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A study on the effects of different irrigation methods and Fertilizer regimes on groundnut (*Arachis hypogea* var. cabri)

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Abstract: An experimental trial was carried out at the University of Mauritius Farm to assess the growth and yield of groundnut (*Arachis hypogea* var. cabri) subjected to different irrigation methods and N:P:Kfertilizer regimes. The leguminous crops were irrigated using drip and micro-sprinkler irrigation systems while the control treatment was performed under rain-fed conditions. The plants were also fertilized with 16:22:22 N:P:Kfertilizer at rates 0, 120, 240, 360 kg/ha over a four-month crop cycle. The experiment was conducted on a low humiclatosol soil with a silt loam texture having pH 6.73 and electrical conductivity 0.388 mS/cm. The main treatment was based on the different irrigation methods which were monitored using a tensiometer and the sub treatments were fertilizer regimes randomly applied at mentioned doses. Statistical analysis revealed an increasing yield of groundnut with increasing doses of N:P:K fertilizer application of 0-360 kg/ha , ranging from 1573 kg/ha to 3837 kg/ha for drip irrigation treatment, 1006 kg/ha to 2768 kg/ha when irrigated using sprinkler system and 0 kg/ha to 126 kg/ha under rainfed conditions. Limited water availability under rain fed condition led to a water deficit condition whereby a decrease in germination rate, plant height, leaf area, leaf number were noted and hence yield declined (126 kg/ha). Although treatments using micro-sprinkler irrigation produced lower yield compared to drip system, the study showed that the kernel and pod sizes of groundnuts were greater than those under drip irrigation system. Hence, considering water scarcity for agricultural use and environmental impacts of fertilizer overuse, the most efficient irrigation system as well as the optimum fertilizer regime must be considered.
Keywords: Groundnut(*Arachis hypogea*), irrigation methods, fertilizer regimes, yield trend, water stress, environmental impacts

INTRODUCTION

Groundnut (*Arachis hypogea*), commonly known as peanut, is one of the most important food legumes cultivated worldwide [1]. Groundnut is a species of legume belonging to the Fabaceae family indigenous to South America, Central America and Mexico [2]. Groundnut has been classified as the sixth most important oilseed crop in the world among other edible oil crops such as sunflower, sesame and soybean [3]. It contains 48-50% oil, 26-28% protein and is rich in dietary fiber, minerals, and vitamins. According to recent statistics, groundnut is grown over acreage of 26.4 million hectare worldwide with a total annual production of 37.1 million metric tonnes resulting in an average productivity of 1.4 metric tonnes per hectare. Moreover, groundnut is a leguminous crop whichundergoes root nodulation to fix nitrogen in the soil, hence increasing soil fertility [4].

Due to the increasing water shortage, it is important to optimize the use of water, mainly for irrigation purposes [5]. Moreover, crop yield is influenced by rainfall patterns depending on the geographical location and season. Mauritius is a sub-tropical country whereby the annual mean rainfall is about 1400 mm in summer and 700 mm in winter [6, 7]. Thus, additional irrigation needs to be supplied so as to increase the yield and improve the quality of produce.

The pathway for achieving a resourceful water use entails the need to systematically make wise use of the soil and water through good management practices and irrigation equipment [8]. In order to evaluate the internal management processes in any irrigation system, key decisions with respect to water delivery should be primarily defined. These key decisions focus on the desired system objectives, the feasibility of the system and the functional system requirements [9]. Various studies showed that there is a great aptitude to attain a more efficient water use via an enhanced distribution uniformity while improving the surface irrigation [10, 11] or pressurised sprinklers and drip irrigation systems [12, 13, 14]. Therefore, many factors need to be considered while choosing the most appropriate irrigation systems. These factors involve irrigation scheduling, soils, system performance, irrigation costs and off farm system performance which should be reliable in terms of timing, discharge rate and pressure in the case of pressurized system [15, 16].

Together with water management, fertilizer management also plays a decisive role in plant development for instance; nitrogenous nutrient which plays a crucial role in both crop yield and quality [17, 18]. Plant growth can be promoted by applying sufficient amount of nitrogen [19] but inappropriate dosage (toxicity) may cause accumulation of compounds in the edible products and eventually leads to plant loss. Phosphorus (P), deficiency decreases agricultural productivity, therefore, correct proportions of P needs to be applied in adequate amount [20]. Finally, Potassium, contributes to the growth and fruit production of plants [21]. It also assists in photosynthesis, enzyme activities, protein synthesis, and cell turgor and has various other roles [22]. Thus, there need to be equilibrium between proper use of fertilizers and water applied for optimum yield and quality of crops.

The aim of this project was to determine the effect of different irrigation methods and fertilizer regimes on the growth and yield of groundnut. The irrigation methods being implemented were; Drip irrigation and sprinkler irrigation through microsprinklers were used and also, a rain fed condition where the ground nut depends solely on rain water and simultaneously acts as a control. On the other hand, the amount of fertilizers used for each treatment varies for each irrigation method. The factors that were investigated entailed; bulk density, soil fertility through NPK test, moisture content of the soil, soil texture and pH, yield under each different treatment, pod quality in terms of size and shape, kernel sizes, hence efficiency of water use and the alteration of NPK in the soil since groundnut is a nitrogen fixing plant.

MATERIALS AND METHODS

Plant material

Groundnut seeds of Spanish variety Cabriwere used for the experimental trial. This groundnut variety was chosen for its quicker maturation time (120 days) as compared to other varieties and also due to its adaptation to the actual season and also for its quality.

Site description and field conditions

The experiment was conducted during the crop year September 2013- January 2014 at the University of Mauritius Farm, Reduit, and located 20.235291° South and 57.490977° East. The experimental soil site was a silt loam soil with an average pH of 6.73 and a soil electrical conductivity of 388 µS, having an average monthly rainfall of 71.83 mm and average monthly evaporation of 31.55 L from September 2013 to December 2013. Conventional tillage practices were done such as disc tilling and ploughing, after which the land was demarcated and levelled before planting. The plot size was 200 m², having a length of 25 m and width of 8 m.

Experimental design

Statistical analysis was made through split-plot design where the main treatment was the irrigation methods and the sub treatments was the fertilizer regimes.

Irrigation and system set up

Two main irrigation methods were investigated namely: Drip, sprinkler using micro-sprinklers and one treatment was under rain-fed. The groundnut was irrigated as per the crop water requirement of the plant and a tensiometer was used for soil moisture monitoring.

The drip system

For this irrigation method, a PVC pipe of diameter 32 mm was used as the main. Dripper lines of 12 mm diameter with equal perforated spacing 10 cm were used along laterals. The dripper lines had a discharge rate of 12 L/hr.

The sprinkler system

For the blocks irrigated by sprinklers, micro-sprinklers of wetting diameter 2 m were used having a discharge rate of 60 L per hour. The simple reason for choosing such sprinkler type is that, these can work even under low pressure water supply which was the case at the University of Mauritius Farm. The overlapping of the sprinklers and the number of sprinklers to fit-in the block was pre-determined.

The rain-fed condition

The plots under rainfed condition were irrigated up to field capacity before sowing and no further artificial application supplied. The plots were then subjected to rainfall only. There were three replicates of this system on investigation.

Fertilizer regimes

NPK fertilizer with ratio 16:22:22 was used for this experiment as per recommendation of Le Guide Agricole (AREU, 2010), which was 300 kg/ha. Different rates of this particular fertilizer were applied to each block of irrigation treatments as shown in table 1.0.

Table 1. Percentage dose applied

Treatments	Percentage of recommended dosage by AREU, %	kg/ha
T1	0	0
T2	40	120
T3	80	240
T4	120	360

Soil sampling

Soil samples were taken using the 'zig-zag' method as illustrated in the figure 1.0; covering the nine blocks of irrigation treatments. This method ensures the uniformity and homogeneity of the whole field under cultivation.

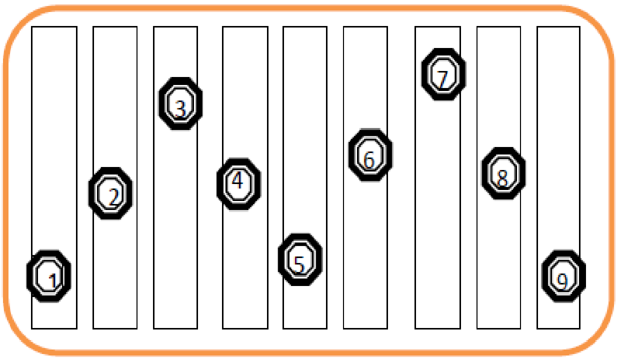


Fig.1:Zig-zag method soil collected

Soil Tests

Several tests were carried out during the cultivation season, which include: soil texture, soil moisture content, bulk density (Iron-core ring method), pH and electrical conductivity, total nitrogen (Kjeldahl method), total phosphorus, total potassium that was initially in the soil, available nitrogen, available phosphorus (Olsen phosphorus Method) and available potassium.

Plant Parameters

The plant parameters included:weekly growth (height, cm/week), progress of number of leaves on weekly basis, plant dry mass, leaf area on weekly basis, kernel size, pod size, pod quality and yield were determined

RESULTS AND DISCUSSIONS

Percentage germination due to treatments

The number of seed germinated was tabulated and the percentage germination calculated.

Table-2: percentage germination

Irrigation, TRT/%	T1	T2	T3	T4
Drip	70.8	69.0	77.4	79.2
Sprinkler	59.5	60.1	60.7	63.1
Rain-fed	0	0.6	5.4	3.0

The highest percentage germination was recorded under the drip irrigation treatment, while the lowest was obtained under rain-fed condition. For seeds to germinate, favourable conditions are necessary which include; adequate amount of water, oxygen and suitable temperature. Although the same amount of water were supplied to, drip and sprinklers, significant changes in the percentage germination was noted. The possible reason accounting for such outcome is due to efficiency of using drip system of irrigation as compared to other systems. Considerable decline in germination was noted under rain-fed conditions, which relied solely on rain while the amount of rainfall was low during this period.

Table-3: Rainfall recorded/mm

Date	September	October	November	December
2013	Amount (mm)	Amount (mm)	Amount (mm)	Amount (mm)
1-5	2.1	1.5	0.0	13.0
6-10	0.0	0.0	1.0	0.0
11-15	0.2	0.0	48.5	0.0
16-20	0.0	3.8	0.3	5.3
21-25	2.4	0.0	11.9	2.0
26-30(31)	0.0	43.8	129.6	21.9

Source: Mauritius Meteorological Services.

As shown from table 3.0, the amount of rainfall during the crop cycle period, that is; mid-September was negligible and was insufficient for activation of the seeds metabolism. This consequently explained the reason behind the low germination in treatments relying on rainfall. It was also noted that despite the lack of water for this treatment, some seeds germinated in particular fertilizer treatments, that is; 240 kg/ha and 360 kg/ha basal applied fertilizer. According to Baskin, and Baskin [23], nitrates are essential chemical factors which trigger germination in certain species which is in line with the present result.

Soil Properties Assessed

Basic soil test was carried out in the laboratory both prior to cultivation and after harvest. These were tabulated as shown in table 4.

Table-4: Basic soil properties investigated

Number	Properties investigated	Results	Units
1	Soil texture	Silt loam	-
2	Soil moisture	14.49	%
3	Bulk density	0.911	g/cm3
4	Soil electrical conductivity	388	µS
5	pH	6.73	-

Soil texture

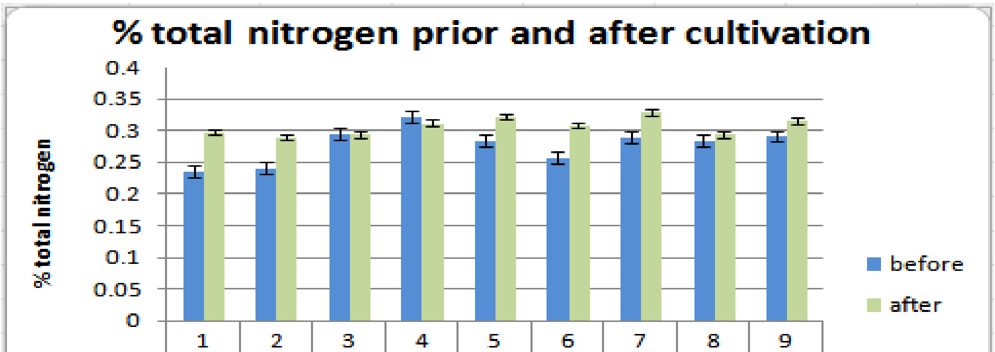
It was mentioned that sandy loam soil was best suited for cultivation of groundnut for its non-sticky characteristics [24]. However, the experiment conducted in silt loamy soil revealed no breakage of the pods while harvesting and did not stick to the pods as well.

Soil moisture content and bulk density

These two factors affected directly plant growth. The ability of providing plant support by the soil is governed by soil bulk density and is affected by water, as it compresses the soil making it compact. As mentioned by Arshad, Lowery, and Grossman [25], the ideal bulk densities for soil textures silt should be greater than 1.4 and loam less than 1.1 g/cm^3 against the obtained value which was 0.911 g/cm^3.

Total Nitrogen

There was significant difference ($p< 0.05$) for the change in total nitrogen in the soil before cultivation and after harvest. Jakbro[26] as well as El-Seesy and Ashoub[27] suggested that N application enhanced growth and yield characters of groundnut, which was similar to the obtained outcome of yield of groundnut produced. Being a leguminous plant, groundnuts also fix nitrogen in the soil [4], which might be the associated reasons for the significant increase in the soil total nitrogen together with the basal fertilizer 16:22:22 applied.



	1	2	3	4	5	6	7	8	9
before	0.23	0.24	0.29	0.32	0.28	0.25	0.28	0.28	0.29
after	0.29	0.28	0.29	0.31	0.32	0.30	0.32	0.29	0.31

Fig-2: Percentage total nitrogen

Total Phosphorus

The leguminous crops require large quantities of phosphorus for the growth of the whole plant, development of a population of free-living *rhizobia* in the rhizosphere, nodules initiation and development and the process of biological nitrogen fixation by the nodules [28]. As the results suggest when tested at 95 % confidence interval, there was no significant difference between the changes in concentration of total phosphorus in the soil. However, in line with the previous statement and the results obtained through Tukey test at 5% error, the mean amount of phosphorus has proved to decline after harvest, which might be accounting for the use of plant growth, which is also parallel to the statement of Rebafka*et al.*[29].

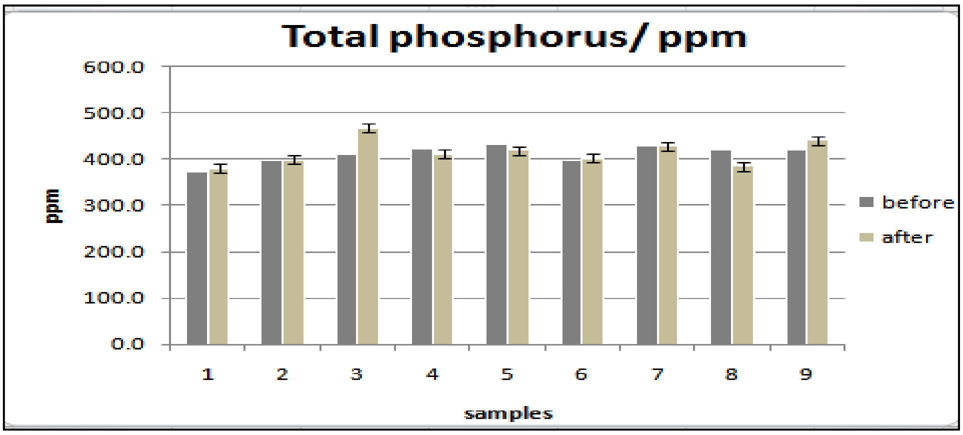


Fig-3: Change in total phosphorus level

Total Potassium

Potassium has a beneficial effect on nitrogen fixation and conversion of photosynthetic from leaves to the root nodules [30]. The results obtained for yield and plant growth give a similar inference; an increasing percentage of potassium has led to higher yield which was detected by several authors [31, 32, 33, 34, 24].

On the other hand, Nour El-Din *et al.*, [35] reported that potassium had no effects on growth and yield of groundnut grown in soil containing high nutrient contents which was contradictory to the obtained results. Comparison using statistical Tukey 95% Simultaneous Confidence Interval method showed no significant changes ($p< 0.05$) in the total potassium content of soil, while the comparison of the means prior to cultivation and after harvest suggested a very small decrease in concentration.

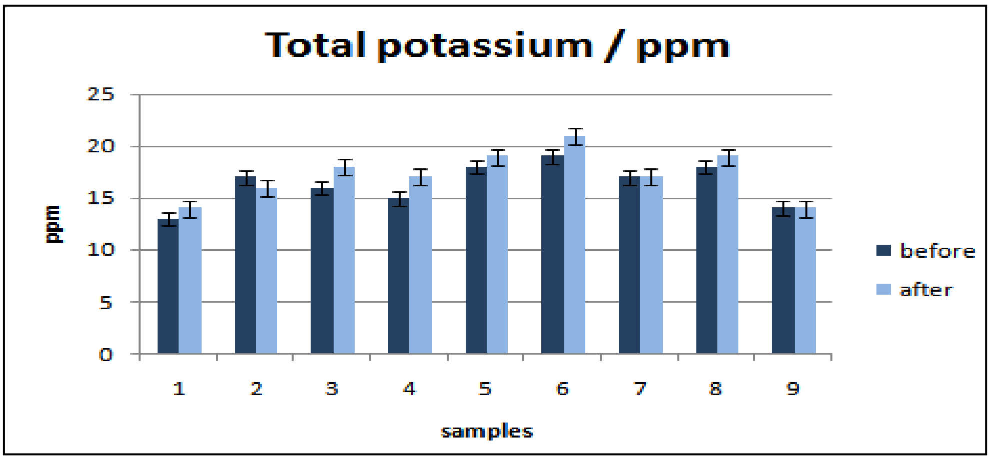


Fig-4: Change in total potassium level

Available Nitrogen

Analogous to the obtained findings, Sharma [4] stated that the application of NPK significantly increased the soil available nitrogen, phosphorus and as well as potassium. Results from statistical soil analysis using CRD and Tukey at 95% confidence interval had revealed significant increase in the concentration of available nitrogen to the plants after harvest. Fixation of nitrogen and application of basal NPK might have led to an increase in the concentration content.

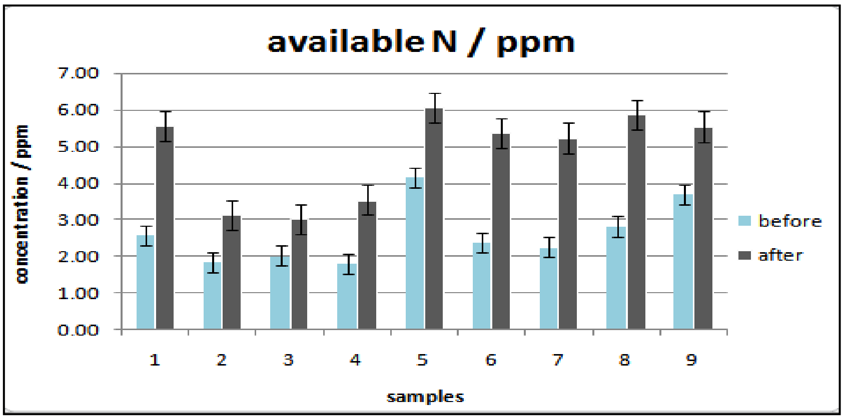


Fig-5: Change in soil available nitrogen

Available Phosphorus

Tested at 95% confidence interval using completely randomized design, it had proved to be significantly different ($p < 0.05$), therefore the null hypothesis of the means of concentration of available phosphorus being unchanged, was rejected. The figure 5.0 showed a general increase in the concentration of available phosphorus as per outcomes of Sharma [4]. Tukey test conducted, also conveyed the same result.

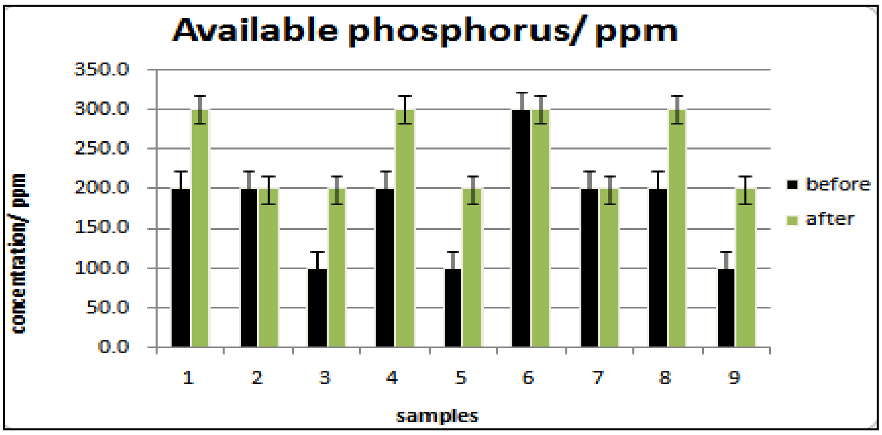


Fig-6: Differences in available potassium level in the soil.

Available Potassium

In line with the findings of Sharma [4], the results obtained showed a significant increase in amount of potassium availability in soil through Tukey test at 95% confidence interval. This increase might be attributed to the application of basal fertiliser NPK to the groundnuts.

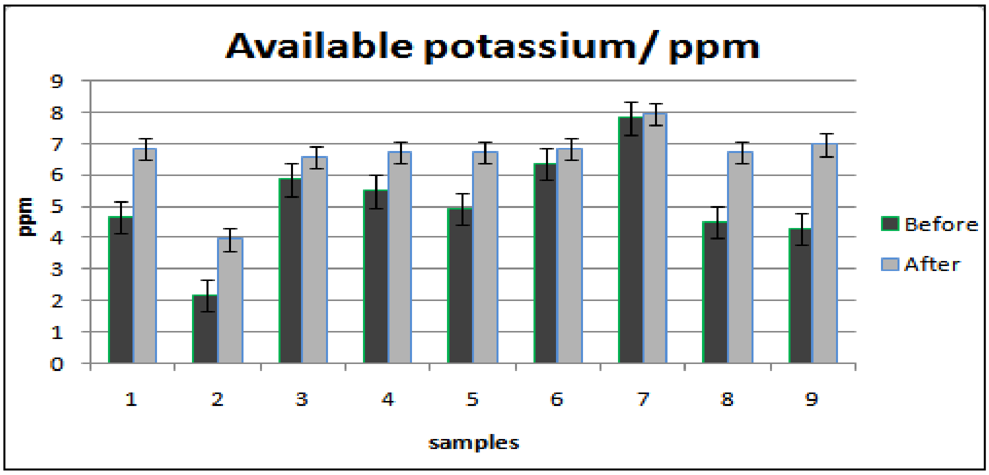


Fig-7: Differences in available potassium level in the soil prior to cultivation and after harvest

Plant parameters Assessed

Average plant height

Plant height was observed as an indicator of the vegetative development of groundnut plants under both irrigated and rain-fed conditions. Plant height was found to be greater under irrigated as compared to non-irrigated conditions showing that water played an essential role in plant growth which was parallel to the statement of Mabhaudhi*et al*., [36] suggesting that plant height as is directly linked to the amount of water applied. Moreover, it was observed that plants exposed to sprinkler irrigation system were slightly taller than those exposed to drip and much difference could be noticed for fertilizer doses 240kg/ha and 360 kg/ha due to the fact that the plant assimilated larger amount of nutrients depending on its availability. This difference in height might be accounted for the fact that more space was available for the plant to grow as the germination rate was lower and thus decreasing the competition for sunlight for photosynthesis and nutrient availability. On the other hand, smaller plants were observed under rain-fed conditions which were consistent with those of Yrissamy*etal*., [37] who mentioned that low water resulted in reduced plant size.

The maximum heights reached were much lower as compared to sprinkler and drip systems. These plants were subjected to water stress as mentioned by Jeff Iles [38], water is vital for plant growth and plant processes. Mabhaudhi*et al*., [36] also mentioned that there existed a trend for which the average height of groundnut plants decreased when water stress was increased; therefore, a difference of 55 mm was recorded between the highest plants under all optimum conditions compared to the highest plant reached suffering from water stress.

Average number of leaves

Despite being shorter in height than those under sprinkler irrigation treatment, the plants that were under drip irrigation treatment were observed to be broader in size and having more number of leaves. This might be due to the fact that the water supplied directly to the root zone and hence enhancing water use efficiency for the drip. Mabhaudhi*et al*., [36] stated that the number of leaves increased when efficiency of water supplied was increased, which corresponds to the actual findings. Greater leaf number implies increased photosynthesis, and therefore more food was produced by the plants resulting in greater number of pods. Nevertheless, the difference between these two irrigation treatments was insignificant as compared to rain-fed condition. The plants could not perform well under water stress conditions, hence resulting in fewer numbers of leaves, and some dried up.

Plant dry mass

Plant dry mass is strictly related to water availability to the plants. As mentioned in the previous section, due to higher efficiency and precise water application under drip irrigation to the targets as compared to sprinklers, the plants under this irrigation method were found to uptake water more easily. This eventually resulted in higher water content in groundnut plants under drip irrigation, followed by sprinkler irrigation method.

Average leaf area as from flowering

The leaf area varied a lot between the ranging treatments. Generally, leaf expansion is inhibited due to soil water deficit [39, 40] which was similar to the actual findings. Larger leaves have been recorded for treatment for irrigated conditions as compared to rain-fed condition. Sprinkler and drip under 240 kg/ha and 360 kg/ha fertilizer applied produced plants with greater leaf areas, while lower leaf areas were recorded for 0 kg/ha and 120 kg/ha fertilizer application. This outcome was mainly due to deficiency in nutrients (fertilizer) leading to smaller leaves.

It could also be noticed that, an increased in amount of fertilizer resulted in broader leaves and also water was essential for nutrients uptake from the roots which was comparatively similar to the results of Reddy *et al*., [41] stating that the leaf area for groundnut decreased due to moisture stress.

Yield of harvested groundnut

Groundnut yield was found to be statistically dependent on the irrigation systems used, the rate of fertilizer application and the interaction effect. The highest yield was achieved under drip irrigation at a fertilization rate of 360 kg/ha. This might be explained due to the interaction effect and nutrient assimilation resulting from its frequent and precise application of water. The obtained results were in line with those of Purushotham and Hosmani, [42] who stated that NPK fertilizer in combination rate resulted in higher yield. It could be deduced that availability of water and higher fertilizer regime enabled the plant to increase productivity. It was also observed that drip irrigation produced the best result as compared to sprinkler irrigation systems and non-irrigated plots. This could be probably due to the fact that drip irrigation reduced run-off, deep percolation, evaporation and the root zone remained wet, as implied by the wetting pattern of drips.

In addition, the higher efficiency of delivering water to the plant root zones of plants resulted in higher number of pods, hence greater yield was obtained with an average difference of 0.6 t/ha between drip system and sprinkler systems. These results were consistent with those of Mabhaudhi and Modi, [36], who all reported that in response to limited water availability under field conditions, yield of seeds was reduced. Under sprinkler irrigation, the yield was much lower than the drip probably due to an increase in evaporation from the wet leaves and soil surface. The non-irrigated plots produced the lowest yield due to extreme water stress.

Sub effects (subplots)

While the amount of water delivered to the plants remained the same for both drippers and sprinklers, the different amount of fertilizers applied created a ranging yield. For the rain dependent system, water deficit has interfered greatly in the yield, hence lowering the harvest. While for the other main plots, the fertilizer regimes created a substantial difference in the yield. Greater yield was obtained for 360 kg/ha fertilizer applied followed by 240 kg/ha. It therefore implies that, decreasing the amount of fertilizer will eventually decrease the yield but on the other hand, excessive fertilizer application could cause of luxury growth effect.

Interaction effects

Significant differences were recorded with interaction effect of both irrigation methods and fertilizer regimes on groundnut. From the figure 8, it could be clearly observed that applying fertilizer without water was futile and water application without fertilizer was economically inefficient in terms of yield. Therefore, a balance between these two should be maintained for optimal growth and yield of groundnut. For which the best regime was for 360 kg/ha under drip irrigation system.

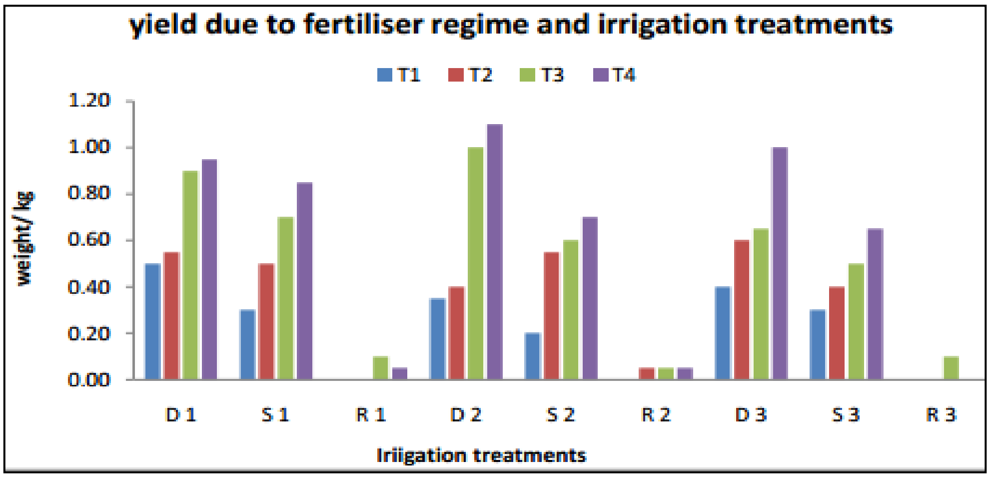


Fig-8: Groundnut yield (kg/ha) harvested under different treatments

Pod size

An essential element linked to yield is the number of pods and qualitatively the pod size of the harvested groundnuts. As figure 8 suggested, there was significant difference between irrigation treatments, and water-deficit exposed plants resulted in smaller pod size. While there was no significant difference between replicated blocks for $p>0.05$, pod size subjected to rain-fed treatment has shown to be smaller. This might be explained by water stressed conditions that were created hence the plants were deprived of water and nutrients uptake.

Those under irrigated conditions achieved a bigger pod size, for which, groundnuts subjected to sprinkler irrigation, was found to be the biggest.

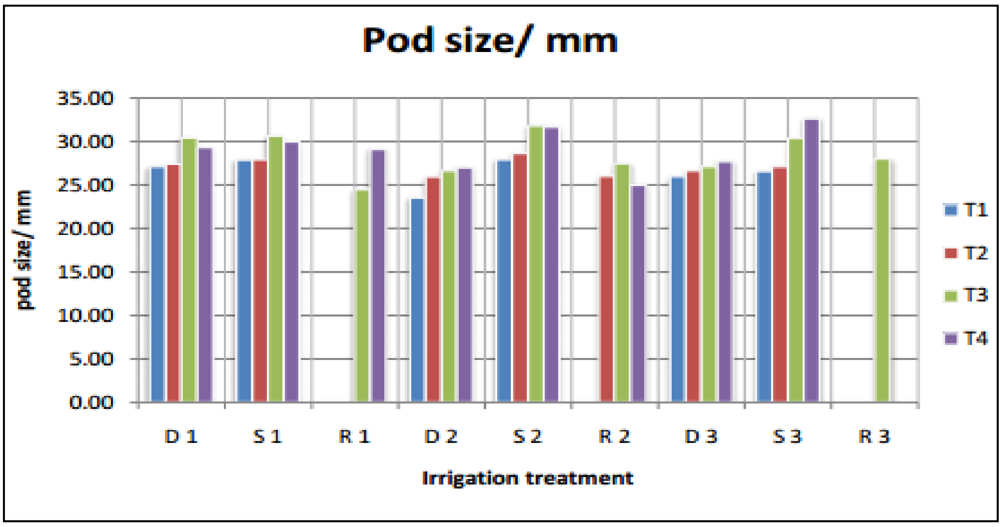


Fig-9: Pod sizes under different treatments

Subplots effects

The pod sizes obtained under fertilizer rate 0 kg/ha and 120 kg/ha applied, proved to be almost equal, while there was consequent variation in pod sizes between treatment 240 kg/ha and 360 kg/ha. The results obtained conveyed the same result as that of Davoodi[43], who stated that adsorption of adequate amount of nitrogen by the plant lead to larger legume seeds, hence larger pod. It was also noticed that plants exposed to 240 kg/ha and 360 kg/ha under rain-fed conditions, performed better as compared to 0 kg/ha and 120 kg/ha fertilization. Since pod size of plants under sprinkler irrigation system was found to be the biggest, it could be inferred that the best quality was obtained for sprinkler methods under 240 kg/ha and 360 kg/ha applied fertilizer.

Kernel size

In the year 2007, Davoodi stated that the sizes of kernels were dependent on amount of nitrogen, which was in line with the obtained results. Both pod sizes and kernel sizes were important factors contributing to quality of groundnut. The obtained results showed that the biggest kernel size was recorded under fertilization treatments of 240 kg/ha and 360 kg/ha. The kernel size for groundnuts under irrigated conditions were greater than that of non-irrigated condition due to the fact that the plants were dependent on rainfall and did not receive adequate amount of water for their metabolic activities such as photosynthesis and respiration, hence affecting the production of the kernel. The interaction effect for which the kernel sizes measured, was observed under sprinkler irrigated conditions with a fertilizer dose of 240 kg/ha which was slightly bigger than those in treatment 360 kg/ha.

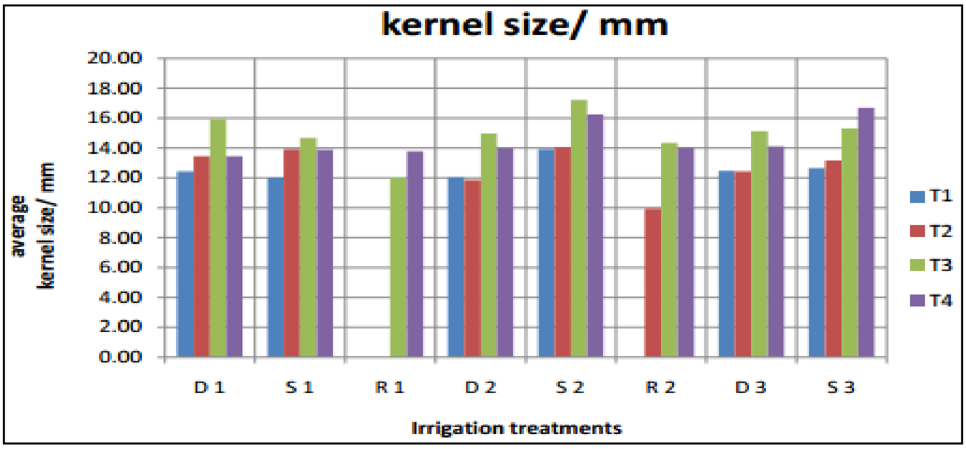


Fig-10: kernel size of groundnut under interaction effect of treatments.

CONCLUSION

In light of the experiments carried out, the study indicated clearly that irrigation is vital to achieve higher yield of groundnuts. Drip irrigation proved to be more efficient from the viewpoint of yield per hectare. It produced the higher yield under a fertilizer regime of 360 kg/ha. Drip irrigation is to be recommended due to the precise distribution of water and nutrients. Although this system of irrigation possessed several advantages such as more efficient use of available water, reduced labor cost, low energy requirement and precise application of nutrients, this system may not be readily adopted among farmers due to associated disadvantages. In order to take a firm decision, financial, economic and technical analysis should be carried out in order to compare the two mutually exclusive irrigation systems. The fertilization rate to be recommended under irrigated conditions was found to be 360 kg/ha for which slightly incremental yield was obtained despite a large fertilizer input as compared to that of 240 kg/ha. Since high price of fertilizer in Mauritius, price is a key aspect that should be taken into consideration when choosing the rate of fertilizer to be applied to the crop and synchronously taking into consideration the environmental impact. Moreover, results have advocated that by the use of micro-sprinklers, the kernel sizes as well as the pod sizes were superior to that compared to drip and rain-fed. Besides groundnut plants have demonstrated the aptitude of fixing soil nitrogen and hence the cultivation of such leguminous plant is recommended either using intercropping or seasonal crop rotation for nutrients recycling and preservation of soil fertility.

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