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Nutrient use in cotton grown under drip irrigation system in north-western India

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ABSTRACT

Drip and furrow irrigation has been related to higher productivity and water saving in cotton, however, the comparison of these systems for the nutrients application and use efficiency are required to be studied. Field experiments were conducted in a semi-arid environment in 2007, 2008 and 2009 to evaluate the drip irrigation for water and nutrients application in cotton. The three seasons varied greatly in amount and distribution of rainfall, which resulted in differential response of seed cotton yield to irrigation levels. During 2007, irrigation applied at 0.6 ETc (Crop evapo-transpiration) produced lowest seed cotton yield, while in 2009, all drip irrigation levels (0.6, 0.8 and 1.0 ETc) were at par with each other but recorded higher seed cotton yield than furrow irrigation. Evenly distributed rainfall in 2008 nullified the effect of irrigation treatments on seed cotton yield, however, water use efficiency was found to be higher in 0.6 ETc drip irrigation level in 2008 and 2009; and at 0.8 ETc drip irrigation level in 2007. Irrigation levels also influenced the nutrient use efficiency, with lowest efficiency recorded under furrow irrigation. Fertilizer applied through drip irrigation resulted in similar yields with 25 % lesser application of fertilizer.

Keywords: Cotton, drip irrigation, fertigation, furrow irrigation, nutrient use efficiency, water use efficiency

Irrigation and fertilizer management are the two most important factors of modern agricultural activity. Research in these areas is driven by the need to intensify production to obtain higher yields; however, modern agricultural intensification has resulted in several sustainability issues. Water is an important resource for agricultural production and is becoming scarce worldwide due to several reasons (Rosegrant *et al.*, 2002) and the most affected areas are the semi-arid regions of Asia, the Middle-East and Sub-Saharan Africa, which have large human population. Besides availability, deteriorated quality of water is also a major concern. Mismanagement of nitrogenous fertilizers has resulted in serious agricultural contamination in many regions. For example, high concentrations of nitrates in drinking water (due to leaching of excessive N application along with flood irrigation) are liable to cause health problems (Environmental Protection Agency, 1990). Also, dry fertilizers applied under traditional methods are generally not utilized efficiently by the crop. A way of managing nitrate pollution is to introduce an alternative irrigation method that reduces chemical transport through soils, as well as can meet agricultural water demand.

Drip irrigation was mainly introduced in wide spaced horticultural crops and high value commercial crops, to save water and increase the water use efficiency in agriculture. The on-farm irrigation efficiency of well designed and managed drip irrigation system is about 90 per cent, in contrast to 35-40 per cent for surface method of irrigation (INCID, 1994). The application of fertilizer through fertigation in drip irrigation system, consequently improves the fertilizer use efficiency compared to conventional methods of fertilizer application, as nutrients are applied through the emitters directly into the active root zone of the crop. Hebbar *et al.* (2004) conducted field experiments and observed significantly higher yields with 100% water soluble fertilizer applied through fertigation than soil applied treatments. Fertigation also reduces leaching of NO_3-N and K to deeper layers of sandy loam soil. In this context, drip irrigation may play a pivotal role in sustainable agricultural intensification, through meeting the demand of ever-growing population without degrading our natural resources.

In India, drip irrigation has been adopted in cotton by farmers of the states of Gujarat, Madhya Pradesh and Maharashtra in heavy textured soils (Bharambe *et al.*, 1997; Tekale *et al.*, 2000). In Indo-Gangetic plains, the light textured soils of cotton growing region and brackish underground water have become determinants for the adoption of drip irrigation in cotton, but still at experimental stage. In this region the main source of irrigation water in this region is canal water, excessive application of which often resulting in high water table and secondary salinization. The land in adjoining districts and state of Haryana has already degraded due to water logging and secondary salinization (Datta and De Jong, 2002). So, there is great need for judicious use of canal

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water, which may allow more area under cotton to be irrigated.

Balancing vegetative and reproductive growth in cotton is required for successful cotton crop. Insufficient soil water content during the sensitive growth stages (peak flowering and fruit-setting stage), can reduce the number of fruiting positions, increased boll shedding, and may result in poorly developed bolls (Aujla *et al.*, 2005). On the other hand, over-irrigation of cotton and excessive N application can cause undesired vegetative growth, which will reduce cotton yields (Karam *et al.*, 2006; McConnell *et al.*, 1996; Wanjura *et al.*, 2002). The studied literature leads to the hypotheses that drip irrigation and fertigation through drip system may require lesser amount of fertilizers and water, thereby, increasing the input use efficiency without decreasing the productivity. Thus, the present investigation was undertaken to evaluate the performance of drip irrigation in cotton at different fertilizer and irrigation levels in the north-western region of India. The objective of the present investigation was to determine the independent and interactive effects of various levels of fertilizers and different quantities of water applied to cotton through drip irrigation on cotton productivity, profitability, water use efficiency and nutrient use efficiencies of applied nutrients i.e., N and K.

MATERIALS AND METHODS

Experimental field

The field experiments were conducted at the Punjab Agricultural University Regional Research Station, Abohar (74.12° E, 30.08° N with an altitude of 185.78 m), Punjab, India, during the summer seasons of 2007, 2008 and 2009. The site belongs to semi-arid region with an annual rainfall of 75-300 mm. The soil type of the experimental field was loamy-sand in texture and in terms of fertility status, it was low in Nitrogen, medium in Phosphorus and high in Potassium (Table 1).

Rainfall pattern

The rainfall pattern showed great variability in all the three growing seasons. A total of 370 mm, 390 mm and 177 mm precipitation were received during the 2007, 2008 and 2009 cotton growing seasons, respectively (Table 2). The seasonal rainfall although same during 2007 and 2008, showed differences in the distribution pattern, where 2007 received larger proportion (78%) in the single month of June i.e., start of growing season, while 2008 showed relatively distributed rainfall over the season. During 2009, the amount of rainfall was less, and major proportion (61%) of this occurred at the time of reproductive stage of cotton.

Description of the experiment

The Bt cotton hybrid RCH 134 was sown on 12.05.2007, 17.05.2008 and 15.05.2009 during the three seasons with dibbling keeping row spacing of 67.5 cm and plant spacing of 90 cm. The cotton sowing was done after a pre-sowing irrigation applied uniformly to the field to ensure proper moisture for its germination. The experiment was laid in split plot design with four irrigation levels/methods comprising 0.6 ETc, 0.8 ETc and 1.0 ETc levels of drip irrigation along with Furrow irrigation (FI) in main plots and four fertilizer levels/ methods comprising 75%, 100% and 125% of University recommended dose of fertilizer (RDF) application through fertigation along with control treatment of 100% of RDF as soil application in sub plots. All the treatments were replicated thrice. RDF used for cotton hybrid was 150 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}. Each experiment unit was laid with 8 rows of 9 m length, with drip lateral at the soil surface for each row, having dripper at 45 cm spacing so as to wet the strip closest to the cotton row and keeping the inter-row space dry. In furrow irrigation treatment, ridges were made as per the row spacing with cotton crop planted on the ridges and irrigation applied in between the furrows. Conventional practices were followed for pest and weed control in the experimental area. At the end of each growing season, the picking of seed cotton was conducted three times for each plot.

Irrigation and fertigation schedule

Irrigation through drip was applied on the basis of Pan Evaporation method by calculating ETc (Crop evapotranspiration) which was estimated from the following formula;

ETc = ETo x Kc;

where ETo is reference evapo-transpiration and Kc is crop coefficient (covering crop aspects of a weed and disease free crop including stage of crop growth and ground coverage)

here, ETo = Epan x Kp

(Epan is the evaporation from open pan evaporimeter and Kp is Pan coefficient which takes into account climate, type of pan and pan environment)

Epan was measured daily from US open pan evaporimeter while Kp values used for calculating ETo varied from 0.75 to 0.9 depending upon the relative humidity and wind velocity at a particular time. Further, Kc values varied from 0.4 to 0.9 depending upon the stage of the cotton crop and ground cover accordingly.

Irrigation to cotton through drip system was applied every alternate day, the amount being equal to 0.6, 0.8 and 1.0 times of ETc, while each irrigation through ridge irrigation was applied as 50 mm, as and when cumulative ETc equals 50 mm. The amount of irrigation being applied to experimental unit was measured through water meters attached in the drip line and was controlled through the check-valve.

Fertilizers were applied in the experimental field either through fertigation or through soil application as per the treatments. Phosphorus in the form of DAP @ 67.5 kg ha^{-1} was applied at the time of field preparation. Nitrogen and Potassium in the form of Urea and MOP (@ 325 kg and 50 kg ha^{-1} for 100% RDF) where applied through fertigation was applied in 6 split doses starting from five weeks after sowing and thereafter at 10 days interval and where N and K is to be supplied as soil application, the dose was applied in 3 equal doses with same start but thereafter at 20 days interval so as to complete the full dose of fertilizer at the time of initiation of flowering. The spray of 2% KNO_3 was done 4 times at weekly intervals starting at the time of initiation of flowering.

Data collection and computation

During each growing season, five representative plants in each experimental unit were tagged for recording data on number of bolls per plant at each picking. Care was taken not to select the plants in outer rows or plants at the boundaries of experimental unit. Seed cotton yield was computed from all the three picking done from the net plot of 6 rows x 5 m. Irrigation water use efficiency (IWUE) was calculated from seed cotton yield per unit of Irrigation water applied (kg ha^{-1} -mm), which was recorded from the flow meters installed for each treatment. While, water use efficiency (WUE) was calculated from seed cotton yield per unit of total water use, which was calculated by adding effective precipitation and soil profile contribution to the irrigation water applied. Nitrogen (N), Phosphorus (P) and Potassium (K) uptake was computed from standard procedures through analyzing plant samples collected at boll opening stage for N, P and K content, and multiplying it with the dry matter of the crop.

Statistical analysis

Data were analyzed using the GLM (General Linear Model) procedure in SAS 9.3 to evaluated the differences between treatments; means were compared using LSD (Least Significant Difference) statement at P = 0.05 (SAS, 2001). The treatment means were grouped by alphabets based on LSD, with same alphabets assigned to means having no differences, while different alphabets represent statistical significant differences between the means. Further, the bivariate analysis and graphing was done in JMP Pro for evaluating the linear and quadratic relationship between variables reported in this study.

RESULTS AND DISCUSSION

Seed cotton yield

During 2007, 0.6 ETc level resulted in significantly lesser bolls per plant and seed cotton yield than both 0.8 ETc level and 1.0 ETc level irrigation scheduling, which were also at par with furrow irrigation treatment (Table 3). The lower yield obtained in 0.6 ETc level was primarily due to lesser growth, the reason for this may be the water stress at 0.6 ETc level water scheduling. Even the rainfall during 2007 was not well distributed over the growing season, with about 78 % of rain occurring in June month. This resulted in more dependence of yield on water applied. Linear relationship was observed between cotton yield and water consumption by Ertek and Kanber (2003) and it was reported that water shortage increases the boll shedding and thereby, decreases the boll number. Irrigation is of utmost importance at the time of flowering and boll formation in cotton (Jalota *et al.*, 2006), which remained less in case of lower level of irrigation (0.6 ETc) applied through drip system in our study. However, due to more uniform rain distribution over the crop season, all irrigation treatments produced similar boll number and seed cotton yield in 2008. In year 2009, furrow irrigation produced significantly lower yield than all the drip irrigation levels. Frequent and evenly applied water in the near the root through drippers provides good soil moisture in the root zone and thus resulting in higher yields (Cetin and Bilgel, 2002). The furrow irrigation plots tend to have more relative humidity in the crop canopy, which makes the conditions favourable for the insect-pests and diseases to infect the crop severely (based on visual observation). Also, more rainfall events during the late growth stage in 2009 resulted in relatively higher humidity than 2007 and 2008. Different fertilizer treatments did not produce significant differences in boll number per plant and seed cotton yield during. This means that 25% of fertilizer dose can be reduced when applied through fertigation as compared to soil application, without adversely affecting the yield in cotton. The interactive effects between the irrigation treatments and fertilizer levels were found to be non-significant.

Water use efficiency

Water use efficiency is the function of both yield and water use for production of that yield. During 2007, the irrigation water use has been used to calculate IWUE, as no data was recorded during that year regarding effective precipitation and soil profile contribution. While, water use efficiency was calculated during 2008 and 2009 by dividing seed cotton yield by total water use. Clearly from the graph of the water use (Fig. 1), it

Table 1: Soil fertility status at the experimental site

Year	pH	EC (ds/m)	O.C (%)	Av. P_2O_5 (kg ha^{-1})	Av. K_2O (kg ha^{-1})
2007	8.38	0.16	0.42	33	560
2008	8.46	0.12	0.49	30	560
2009	8.42	0.13	0.46	28	570
Method used for estimation	Beckmans' glass electrode pH meter (1:2 soil: water suspension)	Solubridge conductivity meter (1:2 soil: water suspension)	Walkley and Black's wet digestion method	0.5 N NaHCO$_3$ extractable P method	Neutral Ammonium acetate extractable K method

Table 2: Rainfall pattern at Abohar, India during 2007-2009

Month/ Year	2007		2008		2009	
	Rainfall (mm)	No. of rainy days	Rainfall (mm)	No. of rainy days	Rainfall (mm)	No. of rainy days
May	-	-	32.5	2	-	-
June	290	6	172.75	8	1.5	3
July	55	4	12	1	67.5	5
August	25	2	116.5	6	104	4
September	-	-	56.25	2	4	1
Total	370		390		177	

Table 3:Productivity and water use efficiencies of Bt cotton under different irrigation and fertilizer treatments

Treatments	Seed cotton yield (kg ha^{-1})			Bolls plant^{-1}			Water use efficiency (kg per ha-mm)		
	2007	2008	2009	2007	2008	2009	2007*	2008	2009
Irrigation treatments									
0.6 ETc	1899±67b	2598±105a	2090±48a	38.3±2.8b	43.0±1.9a	51.0±1.7a	9.16±0.32a	3.93±0.16a	3.68±0.08a
0.8 ETc	2684±104a	2622±97a	1939±78a	54.7±2.9a	46.2±2.6a	49.9±2.5a	9.70±0.37a	3.33±0.12b	2.64±0.11b
1.0 ETc	2645±116a	2702±72a	2001±86a	54.3±2.8a	46.2±2.3a	52.9±2.0a	7.65±0.34b	2.96±0.08c	2.22±0.10c
Furrow irrigation	2545±134a	2499±83a	1109±89b	51.3±3.6a	45.6±1.8a	48.9±2.8a	6.18±0.33c	1.94±0.06d	0.87±0.07d
Fertilizer treatments									
75% Fertigation	2367±162a	2547±89a	1895±126a	46.2±3.9a	44.6±1.9a	49.5±2.0a	7.84±0.50a	2.97±0.23a	2.48±0.31a
100% Fertigation	2512±134a	2731±110a	1723±145a	50.8±3.7a	46.4±3.1a	51.6±2.4a	8.41±0.52a	3.22±0.29a	2.26±0.30a
125% Fertigation	2488±146a	2619±66a	1842±151a	51.9±4.0a	46.9±1.5a	49.9±2.5a	8.34±0.55a	3.04±0.22a	2.43±0.34a
Control	2406±130a	2524±89a	1680±134a	49.6±2.5a	43.1±1.9a	51.6±2.5a	8.10±0.56a	2.94±0.22a	2.23±0.31a

*Note: Means along with standard error have been reported in the table, * values presented here corresponds to irrigation water use efficiency*

indicates that, the water applied in 1.0 ETc level is lesser than the water used in furrow irrigation during 2007. Also, in the next two seasons, total water use showed increase with increasing irrigation levels and was highest in furrow irrigation treatment. IWUE differed significantly for different irrigation scheduling systems during 2007, maximum and significantly higher irrigation water use efficiency obtained in the 0.8 ETc level due to higher yield obtained per mm of water used (Table 3). In 0.6 ETc level, although the water use was less, but the yield from the crop was also significantly lower, which reduced the IWUE. While in 2008 and 2009, WUE was significantly higher in 0.6 ETc level which decreased with the increase in irrigation water

Table 4: Nutrient uptake under different irrigation and fertilizer treatments

Treatments	N-uptake (kg ha^{-1})		P-uptake (kg ha^{-1})		K-uptake (kg ha^{-1})	
	2008	2009	2008	2009	2008	2009
Irrigation treatments						
0.6 ETc	274.9±18.6b	223.4±16.3a	100.5±4.8c	82.4±5.6a	286.6±15.3a	232.7±14.0a
0.8 ETc	289.2±18.5b	229.2±20.6a	120.7±6.3ab	94.2±6.8a	327.8±15.3a	255.7±15.3a
1.0 ETc	355.7±14.1a	265.6±17.2a	113.5±6.3b	85.1±7.1a	342.7±20.0a	255.8±19.7a
Furrow irrigation	351.1±17.4a	147.0±10.9b	126.5±7.3a	53.4±4.4b	309.0±10.2a	131.3±10.5b
Fertilizer treatments						
75% Fertigation	281.9±10.3c	193.4±13.8b	105.6±4.3bc	70.1±5.1b	291.9±12.6b	201.7±13.0b
100% Fertigation	330.9±15.4b	191.1±18.0b	118.5±6.3b	70.6±5.3b	319.3±16.1b	198.5±18.6b
125% Fertigation	375.5±22.7a	231.5±21.9ab	136.0±6.8a	83.1±8.0ab	361.5±16.0a	229.0±25.5ab
Control	282.6±16.0c	249.3±23.7a	101.2±4.4c	91.2±9.3a	293.4±13.1b	246.3±24.2a

Note: Means along with Standard Error have been reported in the table

Table 5: Nutrient use efficiencies under different irrigation and fertilizer treatments

Treatments	NUE (kg ha^{-1})		PUE (kg ha^{-1})		KUE (kg ha^{-1})	
	2008	2009	2008	2009	2008	2009
Irrigation treatments						
0.6 ETc	9.87±0.68a	9.91±0.76a	26.44±1.66a	26.56±1.76a	9.28±0.48a	9.32±0.55a
0.8 ETc	9.55±0.80ab	9.11±0.75a	22.29±1.35bc	21.19±1.04b	8.19±0.49a	7.78±0.39a
1.0 ETc	7.71±0.31bc	7.74±0.39a	24.48±1.26ab	24.71±1.60ab	8.20±0.56a	8.25±0.65a
Furrow irrigation	7.34±0.52c	7.64±0.41a	20.34±1.11c	21.41±1.23b	8.17±0.35a	8.56±0.36a
Fertilizer treatments						
75% Fertigation	9.14±0.40a	9.99±0.68a	24.53±1.27a	27.45±1.49a	8.85±0.38a	9.48±0.54a
100% Fertigation	8.57±0.72a	9.13±0.38ab	24.14±2.10a	24.50±1.22ab	8.78±0.54a	8.87±0.42a
125% Fertigation	7.46±0.78a	8.11±0.42bc	19.61±0.74b	22.79±1.27b	7.42±0.41a	8.44±0.48a
Control	9.30±0.66a	7.17±0.78c	25.27±0.99a	19.13±1.22c	8.80±0.50a	7.13±0.39b

Table 6: Response of seed cotton yield to nutrient uptake (kg ha^{-1}) by cotton as fitted to a quadratic model ($Y = a + bx + cx^2$) in 2008 and 2009*

Response variable	a	b	c	Adjusted R^2	p
N-uptake					
75% Fertigation	1452.7 (491.3)	3.80 (1.77)	-0.030 (0.019)	0.588	<0.0001
100% Fertigation	1229.3 (295.5)	4.84 (0.94)	-0.033 (0.012)	0.685	<0.0001
125% Fertigation	950.4 (227.4)	5.06 (0.84)	-0.021 (0.008)	0.639	<0.0001
Control	1863.4 (589.1)	1.62 (1.91)	-0.040 (0.022)	0.334	0.0141
P-uptake					
75% Fertigation	1496.2 (372.5)	9.95 (3.62)	-0.232 (0.105)	0.640	<0.0001
100% Fertigation	1178.5 (296.0)	13.78 (2.86)	-0.268 (0.079)	0.627	<0.0001
125% Fertigation	686.9 (168.8)	15.57 (1.64)	-0.111 (0.033)	0.816	<0.0001
Control	850.8 (340.4)	14.45 (3.42)	-0.239 (0.083)	0.536	0.0003
K-uptake					
75% Fertigation	1210.9 (335.4)	4.61 (1.19)	-0.030 (0.013)	0.677	<0.0001
100% Fertigation	914.6 (298.5)	5.65 (0.99)	-0.021 (0.010)	0.706	<0.0001
125% Fertigation	992.2 (183.5)	4.89 (0.60)	-0.020 (0.005)	0.774	<0.0001
Control	1400.4 (477.2)	3.16 (1.57)	-0.032 (0.014)	0.546	0.0003

Note: Figures in parentheses are standard errors of parameter estimates; a is the intercept, and b and c are the slope of the quadratic curve; p values correspond to the significance of the quadratic regression model fitted.

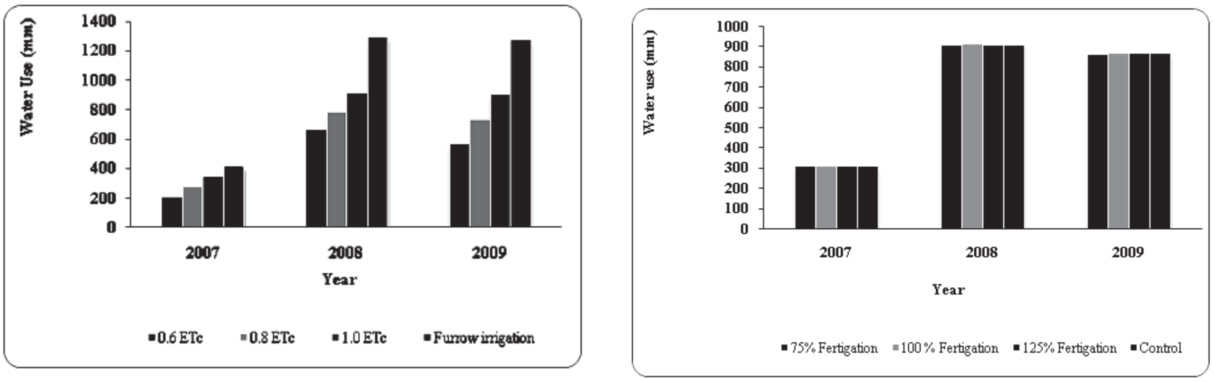
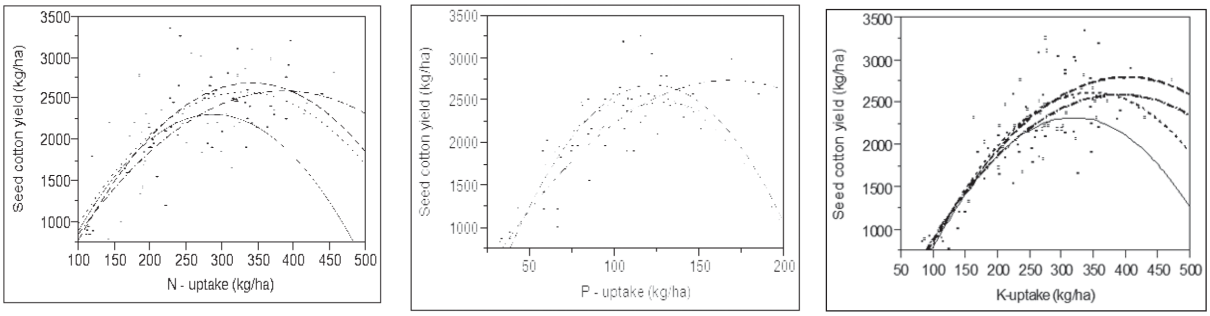


Fig. 1: Water use (mm) under different irrigation and fertilizer treatments during 2007-2009



.............100 % Fertigation .... 75% Fertigation
..............125% Fertigation .... Control

Fig. 2: Relation of Seed cotton yield with N, P and K uptake by cotton under different fertilizer treatments during 2008-2009 (for p values and parameters, refer to table 6)

applied, with lowest value under furrow irrigation. Higher water productivity in drip irrigation treatments is attributed to higher yields accompanied by saving of irrigation water as compared to furrow method of irrigation (Rajak *et al.*, 2006). However, in this study, the water use efficiency is more of a function of water use rather than the seed cotton yield. In context to WUE, Antony and Singandhupe (2004) reported that reduced level of water applied through drip result in the partial closure of stomata, but the effect was more in surface irrigation, resulting in reduced photosynthesis and conductance. As water content in the cell affects the photosynthetic metabolism, the process of photosynthesis is affected by dehydration (Gimenez *et al.*, 1992; Gunasekara and Berkowitz, 1993).

Nutrient uptake and use efficiencies

Nutrient uptake for N, P and K by Bt cotton and nutrient use efficiencies for these nutrients were studied so as to observe the relation between irrigation and fertilizer levels. It was found that N uptake was highest (356 kg ha^{-1} and 266 kg ha^{-1} during 2008 and 2009, respectively) under 1.0 ETc level irrigation. It was significantly higher than 0.8 and 0.6 ETc levels of irrigation during 2008, while at par with these drip irrigation levels during 2009, with only significant difference from the furrow irrigation treatment (Table 4). This was due to the reason that nutrient uptake is directly related to the dry matter produced by the crop, and dry matter production is related with the efficient utilization of water. Further, N uptake was found to exhibit significant increase with increase in fertilizer level from 75% to 125 % RDF. Similar was the trend for P and K uptake under different fertilizer levels; more amount of nutrients applied resulted in more uptake.

Nitrogen and phosphorus use efficiency showed significant differences under different irrigation levels in 2008, however, for 2009, P and K use efficiency exhibited significant differences (Table 5). The irrigation levels/treatments were observed to influence the nutrient use efficiencies with lowest efficiency recorded in furrow irrigation system, where the fertilizer was applied in 3 splits through soil application. Drip irrigation allows applying fertilizer in more splits and through fertigation, resulting in higher nutrient use efficiencies in this system. Fertilizers applied regularly and timely, in small amounts increases the fertilizer use in plant and reduce the leaching losses (Shock *et al.*, 1995). Further, Geleta *et* *al.* (1994) found that the drip irrigation caused lower NO_3 leaching when compared to flood irrigation. This might be one of the reason for higher nutrient uptake and use efficiency under drip irrigation system. For different fertilizer levels, only Phosphorus use efficiency showed significant differences in 2008 with lowest value under 125 % RDF; in 2009, nitrogen, phosphorus and potassium use efficiency showed significant differences among fertilizer treatments with lowest value under 100 % fertilizer through soil application. This showed enhanced fertilizer use efficiency when applied as fertigation as compared to surface application. Uniformity of irrigation reduces the deep percolation of water through the soil, and thereby, decreases the amount of NO_3-N leached into lower soil profile (Rajput and Patel, 2006).

Relation of seed cotton yield with nutrient uptake

The relation between seed cotton yield and N, P and K uptake fitted to second degree polynomial model has been presented in fig.- 2 and table-6. The correlation has been grouped on the basis of different fertilizer treatments here to relate it to the nutrient use efficiencies obtained under these treatments. Under all the fertilizer treatments, seed cotton yield increased with increase in nutrient uptake, which attain a plateau, and thereafter further nutrient uptake may result in decrease in the yield. The nutrient use efficiency for any nutrient may increase up to that plateau, after which stable yield or decreased yield with further nutrient uptake decreases the nutrient use efficiency. Graphical presentation reveal that control treatment (100% fertilizer applied as soil application) has lower yield plateau as compared to other fertilizer treatments. 125% RDF applied through fertigation resulted in increased response of seed cotton yield to higher N uptake but the overall yield level remained similar as that of 75% RDF and 100% RDF. This has relevance in lowering of nutrient use efficiency in the treatment with 125% RDF.

Although it is evident from the study and previous research literature that drip irrigation produces higher yields and higher water use efficiency as compared to conventional or furrow irrigation system and may help in considerable water saving. It can also help in reducing other risks of the crop failure. Even if it produced same yield in one or the other year, like in our study, it helped in water saving and saved the crop in events of lower rainfall, thereby reducing the vulnerability of cotton to climatic factors and yield reduction. Fertilizer nutrients have been found to show increased use efficiencies when applied as fertigation over that of soil application. These findings will help in lowering of fertilizer doses for cotton, up to the point where no yield penalty occurs. In our study, it is suggested to use 75% of the recommended dose of fertilizer through fertigation without any yield reduction. The adoption of drip irrigation system and use of optimum fertilizers may also help in reducing the environmental hazard through pollution of ground water with nitrate and such chemicals, besides saving the dose of fertilizer when applied through fertigation. Other factors like the movement of fertilizer nutrients under drip irrigation system, management of weed infestation near the cotton rows and microclimate parameters need to be studied and related to various pest problems associated in cotton. Further, analysis of drip system for cotton-wheat system as a whole is required, for its better implementation at farm level. Such systems are hypothesized to help in mitigation of climate change through reduced the vulnerability to variability in rainfall, where both excess and less of rainfall could result in failure of cotton crop.

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