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RESEARCH PAPER

Response of groundnut to micro-irrigation and methods of fertilizer application during *rabi* season

LAXMAN CHINCHALI, G. B. SHASHIDHARA AND B. S. YENAGI

Department of Agronomy, College of Agriculture, Dharwad
University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
E-mail: shashidhargb@uasd.in

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Abstract: A field experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during *rabi*, 2019. It comprised of three levels of irrigations at different growth stages and two different methods of fertilizer application, fertigation with calcium nitrate, sulphur granules and basal application of fertilizer as per recommended package of practice (RPP). The treatments were replicated thrice in strip plot design. Drip irrigation applied at 0.6 ET_0 (Seedling) + 1.0 ET_0 (Flowering) + 1.25 ET_0 (Pegging) + 0.8 ET_0 (Pod formation) stages with three split application of nitrogen and phosphorus at nodule formation (on 3rd, 4th and 5th week after sowing) stages and fertigation of three splits of calcium nitrate [$Ca(NO_3)_2$] and sulphur (granular form) at peg formation stage (on 7th, 8th and 9th week after sowing) recorded significantly higher number of pods per plant, pod weight per plant and dry pod yield (28.8, 25.0 g per plant and 3771 kg ha^{-1}) over surface (16.9, 14.9 g per plant and 1937 kg ha^{-1}) and sprinkler (18.7, 16.4 g per plant 2272 kg ha^{-1}) method of irrigation. The same treatment recorded significantly higher net returns (₹ 1,04,109 ha^{-1}) compared to surface (₹ 34,917 ha^{-1}) and sprinkler (₹ 47,775 ha^{-1}) method of irrigation and fetched an additional amount of ₹ 69,192 and 56,334 ha^{-1}, respectively. Similar treatment recorded significantly higher water productivity (1.06 kg m^{-3}) over surface and sprinkler irrigation (0.37 and 0.67 kg m^{-3}, respectively) with a saving of irrigation water to the extent of 31.49 and 12.21 per cent over surface and sprinkler irrigation.

Key words: Drip irrigation, Fertigation, Groundnut, Water productivity

Introduction

Groundnut (*Arachis hypogaea* L.) is also known as supplementary food crop of the world and is one of the important oilseed crops in the economy of Indian agriculture. Oilseeds occupy 2nd position next to food grains in Indian agriculture in terms of value and production. The diverse agro-climatic situations in the country are suitable for developing the principle oilseeds, which are fit for human consumption as edible and non-edible oilseeds. Groundnut is an essential oilseed crop in the tropical and subtropical regions to meet the demand for edible oils and protein sustainability. In Karnataka, groundnut is grown in area of 5.80 lakh hectares (3.75 lakh hectares in *kharif* and 2.05 lakh hectares in *rabi*/Summer season) with a production of 4.23 lakh tonnes (2.32 lakh tonnes in *kharif* and 1.91 lakh tonnes in *rabi*/summer season) and the productivity is 729 kg (619 kg ha^{-1} in *kharif* and 932 kg ha^{-1} in *rabi* /summer season) per hectare (Anon., 2019).

Modern drip irrigation has been the most coveted breakthrough in agriculture in the world which can replace surface irrigation . Higher efficiencies in the use of water is possible with drip irrigation, because it minimizes surface evaporation, surface erosion and deep percolation considerably. In addition, a drip irrigation system is easy to use for fertigation, every crop nutrient requirement can be met with precision. Due to surface irrigation there will be more vegetative growth, but in micro irrigation vegetative growth can be managed. To economize the use of water and to bring more area under irrigation, advanced method of irrigation like drip to groundnut crop is essential. Fertigation enables sufficient water and nutrient supply with precise timing and consistent distribution to meet the demand for crop nutrients. Furthermore, fertigation provides large reductions in fertilizer use and minimizes liquid leaching losses.

If all the fertilizers are applied as basal dose nodule formation will not be active at later stages, it can be met through split application of nitrogen. Half of the nitrogen and phosphorus at the time of sowing and the remaining half after 35-40 days of sowing preferably after weeding should be to split applied at proper moisture level in the soil which plays major role in later stages of crop growth and development. Nitrogen plays an important role on growth and metabolism. Nitrogen is required for three major aspects of yield determinations: (i) Vegetative structures formation for nutrient absorption and photosynthesis; (ii) Formation of reproductive structures and determination of sink strength; and (iii) Production of assimilates to fill the economically important sink. It is reported that 30 days after sowing, pegging and pod development respectively are the critical stages for nitrogen (Puntamcar and Bathkal, 1967). Nitrogen is essential component of many compounds of plant, such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins. Hence, the present experiment conducted to assess the response of groundnut to micro-irrigation and methods of fertilizer application during *rabi* season.

Material and methods

A field experiment entitled Response of groundnut to micro-irrigation and methods of fertilizer application was conducted during *rabi* - 2019 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad. The treatment comprised of three different drip irrigation levels of drip irrigation *viz.,* drip irrigation at 0.4 ET_0 (Seedling) + 0.8 ET_0 (Flowering) + 1.0 ET_0 (Pegging) + 0.8 ET_0 (Pod formation) stages, drip irrigation at 0.6 ET_0 (Seedling) + 1.0 ET_0 (Flowering) + 1.25 ET_0 (Pegging) + 0.8 ET_0 (Pod formation) stages and drip irrigation at 0.6 ET_0 (Seedling) + 1.0 ET_0 (Flowering) + 1.50 ET_0 (Pegging) + 1.0 ET_0 (Pod formation) stages, with two control treatments (sprinkler and border strip method of irrigation). In vertical strip it comprised of two different methods of nutrient application, fertigation of N and P in 3 split at nodule formation (3 times at 3rd, 4th and 5th week) stage and fertigation of calcium [water soluble form of Ca $(NO_3)_2$] and sulphur (granular form) at peg formation stage (3 times on 7th, 8th and 9th week after sowing) and normal fertilizer application of N, P, K (basal) and gypsum (at Flowering and Pegging stages)

The groundnut seeds were hand dibbled as per the treatment in the experimental field on 28th Nov, 2019 using Dh-245 variety. Irrigation was given based on the actual evapo transpiration of the crop at four days interval in drip irrigation, fixed eight days interval in sprinkler irrigation and in surface method of irrigation was provided based on 1.0 IW/CPE ratio. The actual evapotranspiration was calculated by using the following formula (Choudhary and Kadam, 2006).

ETo = Kp x Ep

Where, ETo = Actual evapotranspiration (mm)

Kp = Pan coefficient (0.75) Ep = Daily pan evaporation (mm)

IW (Irrigation water)/CPE (cumulative pan evaporation) = 1.0

Hand weeding was done two times during the cropping period to keep weed free condition and fertilizer was applied to the groundnut as per recommended package of practices. Moisture percentage was recorded by gravimetric method before irrigation and used to calculate the quantity of water to be given.

Groundnut yield parameters like number of pods per plant was counted at harvest, pod weight per plant was computed, shelling per cent was calculated by dividing the weight of kernels to weight of pods and expressed in percentage. Pod yield per plant was calculated from randomly selected five plants in each treatment and pod yield per hectare is worked out from the net plot yield.

The growth and yield parameters of groundnut recorded were analyzed with strip plot design. Growth and yield parameters of the experimental data obtained was compiled and subjected to statistical analysis by adopting Fischer's method of analysis of variance (Gomez and Gomez, 1984). The critical difference values given in the table at 5 per cent level of significance were used.

Results and discussion

Effect of irrigation levels on pod yield and yield parameters

The groundnut yield was significantly higher with irrigation applied through drip at 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 (3274 kg ha^{-1}). However, it was on par with drip irrigation was provided at 0.6 ET_0 at Seedling + 1.0 ET_0 at Flowering + 1.50 ET_0 at Pegging + 1.0 ET_0 at Pod formation stages (3070 kg ha^{-1}) (Table 1). The lower yield was observed when crop was irrigated at 0.4 ET_0 at Seedling + 0.8 ET_0 at Flowering + 1.0 ET_0 at Pegging + 0.8 ET_0 at Pod formation stage (2726 kg ha^{-1}), respectively. The pod yield was increased by 16.8 per cent over drip irrigation applied at 0.4 ET_0 at Seedling + 0.8 ET_0 at Flowering + 1.0 ET_0 at Pegging + 0.8 ET_0 at Pod formation stage. This might be due to, the crop

Table 1. Effect of micro-irrigation and methods of fertilizer application on number of pods, pod weight per plant and pod yield.

Treatments	Number of pods $plant^{-1}$	Pod weight $plant^{-1}$(g)	Pod yield (kg ha^{-1})
Horizontal strip (H)			
I_1	21.9	19.1	2726
I_2	25.4	22.1	3274
I_3	23.9	20.6	3070
S.Em. ±	0.4	0.4	101
C.D. (p = 0.05)	1.7	1.6	398
Vertical strip (V)			
F_1	26.0	22.4	3347
F_2	21.5	18.8	2700
S.Em. ±	0.4	0.5	84
C.D. (p = 0.05)	2.6	3.2	510
Interaction (H V)			
I_1F_1	23.0	19.6	2826
I_1F_2	20.7	18.6	2626
I_2F_1	28.8	25.0	3771
I_2F_2	22.0	19.1	2777
I_3F_1	26.1	22.6	3444
I_3F_2	21.7	18.7	2697
S.Em. ±	0.3	0.3	76
C.D. (p = 0.05)	1.3	1.1	300
Control			
C1	18.7	16.4	2272
C2	16.9	14.9	1937
S.Em. ±	0.6	0.6	114
C.D. (p = 0.05)	1.8	1.7	347

I_1- DI at 0.4 ET_0 (S) + 0.8 ET_0 (F) + 1.0 ET_0 (P) + 0.8 ET_0 (PF) stage (FAO)

I_2- DI at 0.6 ET_0 (S) + 1.0 ET_0 (F) + 1.25 ET_0 (P) + 0.8 ET_0 (PF) stages

I_3- DI at 0.6 ET_0 (S) + 1.0 ET_0 (F) + 1.50 ET_0 (P) + 1.0 ET_0 (PF) stages

F_1- Fertigation of N and P in [three splits at NF] + $Ca(NO_3)_2$ and SG [three split at PGF]

F_2- Application of N, P, K (basal) and gypsum at F, P stages as per (RPP)

C_1- SI at 1.0 ET_0 + RPP

C_2- BSI at 1.0 IW/CPE + RPP

DI-Drip irrigation, S-Seedling, F-Flowering, P-Pegging, PF-Pod formation, NF-Nodule formation, SG-Sulphur granules, PGF-Peg formation, RPP-Recommended package of practice, SI-Sprinkler irrigation, BSI-Border strip irrigation, ET_0- Actual evapotranspiration (mm) and IW/CPE- Irrigation water/cumulative pan evaporation.

requires little higher water during the early stage to put up vegetative growth *viz*., number of branches and nodulation. Giving irrigation of 0.4 ET_0 may not be sufficient to put forth the required growth and dry mater accumulation and distribution this can be seen in later stages of crop growth

The main factors deciding the groundnut yield are number of pods per plant, pod weight per plant, 100 kernels weights and shelling percentage. The number of pods per plant (25.4) and pod weight per plant (22.1 g) were higher with drip irrigation applied at 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 as compared to other treatments significantly lower growth, yield, quality parameters and nutrient uptake were observed with drip irrigation applied at 0.4 ET_0 at Seedling + 0.8 ET_0 at Flowering + 1.0 ET_0 at Pegging + 0.8 ET_0 at Pod formation stage. The per cent increase in these yield parameters was 13.77 and 13.57 per cent with drip irrigation applied at 0.6 ET_0 at Seedling + 1.0 ET_0 at Flowering + 1.25 ET_0 at Pegging and 0.8 ET_0 at Pod formation stages over drip irrigation applied at 0.4 ET_0 at Seedling + 0.8 ET_0 at Flowering + 1.0 ET_0 at Pegging + 0.8 ET_0 at Pod formation stage. Similar results were also observed with irrigation at lower ET_0 by Ranjitha *et al.* (2018). Higher yield parameters observed in groundnut crop were attributable to supply of required quantity of water applied through drip at different growth stages might helped in supplying favorable moisture conditions for crop growth that resulted in improved dry matter accumulation in various plant parts in turn Increased yield parameters ultimately increased the final yield of the crop.

Effect of different methods of fertilizer application on pod yield and yield parameters

Split application of nitrogen and phosphorus at nodule formation, calcium and sulphur at peg formation stages through fertigation, recorded significantly higher dry pod yield (3347 kg ha^{-1}) compared to basal application of fertilizer (2700 kg ha^{-1}). Increase in dry pod yield to an extent of 19.33 per cent under fertigation compared to normal basal application of fertilizer.

The results revealed that three split application of nitrogen and phosphorus at nodule formation stage, and calcium, sulphur with fertigation at peg formation stages helps in determing yield potential of groundnut. The beneficial effect of split application of nutrients during nodulation and pegging stage is mainly attributed to the fact that may be the N, P and S act as protoplasmic elements and calcium act as balancing element. Nitrogen plays a major role in growth and metabolism. The split application of nitrogen is recommended at nodulation stage, because the crop requires more N for nodule formation and this stage will be there for almost three weeks. It is reported that 30 days after sowing, pegging and pod development, respectively are critical stages for nitrogen (Puntamcar and Bathkal, 1967). There may be chances of leaching, denitrification and volatilization losses in groundnut. Hence, split applications of fertilizers helps to reduce this problem. So continuous supply of N has helped to develop more number and quality of nodules, this reflected in crop vegetative growth at later stages (plant height, number of branches and dry matter accumulation at 60 and 90 DAS).

The main factors that decides groundnut yield are number of pods per plant, pod weight per plant, 100 kernel weights and shelling percentage. The number of pods per plant (26) and pod weight per plant (22.4 g) were all higher with fertigation of N and P in three split at nodule formation (on 3rd, 4th and 5th week) stage and fertigation of three splits of calcium and sulphur at peg formation stage (on 7th, 8th and 9th week) in the form of water soluble form of Ca $(NO_3)_2$ and sulphur granules compared to basal application of N, P, K and gypsum at flowering and pegging stages. The former treatment (fertigation) showed significantly higher growth, yield, quality parameters and nutrient uptake in groundnut. The per cent increase in yield attributes of groundnut with respect to fertigation is 16.7 and 16.07 per cent over normal fertilizer application as per RPP. It can be attributed to nutrient supply through irrigation water improved solubility and nutrient availability, reducing the loss to a considerable extent and helped in increasing fertilizer use efficiency (*i.e.,* three split at nodule formation stage and three split at peg formation stages). The result was in line with the Hebbar *et al*. (2004). Further, Sanju (2013) found that even the same amount of fertilizer applied by irrigation water resulted in a higher yield relative to soil application.

Interaction effect of irrigation levels and different methods of fertilizer application on pod yield and yield parameters

Groundnut pod yield varied significantly because of different irrigation levels with different method and forms of fertigation. Significantly higher pod yield recorded with drip irrigation applied at 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 with fertigation of N and P in three split at nodule formation (on 3rd, 4th and 5th week) stage and fertigation of three splits of Calcium and Sulphur at peg formation stage (on 7th,8th and 9th week) in the form of water soluble form of $Ca(NO_3)_2$ and Sulphur granules recorded higher pod yields (3771 kg ha^{-1}) than all other treatments. The per cent increase in yield to the extent of 25.05 per cent over drip irrigation applied at 0.4 ET_0 at Seedling + 0.8 ET_0 at Flowering + 1.0 ET_0 at Pegging + 0.8 ET_0 at Pod formation stage with application of N, P, K (basal) and gypsum at Flowering and Pegging stages (Table 1). It might be due to the fact that, different environmental factors pose different potential nitrogen losses-sometime leaching beyond root zone, denitrification and volatilisation. A special need for calcium develops after the pegs when the pollinated flowers enter the soil. Immediately after the peg entrance, calcium stops moving from the main stem to the peg. Yet the peg must get calcium if it is to develop into filled pod. Consequently, the developing pod must get whatever calcium it needs from the surrounding soil this indicates that need of calcium during peg formation stages (Reddy, 1988). The crop yields are dependent on the crop's complementary interaction between vegetative and reproductive production. As a result of the beneficial impact of fertigation on growth and crop yield parameters, a marked increase in economic yield appeared, increased availability and absorption of nutrients by the crop at the optimum supply of moisture coupled with frequent supply of nutrients by fertigation and consequently better formulation and translocation of assimilates from source to sink may increase yield under fertigation. These results are in concordance with Jain *et al.* (2018).

Effect of irrigation levels and different methods of fertilizer application on water productivity

Water productivity was differed significantly due to levels of irrigation. Significantly higher water productivity (Table 2) was found in treatment with irrigation applied through drip at 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 (0.92 kg m^{-3}). However, it was on par with drip irrigation applied at 0.4 ET_0 (S) + 0.8 ET_0 (F) + 1.0 ET_0 (P) + 0.8 (PF) stages (0.86 kg m^{-3}) compared to drip irrigation applied at 0.6 ET_0 at Seedling + 1.0 ET_0 at Flowering + 1.50 ET_0 at Pegging + 1.0 ET_0 at Pod formation stages (0.76 kg m^{-3}). It is mainly due to the fact that the drip irrigation applied at 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, less quantity of irrigation water was provided compared to drip irrigation applied at 0.6 ET_0 at Seedling + 1.0 ET_0 at Flowering + 1.50 ET_0 at Pegging, 1.0 ET_0 at Pod formation stages, there by increased the water productivity.

Among different methods of fertilizer application, fertigation of N and P in three split at nodule formation (on 3rd, 4th and 5th weeks after sowing) stages and fertigation of three splits of Calcium [water soluble form of $Ca(NO_3)_2$] and Sulphur in granular form at Peg formation stage (on 7th, 8th and 9th week after sowing) recorded significantly higher water productivity (0.94 kg m^{-3}) (Table 2) compared to normal fertilizer application of N, P, K (basal) and gypsum at flowering and pegging stages (0.76 kg m^{-3}). The per cent increase in water productivity was 19.14 per cent. This might be due to higher availability of fertilizer given at regular interval helped the crop to develop more number of pods and ultimately the yield with required quantity of water for the crop. Vijayalakshmi *et al.* (2011) in groundnut also reported that, water supplying soils closer to the plant without much water loss resulted in higher water productivity.

The interaction between irrigation through drip with different method and forms of fertigation recorded significantly higher water productivity with treatment receiving the irrigation at 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 with N and P in three split at nodule formation (on 3rd, 4th and 5th week after sowing) stages and fertigation of three splits of calcium and sulphur at peg formation stage (on 7th, 8th and 9th week after sowing) (1.06 kg m^{-3}). The per cent increase in water productivity to the extent of 36.79 per cent compared to drip irrigation applied at 0.6 ET_0 at Seedling + 1.0 ET_0 at Flowering + 1.50 ET_0 at Pegging + 1.0 ET_0 Pod formation stage with application of N, P, K (basal) and gypsum at Flowering and Pegging stages (0.67 kg m^{-3}).

This might be due to the maintenance of optimum moisture near field capacity throughout the crop period and supplying of required quantity of N and P through fertigation which is required for nodulation and root development and fertilizer *viz.*, Ca and S supplied at the time of pod formation and pod development stage helped the crop to produce more number and pods with higher shelling percentage, which in turn recorded higher water productivity, yield and net returns. However, in case of sprinkler and border strip method of irrigation where fertilizer applied is subjected to more leaching loss and the availability at required crop stage could be inferred from this analysis. The combined fertigation with a reduced irrigation produced comparable yields (El-Habbasha *et al.*, 2015).

Table 2. Effect of micro-irrigation and methods of fertilizer application on total amount of water applied, total number of irrigations and percent water saving through drip, sprinkler and surface irrigation

Particulars	I_1F_1	I_1F_2	I_2F_1	I_2F_2	I_3F_1	I_3F_2	C_1	C_2	Total number of irrigations
Rain fall (mm)	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	-
Water through drip (mm)	297.16	297.16	336.87	336.87	384.11	384.11	-	-	18
Sprinkler (mm)	-	-	-	-	-	-	378.03	-	10
Surface irrigation (mm)	-	-	-	-	-	-	-	500	9
Total water applied (mm)	315.16	315.16	354.87	354.87	402.11	402.11	396.03	518	-
Percent water saving (%)	39.16	39.16	31.49	31.49	22.37	22.37	27.02	0	-
Water productivity (kg m^{-3})	0.90	0.83	1.06	0.78	0.86	0.67	0.60	0.37	-

I_1- DI at 0.4 ET_0 (S) + 0.8 ET_0 (F) + 1.0 ET_0 (P) + 0.8 ET_0 (PF) stage (FAO)
I_2- DI at 0.6 ET_0 (S) + 1.0 ET_0 (F) + 1.25 ET_0 (P) + 0.8 ET_0 (PF) stages
I_3- DI at 0.6 ET_0 (S) + 1.0 ET_0 (F) + 1.50 ET_0 (P) + 1.0 ET_0 (PF) stages
F_1- Fertigation of N and P in [three splits at NF] + $Ca(NO_3)_2$ and SG [three split at PGF]
F_2- Application of N, P, K (basal) and gypsum at F, P stages as per (RPP)
C_1- SI at 1.0 ET_0 + RPP
C_2 - BSI at 1.0 IW/CPE + RPP
DI-Drip irrigation, S-Seedling, F-Flowering, P-Pegging, PF-Pod formation, NF-Nodule formation, SG-Sulphur granules, PGF-Peg formation, RPP-Recommended package of practice, SI-Sprinkler irrigation, BSI-Border strip irrigation, ET_0 - Actual evapotranspiration (mm) and IW/CPE- Irrigation water/cumulative pan evaporation.

Table 3. Effect of micro-irrigation and methods of fertilizer application on gross returns, net returns and BC ratio

Treatments	Gross return (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B-C ratio
Horizontal strip (H)			
I_1	1,44,538	53,564	1.50
I_2	1,73,368	87,374	1.79
I_3	1,62,742	76,747	1.68
S.Em. ±	5188	6577	0.05
C.D. (p = 0.05)	20372	26311	0.20
Vertical strip (V)			
F_1	1,77,259	78,547	1.68
F_2	1,43,173	66,578	1.63
S.Em. ±	4296	1696	0.05
C.D. (p = 0.05)	26145	10322	NS
Interaction (H×V)			
I_1F_1	1,49,772	64,420	1.59
I_1F_2	1,39,303	62,708	1.42
I_2F_1	1,99,503	1,04,109	1.89
I_2F_2	1,47,234	70,639	1.68
I_3F_1	1,82,503	87,109	1.73
I_3F_2	1,42,981	66,386	1.63
S.Em. ±	3982	6037	0.04
C.D. (p = 0.05)	15636	23666	0.15
Control			
C_1	1,20,386	47,775	1.50
C_2	1,02,976	34,917	1.40
S.Em. ±	5895	6984	0.06
C.D. (p = 0.05)	17880	21184	0.18

I_1- DI at 0.4 ET_0 (S) + 0.8 ET_0 (F) + 1.0 ET_0 (P) + 0.8 ET_0 (PF) stage (FAO)

I_2- DI at 0.6 ET_0 (S) + 1.0 ET_0 (F) + 1.25 ET_0 (P) + 0.8 ET_0 (PF) stages

I_3- DI at 0.6 ET_0 (S) + 1.0 ET_0 (F) + 1.50 ET_0 (P) + 1.0 ET_0 (PF) stages

F_1- Fertigation of N and P in [three splits at NF] + $Ca(NO_3)_2$ and SG [three split at PGF]

F_2- Application of N, P, K (basal) and gypsum at F, P stages as per (RPP)

C_1-SI at 1.0 ET_0 + RPP

C_2-BSI at 1.0 IW/CPE + RPP

DI-Drip irrigation, S-Seedling, F-Flowering, P-Pegging, PF-Pod formation, NF-Nodule formation, SG-Sulphur granules, PGF-Peg formation, RPP-Recommended package of practice, SI-Sprinkler irrigation, BSI-Border strip irrigation, ET_0 - Actual evapotranspiration (mm) and IW/CPE- Irrigation water/cumulative pan evaporation.

Effect of irrigation levels and different methods of fertilizer on economics

Application of drip irrigation applied at different ET_0 levels to groundnut differed significantly on the economics of groundnut. Significantly higher gross returns (Rs.1,73,368 ha^{-1}), net returns (Rs. 87,374 ha^{-1}) and B-C ratio (1.79) ratio were recorded with drip irrigation applied at 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.

Among the different methods of fertilizer application, fertigation of N and P in three split at nodule formation (on 3rd, 4th and 5th week) stage and fertigation of three splits of calcium and sulphur at peg formation stage (on 7th, 8th and 9th week) in the form of water soluble $Ca(NO_3)_2$ and sulphur granules recorded significantly higher gross (Rs. 1,77,259 ha^{-1}), net return (Rs.78,547 ha^{-1}) and BC ratio (1.68) (Table 3).

Among interaction between irrigation applied through drip with different methods of fertilizer application, recorded significantly higher gross (Rs.1,99,503 ha^{-1}), net returns (Rs.1,04,109 ha^{-1}) and B-C ratio (1.89) with treatment received the irrigation at 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 with N and P in three split at nodule formation (on 3rd, 4th and 5th week after sowing) stage and fertigation of three splits of calcium and sulphur at Peg formation stage (on 7th,8th and 9th week after sowing) over drip irrigation applied at 0.4 ET_0 at Seedling + 0.8 ET_0 at Flowering + 1.0 ET_0 at Pegging + 0.8 ET_0 at Pod formation stages with application of N, P, K (basal) and gypsum at Flowering and Pegging stages. Similar findings were reported by Arif *et al.* (2016), Jain and Meena (2015) and Ranjitha *et al.* (2018).

Conclusion

Based on the results it was concluded that for groundnut, application of irrigation through drip with fertigation at 0.6 ET_0 (Seedling) + 1.0 ET_0 (Flowering) + 1.25 ET_0 (Pegging) + 0.8 ET_0 (Pod formation) stages with three split application of nitrogen and phosphorus to groundnut at nodule formation with calcium nitrate [$Ca(NO_3)_2$] and sulphur (granular form) at peg formation stages during *rabi* season is found optimum for higher yield, water use efficiency and economics.

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