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Experimental Evaluation of Irrigation Methods on Soil Nutrient Status and Nutrient Uptake of Summer Groundnut

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Authors' contributions

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

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ABSTRACT

Aims: To study the nutrient uptake and status of available nutrients in soil after harvest of groundnut as affected by different irrigation levels and methods at Northern Transitional Zone of Karnataka.
Study Design: The experiment was laid out in randomized block design with different irrigation levels and methods replicated thrice.
Place and Duration of Study: AICRP on Groundnut, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during summer 2021.
Methodology: We took 11 treatments involving different level and methods of irrigation using eight micro-sprinkler treatments, one drip fertigation treatment and two flood irrigation treatments. After harvesting soil nutrient status and nutrient uptake from the soil were analyzed.
Results: Significantly higher total nitrogen, phosphorus and potassium uptake were recorded with drip irrigation applied at 0.6 ET0 at Seedling, 1.0 ET0 at Flowering, 1.25 ET0 at Pegging, 0.8 ET0

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at Pod formation stages along with fertigation of N and P [3 splits at NF on 3rd, 4th and 5th week] and CaNO3 and S nutrients [3 splits at PGF on 7th, 8th and 9th week] (164.0, 27.6 and 129.3 kg ha^{-1}, respectively) and was 40.0, 55.43 and 25.91 per cent higher compared to control (Flood FAO). Same treatment enhanced the soil chemical properties like pH, EC and organic carbon by 1.04, 16.12 and 7.40 per cent compared to control.

Conclusion: Drip irrigation and fertigation enhanced nutrient uptake of groundnut and available soil nutrient status and also improved soil chemical properties as compared to control (Flood irrigation). So, this method can be proved beneficial in reducing the nutrient requirement of the crop under cultivation in the Northern Transitional Zone of Karnataka.

Keywords: Drip; micro-sprinkler; groundnut; nutrient uptake.

1. INTRODUCTION

Oilseed crops are the second most important determinant of agricultural economy, next only to cereals within the segment of field crops. In India, groundnut (*Arachis hypogaea* L.) is a significant oilseed and supplemental food crop. When it comes to sources of vegetable protein (26%) and edible oil (46–51%), groundnut is the third most significant crop. On an equivalent basis, groundnuts have 2.5 times more protein than eggs and 2 times more than beef. Groundnut also has a good supply of calcium, phosphorus, iron, zinc, and boron. In addition to being high in calories, groundnuts also provide minor levels of vitamin B complex and vitamin E [1]. Because of these qualities, groundnut is referred to as the "King of Oilseeds". Groundnut cake contains 45-60% protein, 22-30% carbohydrate, 3.8-7.5% crude fibre, 7 to 8% N, 1.5% P2O5 and 1.2% K2O [2] and can be used as manure. Globally, Groundnut covers 32.7 million hectares with the production of 53.9 million tonnes with the productivity of 1648 kg per hectare [3]. India produced 87 lakh tons of groundnut from an area of 57.05 lakh hectares with an average productivity of 1500 kg per hectare during 2021-22 [4].

Soil moisture is the key limiting factor for the higher yield of groundnut during dry seasons. Therefore, there is need for effective strategies to maximize the water use efficiency from the limited water utilized for the crop growth. Among the other issues, indiscriminate use of water and chemical fertilizers has led to environmental issues, such as groundwater contamination and atmospheric nitrous oxide release. So, proper management of water and nutrients in essential in dry arid and semi-arid regions.

Micro-irrigation has been widely investigated as a valuable and sustainable production strategy in dry regions. Drip or trickle irrigation is a type of micro irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plant. At various crop growth phases, drip-based fertigation offers a range of diverse nutrient treatments. Additionally, periodic fertigation applications of the nutrients ensure continual nutritional availability. The potential yield of groundnuts can be increased while conserving water and nutrients by strategically applying water at important physiological growth phases in response to moisture constraint throughout the summer [5]. A study on the effect of micro sprinkler and surface irrigation on yield of groundnut revealed that irrigating through micro sprinkler at 100% ET (23.86 q ha^{-1}) recorded the highest yield followed by 80% ET (21.60 q ha^{-1}) and 120% ET (20.09 q ha^{-1}) which was superior over surface irrigation (19.75 q ha^{-1}) [6]. On the other hand, with fertigation through drip, the amount of fertiliser needed can be decreased by 15–25% without lowering yield [7]. So, micro-irrigation can be an effective way of improving crop productivity and as well as enhancing nutrient use efficiency by increased nutrient uptake by groundnut crop.

So, keeping in view the above facts, the present experiment was planned and carried out to study the nutrient uptake and available soil nutrient status after crop harvest under different irrigation treatments.

2. MATERIALS AND METHODS

The experiment was carried out at AICRP on Groundnut, University of Agricultural Sciences, Dharwad. The experimental site is located at N 15° 29' 44.23", E 74° 58' 57.28"longitude and at an altitude of 678 m above mean sea level. Dharwad comes under Northern Transition Zone (Zone-VIII) of Karnataka which lies between the Western Hilly Zone (Zone-IX) and Northern Dry Zone (Zone-III).

Monthly maximum (35.4^0C) and minimum temperature (15.2^0C) was noticed during April and February months, respectively. Rainfall received during the cropping period of groundnut (28^{th} Jan 2021 to 30^{th} May, 2021) was 245.6 mm and effective rainfall was 115.2 mm during different phenological stages. Maximum evaporation during the cropping period was in the month of March (205.6 mm) and minimum evaporation was in the month of February (141.5 mm).

Soil was clay in texture with basic pH (7.62), electrical conductivity of 0.30 dS m^{-1}, low in available nitrogen (258.7 kg ha^{-1}), medium in available phosphorus (29.8 kg ha^{-1}) and high available potassium (334.9 kg ha^{-1}).

The experiment was laid out in randomized block design having eight micro-sprinkler irrigation treatments viz. T_1- Sprinkler method (50 mm depth of irrigation at all stages except 60 mm depth at 50 and 60 DAS), T_2- 80% of T_1 Treatment, T_3- 70% of T_1 Treatment, T_4- 60% of T_1 Treatment, T_5- 50% of T_1 Treatment, T_6- 70% of T_1 Treatment + Foliar application of 0.5% KNO_3 at 50 DAS, T_7- 60% of T_1 Treatment + Foliar application of 0.5% KNO_3 at 40 and 60 DAS, T_8- 50% of T_1 Treatment + Foliar application of 0.5% KNO_3 at 30, 50 and 70 DAS, one drip irrigation treatment (T_9) viz. Drip method of irrigation at 0.6 ET_0 (Seedling), 1.0 ET_0 (Flowering), 1.25 ET_0 (Pegging) and 0.8 ET_0 (Pod formation) + fertigation of N and P [3 splits at nodule formation on 3^{rd}, 4^{th} and 5^{th} week] + $CaNO_3$ and S nutrients [3 splits at peg formation on 7^{th}, 8^{th} and 9^{th} week] and two flood irrigation treatments viz. T_{10}- Flood irrigation at 0.45 ET_0 (Seedling), 0.75 ET_0 (Flowering), 1.05 ET_0 (Pegging), 0.70 ET_0 (Pod Formation) (FAO recommendation) [8] and T_{11}- irrigation as per UAS POP (University of Agricultural Sciences package of practice) (Irrigating at 25, 40, 55, 70,and 85 DAS at 60 mm depth) replicated thrice. Irrigation in drip plots was done based on actual evapotranspiration at 4 days interval. Irrigation was applied as per treatments based on deficit water supply at 15, 30, 40, 50, 60, 70, 80 and 90 days after emergence (DAE) in micro-sprinkler irrigated plots. In flood irrigation as per FAO recommendation, irrigation was provided based on actual evapotranspiration depending on growth stage and in flood irrigation as per UAS package of practice, irrigation was provided at 25, 40, 55, 70 and 85 DAS with 60 mm depth at each irrigation. The irrigation provided uniformly to all treatments up to establishment. There was continuous rainfall of 232.2 mm (Effective rainfall was 109.1 mm) from 10^{th} April till harvest, so, irrigation was either skipped or adjusted as per treatment requirement.

The actual evapotranspiration was calculated by using the following formula given by Choudhary and Kadam [9] [49 as, ETo = Kp ×Ep, where, ETo= Actual evapotranspiration, Kp= Pan coefficient (0.70) and Ep= Daily pan evaporation (mm)

Effective rainfall is calculated from actual rainfall received on a day by using the following formula given by Pakhale et al. [10] as follows,

Re= 0.0011 P2 + 0.4422 P Where, Re= Effective rainfall; P= Precipitation

Suppose, Rainfall received in a day = 10 mm

So, effective rainfall for that particular day (Re) = 0.0011 P2 + 0.4422 P = 0.0011*(10)2 + 0.4422*(10) = 4.53 mm

Groundnut variety ‘Kadiri Lepakshi’ was sown using 125 kg/ha seed rate sown at a spacing of 30 cm x 10 cm (Row to row: 30 cm and plant to plant: 10 cm). Two weeks prior to sowing, farm yard manure at 7.5 t ha^{-1} was appliedto all treatments. According to the recommended package of practice (RPP), all the treatment plots received a basal application of N, P, and K (25 kg N, 46 kg P_2O_5 and 25 kg K_2O ha^{-1}) as well as gypsum at flowering and pegging stages with 500 kg ha^{-1}. Fertigation of N and P [3 splits at NF on 3rd, 4th, and 5th week] and 3 splits of Calcium and Sulphur at peg formation stage (on 7th, 8th, and 9th week) in the form of water soluble forms of $Ca(NO_3)_2$ and sulphur granules by hand application are used for drip plots.

2.1 Nutrient Uptake

Plant samples were collected at harvest and oven dried at 75 The plant and grain samples of groundnut crop were collected from each plot at at harvesting and was kept for sun drying for 2-3 days. 100 g grain and 200 g stover samples were dried for 48 to 72 hours or till the constant weight is attained in hot air oven at 65±5 ^oC temperature. These dried samples were ground to fine powder in a Willey mill and passed through 40 mesh sieve. t A known weight of powdered seed and haulm samples was treated with concentrated nitric acid and kept overnight for pre digestion. Next day, the pre digested

Table 1. Methods of nutrient uptake

Sl. No	Parameters	Methods	References
1	Nitrogen (%)	H_2SO_4 digestion followed by kjeldahl distillation Micro Kjeldahl method	Tandon [11]
2	Phosphorus (%)	Diacid digestion followed by spectrometric determination (yellow color method)	Tandon [11]
3	Potassium (%)	Diacid digestion followed by flame photometric determination	Tandon [11]

Table 2. Methods of soil analysis in laboratory

Parameters	Methods	References
pH	pH meter	Piper [12]
EC (dSm^{-1})	Conductivity method	Jackson [13]
Soil organic carbon (%)	Wet oxidation method	Walkley and Black (Jackson) [13]
Available N (kg ha^{-1})	Alkaline $KMnO_4$ distillation method	Saharawat and Buford [14]
Available P_2O_5 (kg ha^{-1})	Olsen's method	Jackson [13]
Available K_2O (kg ha^{-1})	Flame photometer method	Jackson [16]

samples were treated with di-acid mixture (HNO_3:$HClO_4$ at 9:4 ratio) and digested on a sand bath at low temperature till colour less white residue was obtained. The residue was dissolved in 6 N HCl and filtered and made to known volume. After digestion, the following P and K analysis was carried out in the di-acid digest.

The nutrient uptake was calculated using the following formula and expressed in kilogram per hectare.

Nutrient uptake (kg ha-1) = Nutrient concentration (%) × Total biomass (kg ha^{-1}) / 100

2.2 Soil Analysis

Soil sample were taken from the depth of 0-15 cm at before sowing and after harvesting for the analysis of soil chemical properties and available nutrient status in soil. The samples were air dried and then crushed with wooden roller to break the aggregates and passed through a 2 mm sieve (0.2 mm sieve for organic carbon estimation). The sieved samples were stored in clean polythene bags for further analysis.

2.3 Statistical Analysis

Plant and soil samples were analyzed in laboratory and plant nutrient uptake and soil nutrient status were estimated and subjected to statistical analysis by adopting Fischer's method of analysis of variance and the mean values of treatments were then subjected to Duncan's Multiple Range Test (DMRT) [15] in OPSTAT software. The critical difference values given in the Table 2 at 5 per cent level of significance were used.

3. RESULTS AND DISCUSSION

3.1 Nutrient Uptake

The results on nutrient uptake presented in Table 3. It has been observed that significantly higher uptake of total nitrogen, phosphorus and potassium uptake under drip irrigation treatment, (T_9) [i.e irrigation applied on 0.6 ET_0 at seedling, 1.0 ET_0 at flowering, 1.25 ET_0 at pegging, 0.8 ET_0 at pod formation stages along with fertigation of N and P (3 splits at NF on 3rd, 4th and 5th week) and $CaNO_3$ and S nutrients (3 splits at PGF on 7th, 8th and 9th week)] as 164.0, 27.6 and 129.3 kg ha^{-1}, respectively. .It was 66.67, 122.58 and 34.97 per cent higher compared to control T_{10} (flood FAO) and 22.26, 24.27 and 13.53 per cent higher compared to treatment T_1 (sprinkler with 50 mm irrigation depth) (Table 3). Similarly, providing drip fertigation with 100% normal fertilizers registered markedly higher uptakes of N (114.4 kg/ha), P (30.5 kg/ha) and K (67.2 kg/ha) over all the treatments in groundnut and showed 18.1, 16.9 per cent higher N and P uptake, respectively as compared to control ([100% normal fertilizers (NF) with surface irrigation) as reported by Jain et al. [16]. This was in conformity with the results reported by Chandini et al. [17], Sanju et al. [18], Maurya et al. [19].

Table 3. Effect of different irrigation levels and methods on major nutrient uptake of groundnut at harvest

Treatments	Major nutrient uptake (kg ha^{-1})			Total nutrient (NPK) uptake (kg ha^{-1})
	N	P	K	
T_1	127.5 ^{b}	20.9 ^{b}	111.8 ^{b}	260.2 ^{b}
T_2	121.3 ^{bc}	19.0 ^{bc}	108.6 ^{b}	248.9 ^{bc}
T_3	115.2 ^{bcde}	16.9 ^{cd}	104.2 ^{bc}	236.3 ^{cde}
T_4	105.9 ^{def}	15.5 ^{d}	101.8 ^{bc}	223.2 ^{ef}
T_5	97.4 ^{f}	12.2 ^{e}	93.4 ^{c}	203.0 ^{g}
T_6	119.5 ^{bcd}	19.1 ^{bc}	109.7 ^{b}	248.3 ^{bc}
T_7	114.8 ^{bcde}	18.2 ^{c}	107 ^{b}	240.0 ^{cd}
T_8	109.7 ^{cdef}	17.1 ^{cd}	101.5 ^{bc}	228.3 ^{de}
T_9	164 ^{a}	27.6 ^{a}	129.3 ^{a}	320.9 ^{a}
T_{10}	98.4 ^{f}	12.4 ^{e}	95.8 ^{c}	206.6 ^{g}
T_{11}	100.4 ^{ef}	12.3 ^{e}	96.2 ^{c}	208.9 ^{fg}
S.Em±	**4.6**	**0.7**	**3.3**	**5.2**

T_1 -Sprinkler irrigation (SI) (50 mm except 60 mm at 50 and 60 DAS)
T_2 -SI (40 mm except 48 mm at 50 and 60 DAS) i.e. 80 % of T_1
T_3 -SI (35 mm except 42 mm at 50 and 60 DAS) i.e. 70 % of T_1
T_4 -SI (30 mm except 35 mm at 50 and 60 DAS) i.e. 60 % of T_1
T_5 -SI (25 mm except 30 mm at 50 and 60 DAS) i.e. 50 % of T_1
T_6 -SI (35 mm except 42 mm at 50 and 60 DAS) + FA of 0.5 % KNO_3 at 50 DAS
T_7 –SI (30 mm except 25 mm at 50 and 60 DAS) + FA of 0.5 % KNO_3 at 40 and 60 DAS
T_8 -SI (25 mm except 30 mm at 50 and 60 DAS) + FA of 0.5 % KNO_3 at 30, 50 and 70 DAS
T_9 -DI at 0.6 ET_0 (S), 1.0 ET_0 (F), 1.25 ET_0 (P) and 0.8 ET_0 (PF) + fertigation of N and P [3 splits at NF on 3rd, 4th and 5th week] + $CaNO_3$ and S nutrients [3 splits at PGF on 7th, 8th and 9th week]
T_{10} -Flood irrigation at 0.45 ET_0 (S), 0.75 ET_0 (F), 1.05 ET_0 (P), 0.70 ET_0 (PF) (FAO recommendation)
T_{11} – Irrigation as per UAS POP (Irrigating at 25, 40, 55, 70 and 85 DAE at 60mm depth)
SI= Sprinkler Irrigation; FA= Foliar Application; DI= Drip Irrigation; S = Seedling; F = Flowering; P= Pegging; PF = Pod Formation; NF = Nodule formation; PGF= Peg formation

Higher nutrient uptake in drip irrigation with fertigation was mainly due to application of controlled water near the crop root zone thus providing conditions for vigorous root development which helped in better water and nutrient uptake by the crop and higher root initiation with three equal splits caused significant differences in nutrient uptake pattern. This is due to the split application of nutrients, which may have improved the solubility of nutrients, leading to better nutrient availability in the crop root zone and resulted in higher root activity and thus improving nutrient uptake.

Among the sprinkler treatments, total nutrient uptake was significantly lower in case of treatment t_5 (25 mm irrigation depth) as 203 kg ha^{-1}, and it was 21.98 per cent lower as compared to the treatment t_1 (50 mm irrigation depth) as 260.2 kg ha^{-1}.similarly, meti et al. [20] reported that nitrogen, phosphorus, potassium and sulphur uptake increased from 88.64 to 191.17 kg N ha^{-1}, 8.34 to 9.05 kg P ha^{-1}, 60.59 to 65.34 kg K ha^{-1} and 8.86 to 10.01 kg S ha^{-1}, respectively by increasing water application rate through irrigation scheduling at 0.8 to 1.0 IW/CPE ratio. This was due to lower water availability in crop root zone reducing nutrient mobility and uptake by the crop plant. However, sprinkler treatments with foliar spray of KNO_3 performed better in terms of nutrient uptake.

3.2 Soil Chemical Properties and Available Nutrient Status after Harvest of Groundnut

3.2.1 Soil chemical properties

The soil pH, electrical conductivity (EC) and organic carbon content did not differ significantly under different irrigation levels at harvest of groundnut. However, pH ranged from 7.63 to 7.71, EC from 0.26 to 0.31 dS m^{-1} and soil organic carbon content from 5.0 to 5.4 mg kg^{-1} (Table 4).

However, treatment T_9 recorded numerically higher soil chemical properties and enhanced the pH, EC and organic carbon by 1.04, 19.23 and 8.0 per cent respectively compared to control treatments (Flood FAO and flood irrigation as per UAS POP) which indicated the role of drip fertigation in enhancing chemical properties of soil. Higher soil organic carbon in the drip fertigation treatment was due to the increasing availability of N, P and K in soil with congenial soil moisture regime as a result of drip fertigation which might have increased the soil microbial activity leading to increased levels of soil organic carbon (Salvin, [21]; Kavino et al. [22]).

3.2.2 Available nutrient status in soil (kg ha^{-1})

The data pertaining to available major nutrients (nitrogen, phosphorus and potassium) in soil after harvest of groundnut as influenced by different levels of irrigation are given in Table 5.

The influence of different irrigation levels had failed to show significant difference on soil available nitrogen, phosphorus and potassium after harvest. However, it ranged from 255.73 to 283.62 kg ha^{-1} for nitrogen. Whereas, it ranged from 28.47 to 29.84 kg ha^{-1} for available phosphorus and range of soil available potassium was 350.39 to 355.49 kg ha^{-1} for different treatments after harvest of the crop. Similarly, \ Shashishekhar [23] observed that irrigation scheduled at 0.6 CPE recorded significantly higher soil available nitrogen (161.9 kg ha-1) over other irrigation levels (0.8 and 1.0 CPE) in groundnut whereas available soil phosphorus and potassium did not vary significantly among the irrigation levels.

Available nitrogen, phosphorus and potassium in soil at harvest of groundnut did not differ significantly due to different irrigation levels. However, major nutrient availability was numerically higher with drip irrigated treatment T_9 i.e. 8.54, 4.45 and 1.37 per cent higher compared to control treatment T_{10} (Flood FAO) (Table 5). This was mainly due to split of application of nitrogen, phosphorus and potassium in drip fertigation treatment.

Table 4. Effect of different irrigation levels and methods on soil ph, electrical conductivity (ec) and organic carbon (oc) after harvest of groundnut

Treatments	pH	EC (d Sm^{-1})	OC (mg kg^{-1})
T_1	7.70 ^{a}	0.31 ^{a}	5.3 ^{a}
T_2	7.68 ^{a}	0.30 ^{a}	5.2 ^{a}
T_3	7.67 ^{a}	0.28 ^{a}	5.1 ^{a}
T_4	7.66 ^{a}	0.27 ^{a}	5.0 ^{a}
T_5	7.64 ^{a}	0.27 ^{a}	5.0 ^{a}
T_6	7.67 ^{a}	0.28 ^{a}	5.2 ^{a}
T_7	7.66 ^{a}	0.28 ^{a}	5.2 ^{a}
T_8	7.64 ^{a}	0.28 ^{a}	5.0 ^{a}
T_9	7.71 ^{a}	0.31 ^{a}	5.4 ^{a}
T_{10}	7.63 ^{a}	0.26 ^{a}	5.0 ^{a}
T_{11}	7.64 ^{a}	0.26 ^{a}	5.0 ^{a}
S.Em±	**0.13**	**0.02**	**0.32**

Table 5. Effect of different irrigation levels and methods on available nutrients after harvest of groundnut

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1	280.82 ^{ab}	29.74 ^{a}	354.83 ^{a}
T_2	278.33 ^{ab}	29.37 ^{a}	353.79 ^{a}
T_3	269.67 ^{ab}	29.07 ^{a}	352.73 ^{a}
T_4	264.10 ^{ab}	28.64 ^{a}	351.85 ^{a}
T_5	255.73 ^{b}	28.47 ^{a}	350.39 ^{a}
T_6	272.46 ^{ab}	29.20 ^{a}	352.79 ^{a}
T_7	269.67 ^{ab}	28.98 ^{a}	351.86 ^{a}
T_8	264.09 ^{ab}	28.57 ^{a}	350.86 ^{a}
T_9	283.62 ^{a}	29.84 ^{a}	355.49 ^{a}
T_{10}	261.30 ^{ab}	28.57 ^{a}	350.69 ^{a}
T_{11}	264.09 ^{ab}	28.74 ^{a}	351.00 ^{a}
S.Em±	**7.36**	**0.78**	**5.55**

4. CONCLUSION

From the present investigation, it can be concluded that highest nutrient uptake was recorded in drip irrigation and fertigation treatment and it was significantly higher than control flood irrigation. There was no significant differences among the treatments for soil chemical properties and available major nutrients in soil at harvest of groundnut but the values were numerically higher in drip fertigation treatment. So, micro-irrigation strategies, particularly, drip irrigation and fertigation can be a solution for improving crop nutrient uptake and improved nutrient status in soil thus reducing the use of excessive amount of water and nutrients in crops and help in improving crop productivity through optimized supply of resources in the crop root zone.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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