Original Research Article

Field Evaluation of Site Specific Drip Fertigation in Tomato

ABSTRACT

Evaluation of site specific drip fertigation system based on GIS integrated nutrient status maps was conducted at Instructional Farm, KCAET, Tavanur, Malappuram, Kerala. Using the spatial variability maps of the soil nutrients, two test plots, one from high fertility zone and one from low fertility zone were identified with the help of GPS for raising the tomato crop. The experimental plot was laid out in a Completely Randomized Design with four treatments and four replications. The results showed increase in yield and growth parameters under site specific drip fertigation treatment in low fertility area due to the adequate fertiliser application than general recommendation. In high fertility area, reduction of fertilizer to site specific requirement has produced almost similar result of general recommendation which indicates that site specific dose was sufficient to produce optimum yield from the crop. Site specific drip fertigation helped to achieve a higher water and nutrient use efficiency with high economic return of agricultural produce. From this study, it could be concluded that, instead of going blanket nutrient recommendation, a site specific nutrient recommendation may help the farmers who want to achieve higher profit from unit land area by using optimum inputs, thereby reducing environmental stress due to over fertilizer application.

Keywords: Site specific drip fertigation, Spatial variability maps, Nutrient recommendations, GIS, GPS, Nutrient use efficiency.

1. INTRODUCTION

Agriculture sector is under increasing pressure to produce more food for an ever-growing global population. Meeting the food requirements with limited resources of the planet is a big challenge. The time has now arrived to exploit all the modern tools available by bringing information technology and agricultural science together for improved economic and environmentally sustainable crop production. Precision farming is one of the main emerging technologies to sustain the productivity. The efficient nutrient management in crop fields can be attained through the application of precision farming based on geo-spatial technologies such as Geographical Information System (GIS), Global Positioning System (GPS) and Remote Sensing.

Nutrient management is a major component of soil and crop management system. Knowing the required nutrients for all stages of growth and understanding the soil’s ability to supply those needed nutrients are critical to profitable crop production. Excessive fertilizer use has several detrimental environmental effects. Conversely, insufficient fertilizer application limits crop yield. In order to attain high crop productivity and agricultural sustainability, a balanced nutrient fertilization is necessary. Site Specific Nutrient Management (SSNM) is an approach of feeding crops with nutrients as and when needed. The systematic implementation of best management practices into a site specific system provides the best opportunity to develop a truly sustainable agriculture system [1].

Site Specific Nutrient Management (SSNM) is a relatively new approach for nutrient recommendations based on the crop's need to achieve the desired yield. The development of SSNM recommendations could be based purely on the soil analysis or on soil cum plant analysis. Four primary factors must be taken into consideration in SSNM in order to supply desired nutrients for crop production viz. right input, right quantity, right place and right time [2]. It includes the use of both organic and inorganic resources, as well as consideration of the spatial and temporal variability of the soil, crop nutrient requirements, nutrient availability in the soil, cropping systems, the capacity of the soil to supply nutrients, the efficiency of nutrient use and the productivity of the varieties without impairing the quality of the soil and the environment. By limiting excessive and/or inadequate nutrient inputs, SSNM helps to lower the cost of fertilizer and help to increase profit [3]. Similarly, adoption of micro irrigation techniques such as drip fertigation is one of the best ways to attain high water use efficiency instead of traditional irrigation methods. It helps to increase fertilizer use efficiency by applying fertilizer through a drip system to the active plant root zone.

With these considerations, the present study was undertaken to make a field evaluation of site specific fertigation recommendation for tomato using GIS integrated nutrient status map in the Instructional Farm of Kelappaji College of Agricultural Engineering and Technology (KCAET), Tavanur, Malappuram with the following objectives (i) To study the response of site specific fertilizer application in different fertility zones of the study area by conducting field experiment in tomato, (ii) To study the soil moisture and soil nutrient dynamics under different fertigation treatments and (iii) To evaluate the economic feasibility of GIS integrated site specific drip fertigation.

2. MATERIAL AND METHODS

2.1 Site Characteristics

The experiment was conducted in the Instructional Farm of KCAET, Tavanur, Malappuram district in Kerala during January- August 2022. The total geographical area of the research work is 21.4 ha, which is lies between 10°51'15.25" and 10°51'30.51"N latitude and 75°58'59.42" and 75°59'24.74"E longitude. Agro-climatically, the area falls within the border line of northern hemisphere and central zone of Kerala. The location map of the study area is shown in Fig. 1.

For better site-specific nutrient management within the selected study area, the fertility zones were identified [4]. The field was divided into three different fertility zones using the spatial variability maps of three macronutrients (N, P and K) prepared by the GIS interpolation method. Out of these, two test plots, one from high fertility area and another from low fertility area were located with the help of GPS to raise the tomato crop. Climatic data was collected from Meteorological Observatory in KCAET campus. The area is humid tropical climate with maximum and minimum temperature of 37.73℃ and 22.42℃ respectively. The average relative humidity, sunshine hours and wind speed are 73.66%, 6.05 and 3.5 km hr^{-1} respectively.

Soil texture of both test plots was sandy clay loam. Soil moisture constants such as Field Capacity (FC) and Permanent Wilting Point (PWP) were determined using Pressure Plate Apparatus in the laboratory. The samples collected from two plots were subjected to chemical analysis to measure available N, P and K for site specific nutrient application. The detailed physio-chemical properties of the soils are given in Table 1.

The tomato (*Solanumlycopersicum* L) variety Manuprabha developed by KAU (Kerala Agricultural University) was selected for the field experiment. Manuprabha is a newly released high yielding bacterial wilt resistant tomato variety with medium sized fruits.

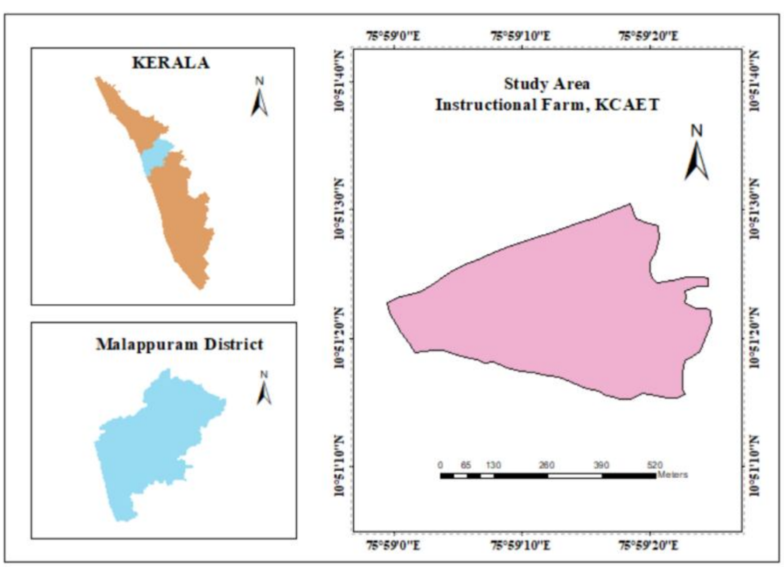


Fig. 1 Location map of the study area

Table 1.Soil properties of high and low fertility area

Soil characteristics	Particulars	Location Ⅰ (High)	Location Ⅱ (Low)
Physical properties	Field capacity (%)	23.01	22.21
	Permanent wilting point (%)	14.71	16.28
	Available moisture (%)	7.14	7.83
Chemical properties	pH	6.72	6.93
	EC	0.427	0.843
	Organic carbon (%)	2.267	0.156
	Available nitrogen (kg/ha)	330.8	126.5
	Available phosphorous (kg/ha)	161.06	7.9
	Available potassium (kg/ha)	390.84	12.6

2.2 Design and Treatments

The experimental plots were arranged in a Completely Randomized Design (CRD) with four treatments and four replications. The details of different treatment are as follows:

T1 – Fertilizer application based on the available nutrient status map of the field, through drip fertigation (Site specific drip fertigation).

T2– Fertilizer application based on the fertigation recommendation of KAU, through drip fertigation (POP recommended drip fertigation).

T3– 80% of fertilizer application based on the fertigation recommendation of KAU, through drip fertigation.

T4 – 60% of fertilizer application based on the fertigation recommendation of KAU, through drip fertigation

2.3 Design and Layout of the Drip System

The design of drip system involves selection of emitters, laterals, sub main, mainline, required pumping unit and necessary accessories. Based on friction loss calculated using Hazen- William equation, laterals and sub mains were selected for the desired flow rate and pressure head. Water was pumped from the source through a 1.5 HP pump and conveyed to the field using 63 mm diameter PVC pipe. From the mainline, water is distributed through sub main lines of 50 mm PVC pipes and online laterals of 12 mm diameter. On line drippers of 4 lph were used for applying water to the field at a spacing of 60 cm apart. A 25mm sized venturi injector was used for applying water soluble fertilizers efficiently along with irrigation water. Lateral flow control valves placed in the laterals were used to control the fertiliser application to different treatments. The layout were made in such a way that the fertigation could be made as per the requirement of different treatments (Fig. 2).

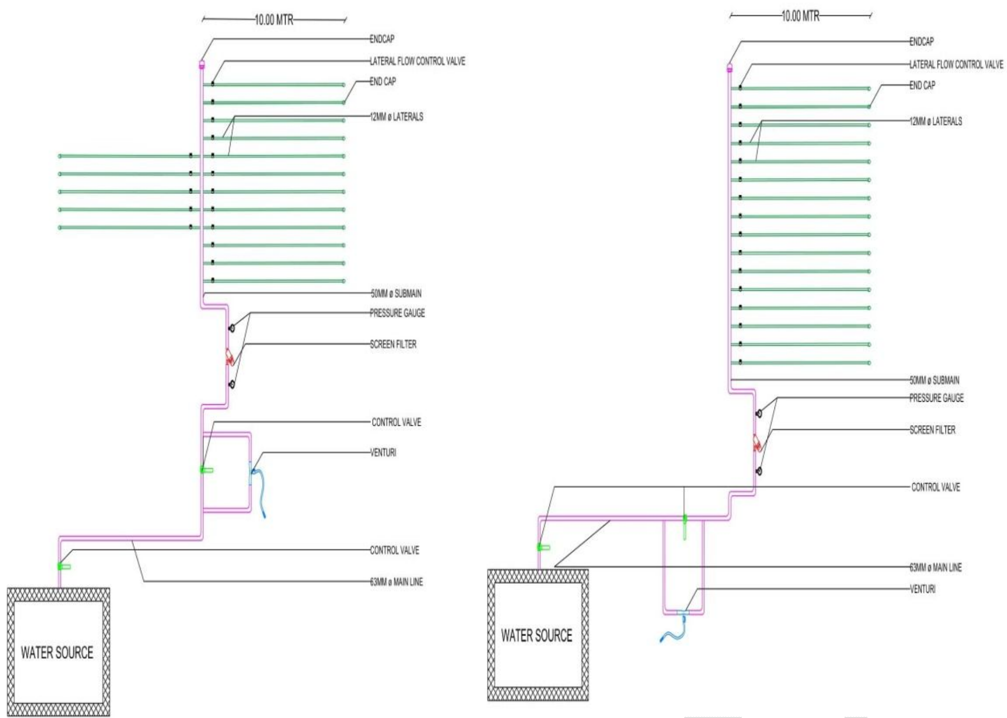
The field was prepared and formed into beds and channels for the required dimension. 16 beds were prepared with 10m length, 0.3m width and 0.3m height at spacing of 0.6m at both the locations. One month old seedlings were planted in both low and high fertility plots at a spacing of 60cm.

2.4 Fertigation Treatments

The water soluble fertilizers used for supplying N, P and K through drip irrigation were urea, 19:19:19, potassium nitrate (13:0:46) and MAP (12:61:0). Phosphorous was applied as basal dose. The recommended dose of fertilizer for tomato was 280:130:380 (N:P:K) as per Package of Practice (POP) of KAU (2020). The site specific recommendations of fertilizers were calculated based on Table 2 [5]. The site specific recommendation for high fertility area is 151:32:95 and for low fertility area is 358:138:486. Fertigation was given once in three days starting from 3 DAP up to 90 DAP (Days After Planting) with help of lateral control valves provided at the takeoff points of laterals.

Table 2. NPK ratings and fertilizer recommendations for field crops on area basis

Soil fertility class	% of organic carbon	N as % of general recommendation	Available P (kg/ha)	Available K (kg/ha)	P and K as of general recommendation	P and K as of general recommendation
	Sandy	Clayey/loamy				
0	0.00-0.1	0.00-0.16	128	0.0-3.0	0-35	128
1	0.11-0.2	0.17-0.33	117	3.1-6.5	36-75	117
2	0.21-0.3	0.34-0.5	106	6.6-10.0	76-115	106
3	0.31-0.45	0.51-0.75	97	10.1-13.5	116-155	94
4	0.46-0.6	0.76-1.00	91	13.6-17.0	156-195	83
5	0.61-0.75	1.01-1.25	84	17.1-20.5	196-235	71
6	0.76-0.9	1.26-1.5	78	20.6-24.0	236-275	60
7	0.91-1.1	1.51-1.83	71	24.1-27.5	276-315	48
8	1.11-1.3	1.84-2.16	63	27.6-31.0	316-355	37
9	1.31-1.5	2.17-2.5	54	31.1-34.5	356-395	25



(a) **(b)**

Fig. 2 Layout of drip irrigation system in (a) High fertility area (b) Low fertility area

2.5 Field Data Collections

The important crop growth parameters such as plant height, stem girth and primary branches per plant were observed. Yield parameters such as fruit weight, fruit girth, number of fruits per plant and yield per plant were observed from each treatment. Water requirement of the crop period was calculated from total water used and effective rainfall from the area and expressed as ha cm. Water Use Efficiency (WUE) was worked out from total tomato yield and total water used.

The soil moisture distribution patterns in both the areas were studied and plotted using the software "SURFER". Soil moisture content was estimated by gravimetric method using soil samples taken before irrigation and 30 minutes after irrigation at the emitter and at the radial distance of 15, 30 and 45 cm from the emitter and at depth of 0-15, 15-30, 30-45 cm from the dripper.

Nutrient dynamics in the soil profile was studied by collecting soil samples from dripper point and at the radial distance of 15, 30 and 45 cm from the emitter and at depth of 0-15, 15-30, 30-45 cm from the surface. The samples were air dried and analyzed for available nitrogen, phosphorous and potassium in the soil. The computer program viz. "SURFER" was used to plot the nutrient dynamics in the soil under each treatment. Residual nutrient status of the soil was studied by collecting soil samples from each treatment after two weeks of final harvesting. Samples were kept for air drying and analyzed for available N, P and K in the soil. Nutrient Use Efficiency was calculated and expressed in kg yield per kg nutrient applied. Economic analysis was carried out for each treatment and Benefit Cost (BC) ratio was calculated from gross return and total cost of cultivation.

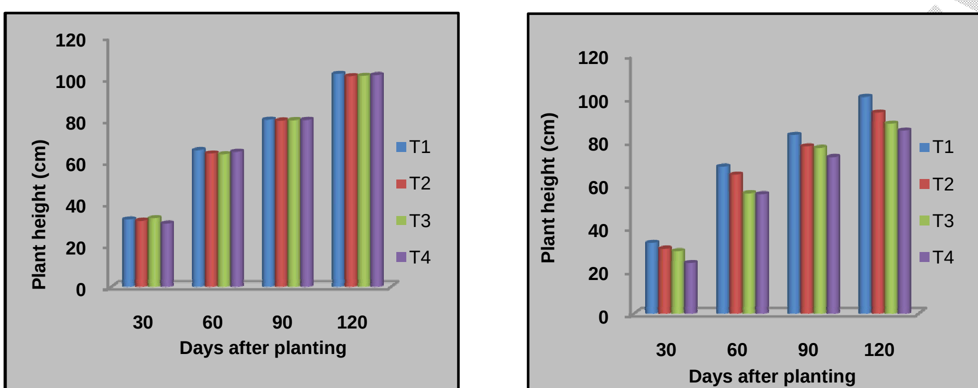
The observation on various parameter studied during the research work were statistically analyzed using standard program SPSS (Statistical Package for the Social Sciences) for CRD design. Whenever, any significant differences in results of growth and yield parameters for different treatments, critical differences were worked out at 5 per cent probability level (Least Square Difference test).

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

In case of high fertility area, growth parameters has no significant difference between the treatments with site specific drip fertigation (T1) and POP recommended drip fertigation (T2). All the treatments resulted almost similar plant growth, but the maximum plant height (102.2 cm) and stem girth (6.72 cm) was noted under the treatment with site specific drip fertigation (Fig. 3.a). In low fertility area, the statistical analysis indicated that treatments vary significantly at 5% level of significance. Large variation found between site specific drip fertigation as well as POP recommended drip fertigation. The plant height was significantly higher (100.5cm) in the treatment with site specific drip fertigation (T1) than all other treatments (Fig. 3.b).

Even though there was reduced amount fertilizer application in site specific drip fertigation treatment under high fertility area, it resulted in similar growth parameters in the treatment with POP recommended drip fertigation. Whereas in low fertility area, site specific recommendation of fertilizer was higher than POP recommendation and higher growth parameters were observed under the treatment with site specific drip fertigation. This result clearly demonstrated that, irrigation and fertilizer levels have a significant impact on plant growth parameters in low fertility area [6].By ensuring moisture and nutrient availability, fertigation regarded to be one of the key aspects that result in increased plant growth [7].



(a) (b)

Fig. 3 Effect of fertigation on plant height (cm) for (a) High fertility area (b) Low fertility area

3.2 Yield parameters

In high fertility area, there was no significant difference in fruit weight and fruit girth between various treatments, even though highest fruit weight (52.22 gm) was observed under site specific drip fertigation (T1). Almost same number of fruits per plant was observed under all the treatments in high fertility area (Fig. 4.a).

In low fertility area, it is evident that fruit weight and fruit girth is directly proportional to the rate of fertilizer applied and highest average fruit weight (52.1gm) was observed under site specific drip fertigation (T1). It is comparatively higher than the fruit weight observed under POP recommended drip fertigation and clearly narrates the necessity of a site specific nutrient application in low fertility area(Fig. 4.b). Similarly, significant differences in number of fruits per plant were observed between different treatments in low fertility area. Higher number of fruit per plant (30 fruits per plant) was observed in site specific drip fertigation. While, treatment with POP recommended drip fertigation resulted in 22 fruits per plant, which is very less when compared with T1 (Fig. 5).

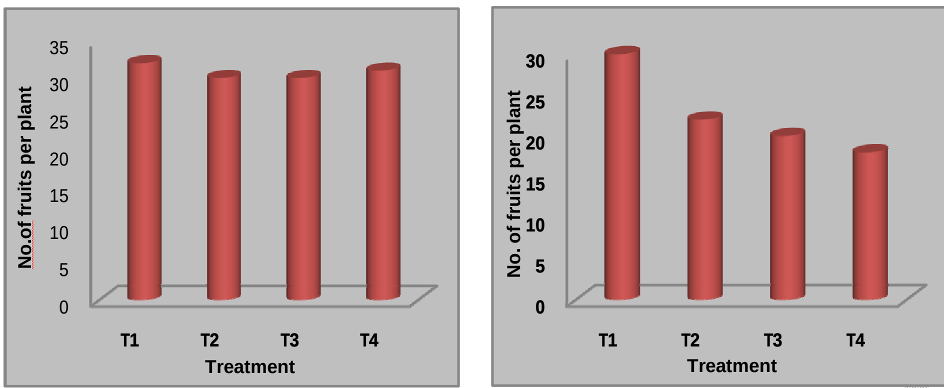
The application of site-specific drip fertigation results 36% more yield than the POP recommended drip fertigation in low fertility area. For high fertility area, it is nearly 6.5% more than POP recommended drip fertigation, which indicate that site specific drip fertigationis enough to produce maximum yield per plant (Fig.6).

This result clearly demonstrates that, when fertilizers applied to an area having low fertility, a general fertilizer recommendation is insufficient to meet the actual nutrient requirement of the crop. Thus, a site-specific fertilizer recommendation is more preferable than general fertilizer recommendation [8].

3.3 Water Use Efficiency

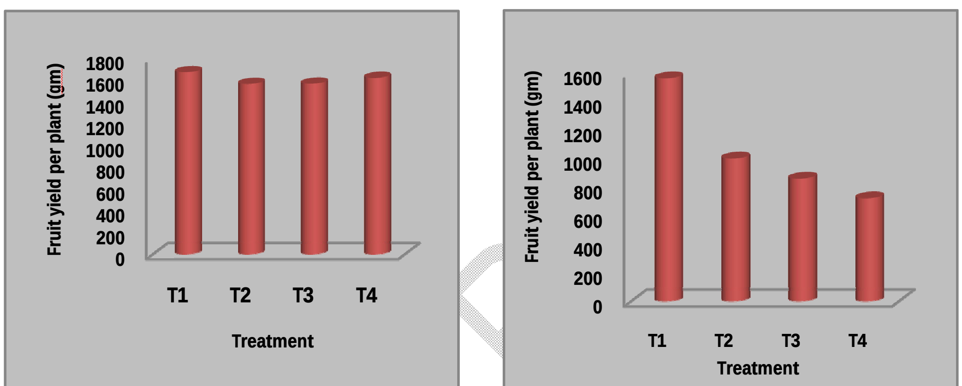
In high fertility area, highest WUE (88.82 kg/ha.mm) was observed from treatment T1 because of the high yield obtained from this treatment in high fertility area. It is on par with 60% 0f POP recommended treatment (85.52 kg/ha.mm). WUE is somewhat low in POP recommended dose (Fig. 7.a).

In low fertility area, WUE is significantly higher for site specific drip fertigation(79.49 kg/ha.mm) and very low for T4, treatment with 60% of recommended POP application (35.76 kg/ha.mm). It indicates that effective use of fertilizer and water together may be the reason for increased WUE in low fertility areas (Fig. 7.b).



(a) (b)

Fig. 4 Effect of fertigation on Average fruit weight in (a) High fertility area (b) Low fertility area



(a) (b)

Fig. 5 Effect of fertigation on Number of fruits per plant in (a) High fertility area (b) Low fertility area

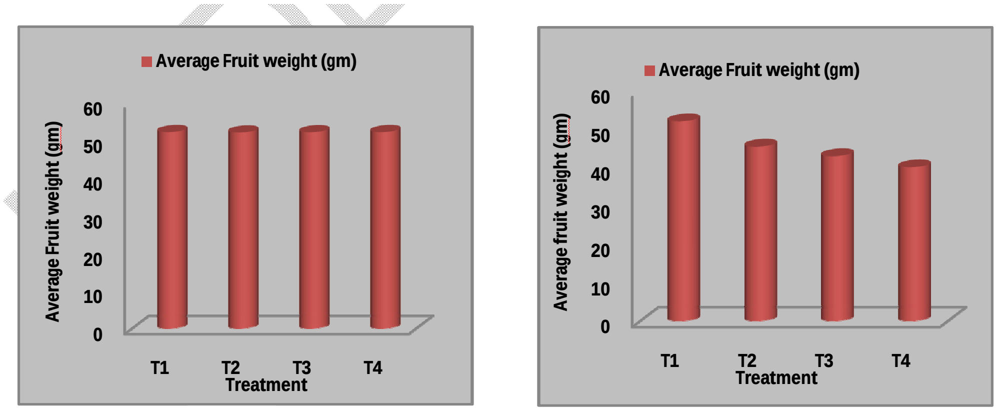


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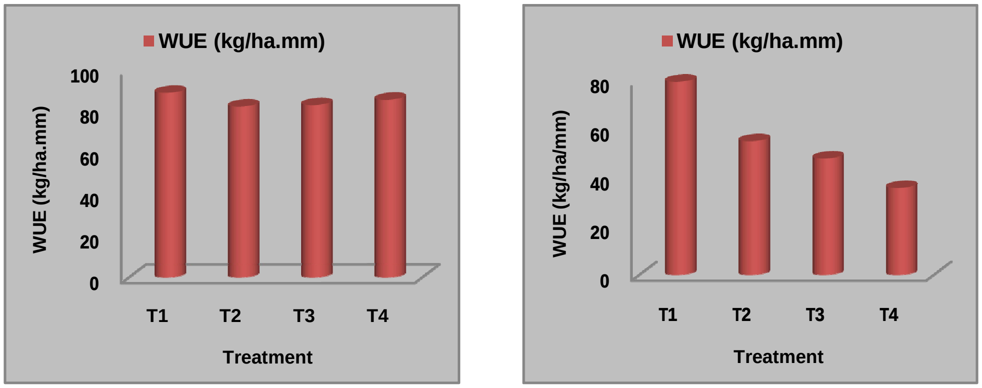
Fig. 6 Effect of fertigation on yield per plant in (a) High fertility area (b) Low fertility area



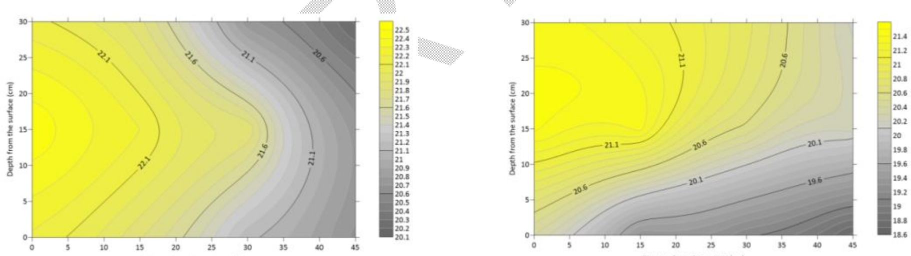
(a) **(b)**

Fig.7 Water Use Efficiency under different treatments in (a) High fertility area (b) Low fertility area

3.4 Soil Moisture Distribution

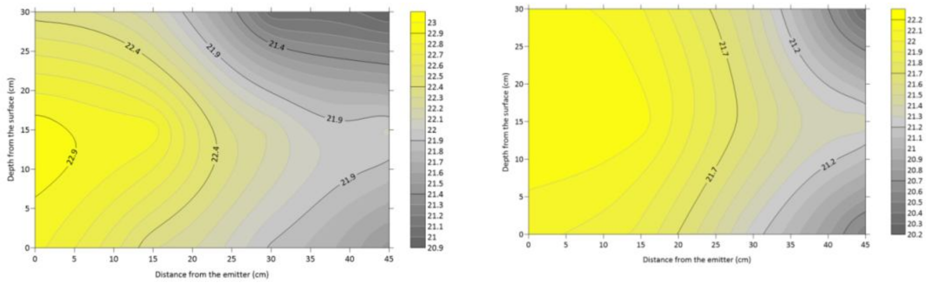
Water distribution pattern beneath the drippers is affected by many factors, of which discharge rate and amount of irrigation water applied in each irrigation are most important [9].In both the locations, the moisture content before irrigation increased with depth, whereas the same decreased with the radial distance from the emitter (Fig. 8). This may be due to the evaporation from the surface. After irrigation, a certain amount of water gets evaporated from the top and a larger amount is infiltrated down to the roots. Moreover, water gets evaporated more quickly in low fertility areas than in high fertility areas.

Analysis of the soil moisture at 30 minutes after irrigation shows that the soil moisture right below the dripper or 0 cm away from the dripper was closer to the field capacity, whereas the soil moisture at 45 cm away from the dripper was found to be less. Good moisture distribution was found laterally between the emitter positions (Fig. 9). Even at 30 cm from the laterals, it was found that drip irrigation consistently maintained above 80% of the soil moisture content over the available soil moisture [10].



(a) **(b)**

Fig.8 Moisture distribution before irrigation in (a) High fertility area (b) Low fertility area



(a) **(b)**

Fig.9 Moisture distribution 30 minutes after irrigation in (a) High fertility area (b) Low fertility area

3.5 Nutrient Dynamics under Different Treatments

Generally, nutrient concentration is increased from 0-15 cm to 15-30 cm, whereas the same decreased with the radial distance from the emitter under all the treatments. Moreover, NPK content was high in site specific nutrient recommendation than all other treatments in low fertility area. In high fertility area, amount of available nitrogen in the soil was found to be higher in POP recommended drip fertiation than site specific recommended drip fertiation (Fig. 10.a). In low fertility area, nitrogen shows a uniform distribution over root zone in all the treatments, but the amount of nitrogen was found to be higher in site specific fertilizer recommendation (T1) than all other treatments (Fig. 10.b).

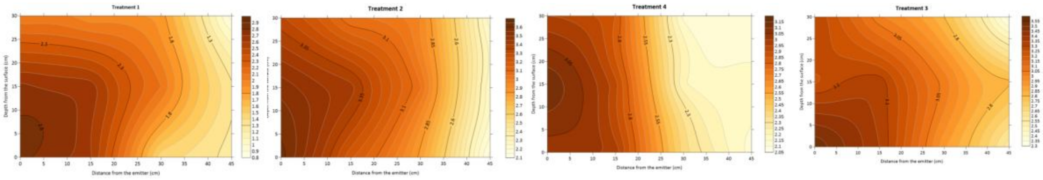
Fig. 11 shows the phosphorous dynamics in the root zone under different treatments in the high and low fertility area. In high fertility area, phosphorous content was more at deeper depth of 15 to 45cm when compared with the dripper point in site specific drip fertiation (T1). This might be due to the fact that, only less amount phosphorous fertilizers were provided in site specific recommendation at the earlier stages of growth, since the phosphorous content was already very high in the region. Continued application of P fertilizers in excess of plant requirements inevitably leads to significant accumulation of P in the soil due to the less mobility of phosphorous in the soil [11]. Phosphorous dynamics were more visible in all other treatments and varied from the dripper point. In contrast to the site specific treatment in high fertility area, more clear movement of phosphorous was visible for low fertility area (Fig. 11.b). This is because, adequate phosphorous fertilizer was provided through drip fertigation rather than basal dose in site specific treatment.

The movement of potassium around the root zone under different treatments in high and low fertility area is shown in Fig. 12. In high fertility area, potassium content was about 620.31 kg ha^{-1} at the dripper point in site specific drip fertigation (T1) but the same was about 645.82kg ha^{-1} in POP recommended drip fertigation (T2) due to higher application of fertilizer in treatment T2. From the Fig. 12.b, it can be seen that, potassium was found maximum at the dripper point in all the treatments and then decreased to deeper depth in low fertility area [12].

3.6 Residual Nutrient Status of the Soil

In high fertility area, highest residual nutrients were observed under the treatment with POP recommended drip fertigation and lowest residual nutrient status was observed with site specific drip fertigation. This result clearly demonstrates that, when the recommended POP dose was applied to a field where the initial soil nutrient status was already high, soil nutrient availability became greater than the actual requirement of the crop. Hence the residual nutrient status was high in POP recommended drip fertigation, whereas there is no possibility of excess nutrients loss in site specific drip fertigation, because the nutrients appear to the soil exactly match with the crop requirement.

In low fertility area, highest residual nutrients were observed under the treatment with site specific drip fertigation, followed by the POP recommended dose. The lowest residual nutrient values were observed in the treatment with 60% of POP recommended drip fertigation. This is because of the reason that the available soil nutrients in low fertility areas are insufficient to meet actual crop requirement, hence the treatment resulted in lower residual nutrient status.



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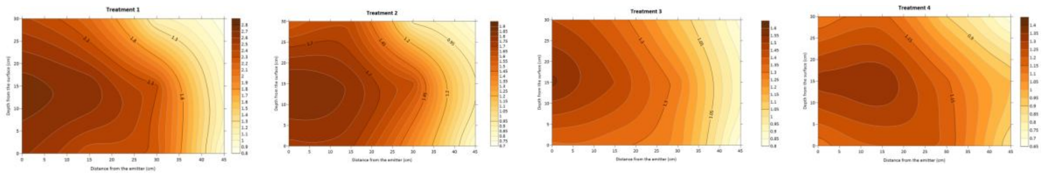
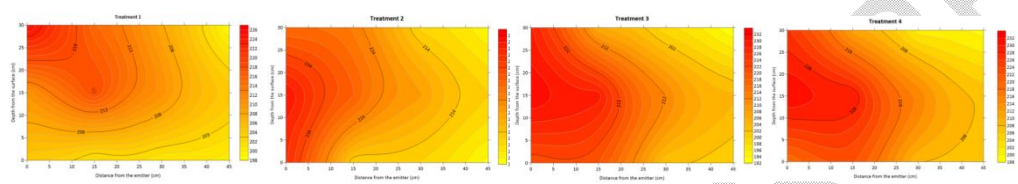


(b)

Fig.10 Nitrogen dynamics in the root zone for different treatments in (a) High fertility area (b) Low fertility area



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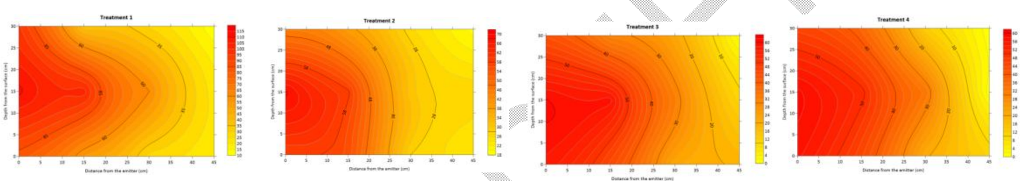


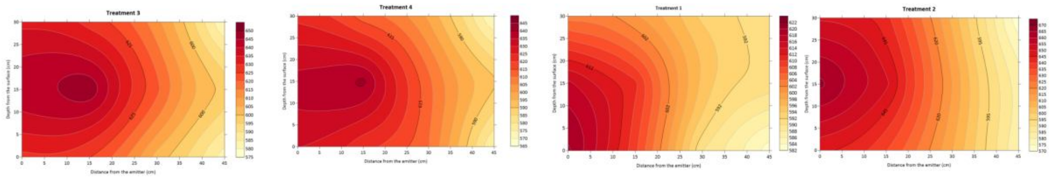
(b)

Fig.11 Phosphorous dynamics in the root zone for different treatments in (a) High fertility area (b) Low fertility area

3.7 Nutrient Use Efficiency

The treatment with site specific drip fertigation resulted in higher Nutrient Use Efficiency (NUE) than POP recommended drip fertigation in high fertility area. Even though less amount of nutrients were applied in T1 compared to T2, it could produce higher yield as T2, hence it has comparatively higher nutrient use efficiency of 60.32 kg/kg (Fig. 13.a).

Similarly in low fertility area, highest NUE was obtained under treatment with site specific fertigation (24.75 kg/kg) even though applied nutrient was quit higher than general recommended dose (21.76 kg/kg). It is might be due to the effective utilization of applied nutrients, which resulted in higher yield than any other treatment (Fig. 13.b). But NUE of site specific fertigation treatment of low fertility area was lesser than that of the high fertility area. This is because the application more fertilizer in low fertility area [13].



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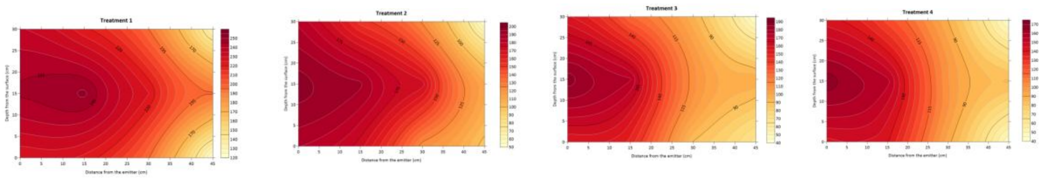


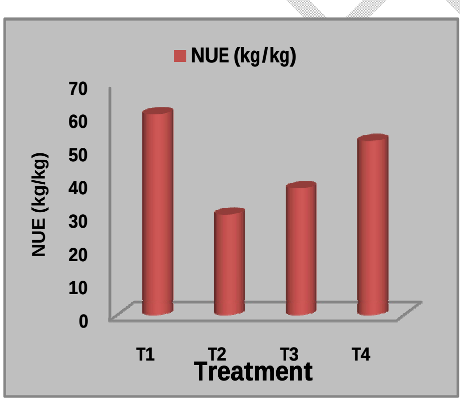
(b)

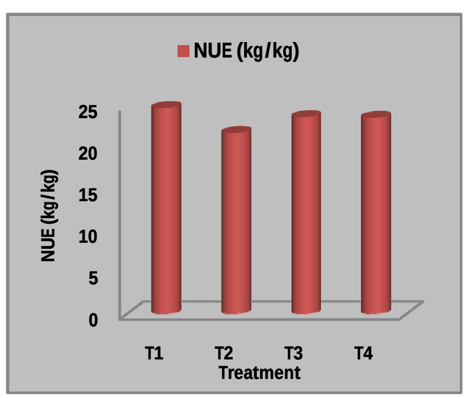
Fig.12 Potassium dynamics in the root zone for different treatments in (a) High fertility area (b) Low fertility area

3.8 Economic Analysis

The Benefit Cost (BC) ratio values calculated for various treatments showed that highest BC ratio was recorded with the treatment of site specific drip fertigation for both fertility areas (3.12 and 2.84 for high and low fertility area respectively). The lowest BC ratio was found in POP recommended drip fertigation (2.8) in high fertility area. In low fertility area, lowest BC ratio was found in 60% of POP recommended fertilizer treatment (1.45).

In high fertility area, site specific drip ferigation leads to savings in fertilizer cost. In the present study, it was observed that an amount of Rs. 3680/- per ha could be saved due to fertilizer saving and an additional return of Rs. 30830/- per ha was obtained under site specific drip fertigation compared to POP recommended drip fertigation. Whereas in low fertility area, though there was an additional cost of Rs. 4000/- per ha for fertilizers in case of site specific drip fertigation than POP recommended drip fertigation, there was an additional return of Rs. 105700/- per ha due to the increased yield through site specific drip fertigation.





(a) (b)

Fig.13 Nutrient Use Efficiency under different treatments in (a) High fertility area (b) Low fertility area

4. CONCLUSION

The results of this study showed that, increase in yield and growth parameters under site specific drip fertigation treatment in low fertility area is due to the adequate fertilizer application than general recommendation, which might be inadequate for that low fertility area. In case of high fertility area, reduction of fertilizer to site specific requirement has produced almost similar result of general recommendation which indicates that site specific dose was sufficient to produce optimum yield from the crop. Moreover, higher water use efficiency and nutrient use efficiency was obtained from the both the fields under the treatment with site specific drip fertigation. It may be due to effective utilization of fertilizer along with water.

In high fertility area, the initial soil nutrient status was already high and after applying the recommended dose to the field, nutrient availability became excess than the actual need of the crop, which resulted in high residual status in that area. In low fertility area, the residual nutrient status was lowest in the treatment with POP recommended drip fertigation, because the available soil nutrients are not enough to meet the requirement of crop in low fertility area.The SSNM approach increased net return from the agriculture production with high benefit cost ratio.

From this study, it can be concluded that instead of going blanket nutrient recommendation, a site specific nutrient recommendation may help the farmers who want to achieve higher profit from unit land area by using optimum inputs, thereby reducing environmental stress due to over fertilizer application.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

Here is the Definitions section. This is an optional section.
Term: Definition for the term