertigation rate records the highest value of seed yield/ha followed by treatment drip irrigation + 80% irrigation deficit+100% fertigation rate, while the lowest treatments are sprinkler irrigation+40% irrigation deficit+60% fertigation rate and sprinkler irrigation + 40% irrigation water deficit+80% fertigation rate.

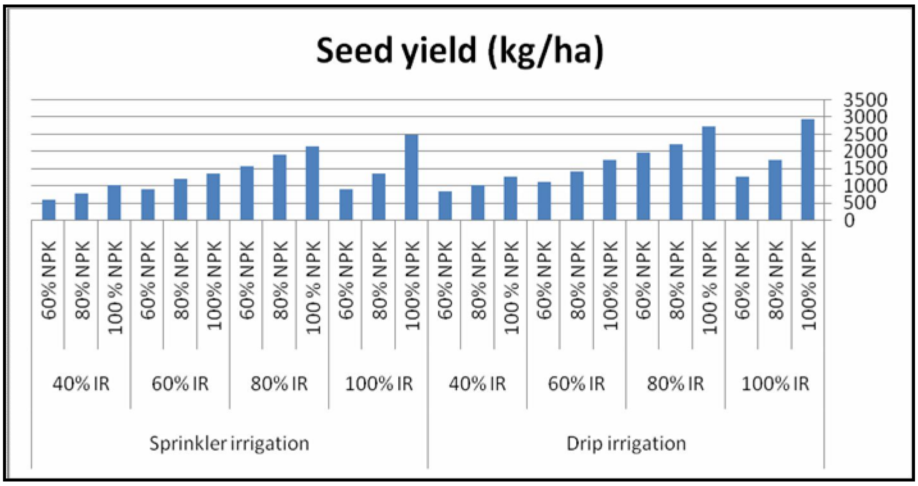

Fig (2) Effect of interaction between irrigation systems, irrigation water deficit and fertigation rates on seed yield/ha (kg/ha)

Data presented in Figs (3 and 4) shows the treatment sprinkler irrigation+100% irrigation deficit+100% fertigation rate gave the highest value of oil percentage (46.97%) followed by drip irrigation+100% irrigation water deficit+60% fertigation rate (45.50%), while drip irrigation+80% irrigation deficit+100% fertigation rate records the highest value of protein percentage followed by sprinkler irrigation + 80% irrigation deficit+80% fertigation rate and sprinkler irrigation+100% irrigation deficit+100% fertigation rate.

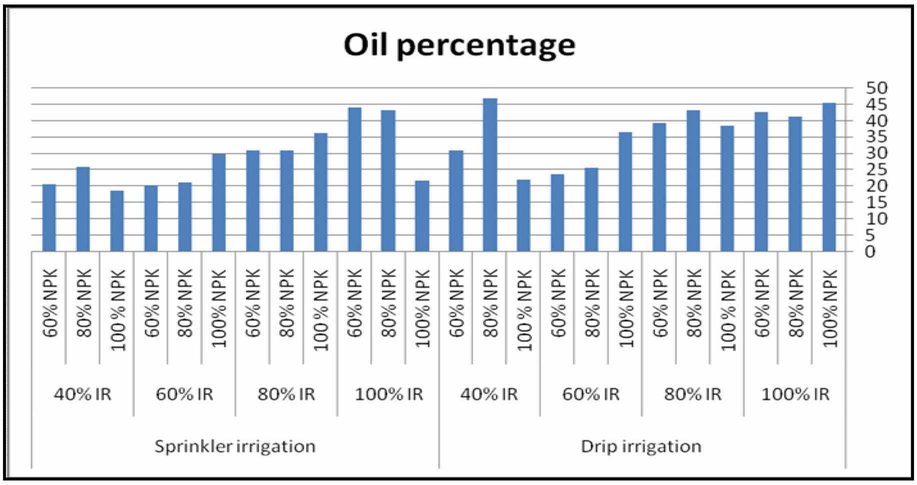

Fig (3) Effect of interaction between irrigation systems, irrigation water deficit and fertigation rates on oil percentage

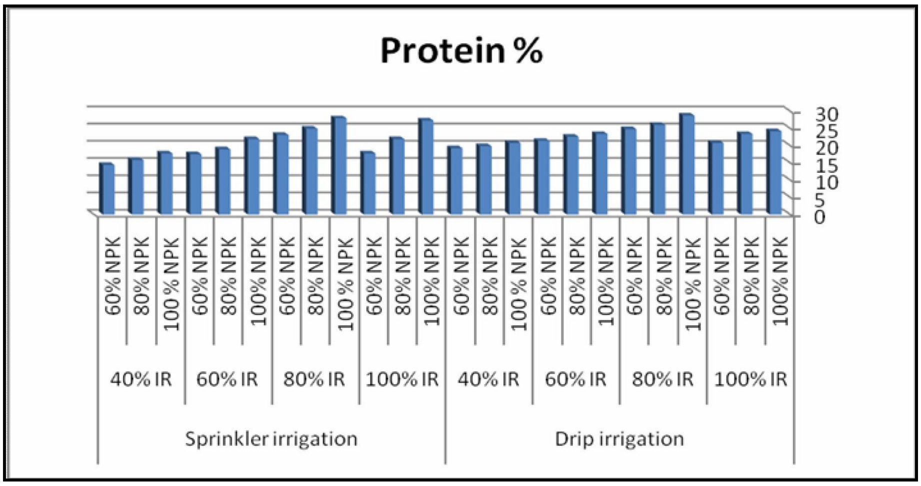

Fig (4) Effect of interaction between irrigation systems, irrigation water deficit and fertigation rates on protein percentage

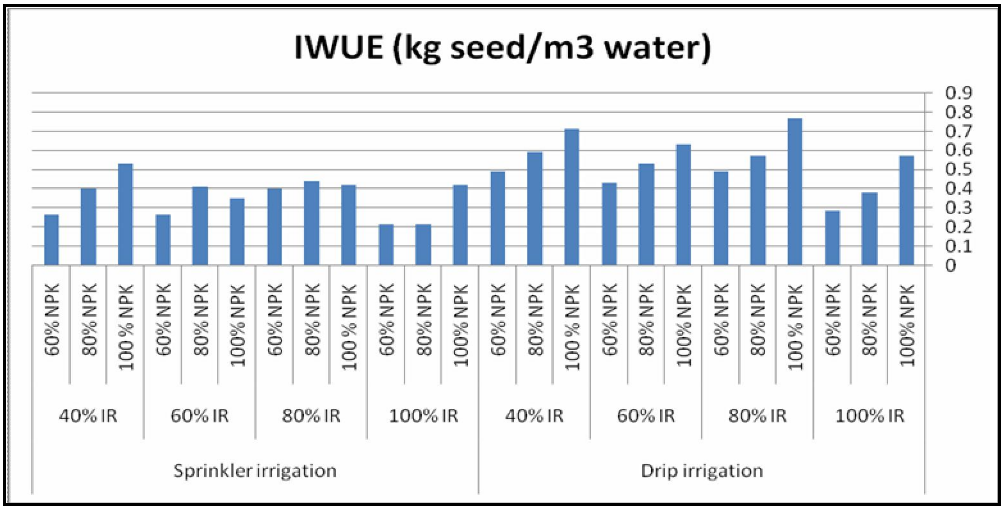

Fig (5) Effect of interaction between irrigation systems, irrigation water deficit and fertigation rates on irrigation water use efficiency of groundnut seed

Data presented in Fig (5) shows the highest value of irrigation water use efficiency recorded by drip irrigation + 80% irrigation water deficit + 100% fertigation rate (0.771 kg seed/m^3 water) followed by drip irrigation + 40% irrigation water deficit + 100% fertigation rate (0.711 kg seed/m^3 water) and drip irrigation + 60% irrigation water deficit + 100% fertigation rate (0.631 kg seed/m^3 water). Drip irrigation is purported to maximize water-use efficiency (WUE) by reducing soil evaporation, percolation, and runoff[20,21].

It could be concluded from this study the possibility of reducing irrigation water duty with drip irrigation system comparing to sprinkler irrigation system. The combined fertigation with reduced irrigation duty up to 80% could effectively produce similar yields with good quality to 100% irrigation quantity plus full rate of NPK.

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