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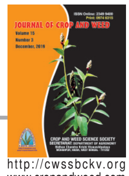

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Assessment of productivity, profitability and economics of high-density cotton-sweetcorn production system under drip irrigation and fertigation levels

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ABSTRACT

During the kharif-summer of 2019 to 2021, an experiment was undertaken at College farm, PJTSAU, Hyderabad, to investigate the influence of drip irrigation and fertigation levels on productivity, profitability, and economics of a high-density cotton-sweetcorn production system. The experiment included twelve treatments with three irrigation and four fertigation levels, all replicated three times in a Factorial randomized block design (FRBD). Compared to 0.6 and 0.8 Epan, irrigation at 1.0 Epan produced considerably higher system gross returns, system net returns, system B:C ratio, system profitability, and system productivity. Among the fertigation levels, application of 125 percent RDNK in differential dosage as per crop coefficient curve resulted in higher system gross returns, system net returns, system B:C ratio, system profitability, and system productivity, all of which were comparable to application of 125 percent RDNK in differential dosage as per recommendation.

***Keywords*:** Irrigation, fertigation, grossreturns, net returns, productivity and profitability.

Cotton (*Gossypium* sp.) is regarded as the "King of Fiber" and "White Gold" because it has the highest economic value among cultivable crops for a long time. India is the world's largest cotton-growing country, with a total area of 13.47 million hectares and production and productivity of 36.06 million bales and 455 kilogrammes per hectare, respectively (Directorate of Economics and Statistics, 2020-21). Cotton is grown on 2.45 million hectares in Telangana, with production and productivity of 5.03 million bales and 353.73 kg ha^{-1}, respectively (Directorate of Economics and Statistics, 2019-20). About 34.0% of area in India is under irrigation whereas, in Telangana it is only 11.6 % (Directorate of Economics and Statistics, 2016-17). Cotton is grown as a rainfed crop in Telangana's low to medium fertile soils, where closer planting is required to accommodate more plants per unit area and maximise the potential of cultivars. Bt cotton hybrids contributed significantly to India's output self-sufficiency and effectively eliminated boll worm attacks. However, in recent years, Bt cotton has developed resistance to boll worms and has proven to be inefficient against sucking pests, resulting in increased pesticide use and higher seed costs when compared to non-Bt cotton seeds. Cotton farming is becoming increasingly dangerous and unprofitable as a result of the aforementioned issues (Kathage and Matin, 2012). Non-Bt cotton cultivars will be used as a substitute for Bt cotton hybrids in this scenario, and will provide higher yields if suitable management methods are followed.

To increase overall food grain output, judicious irrigation water utilisation along with effective nutrition management is more crucial (Jha *et al.,* 2015). Fertigation is a cost-effective and efficient way to provide soluble plant nutrients to the active plant root zone (Anitta *et al.,* 2011). Crop response to varied fertigation patterns may differ, necessitating further inquiry. To get the most out of available resources (water and nutrients), modern technology is needed, such as drip irrigation with a high density population, which allows irrigation water and fertilisers to be administered precisely and in a balanced manner to meet the needs of agricultural plants (Veeraputhiran and Chinnusamy, 2009). Due to the higher density (55.5 to 77.7%) compared to normal planting density (*i.e.* 18517 and 37037), it is necessary to revalidate the cotton fertilisation schedule in order to achieve maximum production potential from the increased population.

Sweetcorn (*Zea mays saccharata* L.) is a commercially important maize variety. Following the cotton harvest in January (which covers the majority of Telangana's cotton area), the land will lie fallow for a longer period of time until monsoon rains arrive. Any crop that fits into a sequence crop and has a low water

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requirement is a feasible and low-cost alternative income source for farmers. Sweet corn is a medium-sized plant that bears green ears 65 to 85 days after planting. Sweet corn is becoming more popular as a crunchy snack in and around Telangana's cities. It is also an excellent supplementary supply of green feed in the summer to keep the cow herd afloat. Because of its short growing season, it can be used as a second crop following cotton in the summer when irrigation is limited. As a result, sweet corn was introduced.

Sweet corn productivity is increased by an optimal plant stand that effectively exploits growth variables. When compared to wider crop geometries, most researchers have documented superior sweet corn growth and yield features with closer crop geometries (Sandhya *et al.,* 2016; Spandana, 2012). To sustain uniform growth, development, and grain yield at increasing population levels, resources (water and nutrients) must be sufficient (Rao *et al.,* 2014). Sweetcorn's response might vary depending on fertigation patterns, just as cotton's. When comparing fertigation administered in equal splits throughout the crop growth period to fertigation given in differential dosage, studies found that fertigation delivered in differential dosage resulted in higher cob production (Jha *et al.,* 2015). Because the planting density has been increased by 50% (from 83,333 to 1,66,666), it is necessary to revalidate the sweetcorn fertiliser schedule in order to get the maximum yield potential from the increased population. The only available information on fertigation scheduling for cotton and sweetcorn based on crop growth stages and nutrient uptake is based on assumptions. Cotton does not have precise water and nutrient scheduling based on scientific principles such as crop coefficient (Kc) values. An experiment was conducted to study the effect of drip irrigation and fertigation levels on productivity, profitability, and economics of the cotton-sweetcorn production system, keeping in mind the importance of precise use of two vital inputs such as irrigation and nutrients to cotton based cropping systems.

MATERIALS AND METHODS

The present experiment was carried out at College Farm, College of Agriculture, Rajendranagar, Hyderabad, Telangana State during 2019-2021. The farm is geographically situated at an altitude of 542.3 m above mean sea level at $17^0 19'$ N latitude and $78°23'$ E longitude in the Southern Telangana agro-climatic zone of Telangana and it is classified under semi-arid tropics (SAT) according to Troll's classification. The mean weekly maximum temperature during cropping period ranged from 31.00 to 39.00 ^{o}C with an average of 34.31 ^{o}C in 2019-20 and 37.14 to 35.50 ^{o}C with an average of 30.63 ^{o}Cin 2020-21, respectively. Whereas the weekly mean minimum temperature varied between 10.64 to 24.29^{o}C with an average of 19.40 ^{o}C in 2019-20 and 11.21 to 16.21 with an average of 14.90^{o}C during 2020-21. During the crop growth period rainfall of 21.00 mm was received in five rainy days in 2019-20 and 4.6 mm in one rainy day in 2020-21.The mean weekly pan evaporation (PE) ranged from 3.74 to 7.90 mm in 2019-20 and 2.49 to 5.96 mm in 2020-21 respectively. The total evaporation during the crop study was 366.8 mm in 2019-20 and 335.5 mm during 2020-21. During both the years of study, the crop was largely raised under irrigation due to less quantity of rainfall received.

The soil of the experimental was sandy clay loam in texture (75.24% sand, 10.4 % silt, and 14.06 % clay) with an average bulk density of 1.59 Mg m^3 for 0-60 cm depth and is slightly alkaline in reaction with pH of 7.5 and Ec of 0.27 (ds m^{-1}). The available N, P, and K was 187.5, 64.3, and 334.2 kg ha^{-1}. The experiment consisted of twelve treatments laid out in Factorial randomized block design (FRBD) and replicated thrice.Three irrigation levels (irrigation scheduled at 0.6 [I_1], 0.8 [I_2] and 1.0 Epan [I_3], throughout the crop growth period) and four fertigation levels (100 % RDNK in differential dosage as per recommendation [F_1], 100 % RDNK in differential dosage as per crop coefficient curve [F_2], 125 % RDNK in differential dosage as per recommendation [F_3] and 125 % RDNK in differential dosage as per crop coefficient curve) [F_4], were included as treatments in this study. The cotton crop was sown on July 15th,2019 during 1st season and on June 18th, 2020 during 2nd season. Cotton composite variety which was used in the study is ADB-542. The spacing followed was 60 x 20 cm. The crop was supplied with recommended dose of fertilizers with 90 kg N, 48 kg P_2O_5 and 48 kg K_2O ha^{-1} through urea, single super phosphate and sulphate of potash, respectively according to the fertigation levels. Entire phosphorus was applied as basal to all the treatments before sowing. Nitrogen and potassium were applied through fertigation according to the treatments. Fertigation in 17 splits once in 6 days interval in differential dosage as per crop growth was carried out from 10 DAS to 110 DAS. For the treatments F_1 and F_3 fertigation was given in differential dosages as per recommendation in 100% and 125% RDF which is given in detail in Table 1. Whereas, for the treatments F_2 and F_4 fertigation was given in differential dosages as per crop coefficient curve in 100 % and 125 % RDF respectively which is given in detail in Table 2.

Sweet corn variety Madhuri was sown on February 5th,2020 during 1st season and on December 11th, 2020 during 2nd season by adopting a spacing of 30 x 20 cm. The recommended dose of fertilizer (RDF) 180, 60 and

50 kg N, P_2O_5, K_2O ha^{-1} respectively was applied in the form of urea, single super phosphate and sulphate of potash. A common dose of phosphorus was applied to the treatments as basal. Nitrogen and potassium were applied in 10 splits through fertigation as per treatments. For the treatments F_1 and F_3 fertigation was given in differential dosages as per recommendation in 100% and 125% RDF which is given in detail in Table 3. Whereas, for the treatments F_2 and F_4 fertigation was given in differential dosages as per crop coefficient curve in 100 % and 125 % RDF respectively which is given in detail in Table 4.

Irrigation was scheduled at three days interval. The irrigation water was applied on the basis of pan evaporation (PE) data obtained from USWB open pan evaporimeter installed at the Agroclimatic Research Centre, ARI, Rajendranagar, Hyderabad. The quantity of applied water to each treatment was measured with the help of water meter. During rainy days,the volume of water applied to each treatment was adjusted for the effective rainfall received. The laterals of 16 mm diameter were laid at 0.6 m apart with spacing of 0.2 m distance between two inline emitters. The emitter discharge was 2.0 liters per hour. The application rate in drip irrigated treatments was calculated using following formula.

$$\text{Application rate (mm hr}^{-1}) = \frac{Q}{D_L \times D_E}$$

Whereas

Q = Dripper discharge (liters h^{-1}),

D_L = Distance between lateral spacing (m)

D_E = Distance between dripper (emitters) spacing (m)

Irrigation time for each treatment was calculated using following formulae.

$$\text{Irrigation time(minutes)} = \frac{\text{Epan (mm)} \times 60}{\text{Application rate (mmhr-1)}}$$

The cotton crop was harvested on 22nd January 2020 and 23rd November 2020 during 1st and 2nd seasons respectively. The cumulative yield of seed cotton from each picking in each treatment from net plot was weighed in g $plot^{-1}$ and converted to kg ha^{-1}. The cotton stalk uprooted from corresponding net plot area of treatment was sun dried for one week and the dry weight was recorded and expressed in kg ha^{-1}. The sweetcorn crop was harvested on 24th April 2020 and 12th March 2021 during 1st and 2nd seasons respectively. The fresh cobs which were harvested from the net plot were weighed and expressed in kg ha^{-1}.After harvesting green cobs, the left-over plants were harvested to the base and the green fodder from net plot was weighed and expressed in kg ha^{-1}.The prices of the inputs prevailed in local market during experimentation were considered for working out the cost of cultivation of cotton and sweet corn. The profitability and productivity of the system was assessed by using the following formulae.

1. System cost of cultivation (ha^{-1})

Total system cost of cultivation was calculated for different irrigation and fertigation treatments on the basis of cost of inputs used for both cotton and sweetcorn crops.

2. System gross returns (ha^{-1})

Gross monetary returns for both the crops were calculated for every treatment and given as system gross returns.

3. System net returns (ha^{-1})

System net monetary returns were calculated by deducting the cost of cultivation from gross returns of each treatment for both the crops.

4. System benefit: cost ratio

System benefit cost ratio was calculated by dividing gross returns with cost of cultivation for each treatment for both the crops.

5. System productivity (kg $ha^{-1}day^{-1}$)

Yields of different crops were converted into single crop equivalent yield expressed as kg **ha^{-1} day^{-1}**

The equivalent yield was calculated as:-

P= TP/R

where,

P = Productivity (kg ha^{-1} day^{-1})

TP = Total production (kg ha^{-1})

R = Resource used (days)

6. System profitability (ha^{-1} day^{-1})

Profitability of the system was calculated by dividing the net return ha^{-1} in a sequence by 365 days.

System profitability (**ha^{-1} day^{-1}**) = net return ha^{-1}/ 365 days

7. Land use efficiency (%)

Total field duration of a cropping system expressed in percentage of 365 days was taken as the land-use efficiency (LUE) of the system. It was calculated by the following formula

LUE (%) = TND (i) /365 X 100

where,

TND = Total no. of days field remained occupied under different crops (i= 1…..n)

The experimental data recorded on different parameters were analyzed statistically by applying the technique of analysis of variance for FRBD and significance was tested by F-test. Critical difference for examining treatmental means for their significance was calculated at 5 percent level of probability (Gomez and Gomez, 1984).

RESULTS AND DISUSSION

Seed cotton yield (kg ha^{-1})

A perusal of data (Table 5) on seed cotton yield revealed that the seed cotton yield was not significantly influenced by the different drip irrigation levels during both the years of study and in means. This was mainly due to the fact that throughout the crop growth period during the 1st season of study *i.e*., from 15th July 2019 to 23rd January 2020 there was an amount of rainfall of 706.1 mm. Most of the rainfall was distributed during the months of August, September and October where it coincided with the moisture sensitive stages of the cotton crop *i.e*., square formation, flowering and boll formation stages. Due to heavy rains during these crop growth stages irrigation was not scheduled and the treatment effect got nullified. While, during the second season of study *i.e* 18th June 2020 to 28th November 2020, the total amount of rainfall (1283.2 mm) was received which was distributed during the months of July, August, September and October, which resulted into continuous rains throughout the crop growth stages. As a result, crop did not suffer from moisture stress during moisture sensitive periods and there was uniform distribution of soil moisture in the root zone. In this way during both the years of study, crop was grown with sufficient amount of moisture received through rainfall. This might be the reason that there was no significant effect of irrigation regimes on seed cotton yield.

Among four fertigation levels, application of 125 % RDNK in differential dosageas per crop coefficient curve (F_4) produced significantly higher seed cotton yield over application of 100 % RDNK in differential dosage as per recommendation (F_1) and application of 100 % RDNK in differential dosage as per crop coefficient curve (F_2) which was statistically at par with the seed cotton yield obtained with the application of 125 % RDNK in differential dosage as per recommendation (F_3) during 2019, 2020 and in means. While application of 100 % RDNK in differential dosage as per recommendation (F_1) resulted in lower seed cotton yield which was on par with F_2 during both the years and in means. Further seed cotton yield obtained through F_3 was also comparable with F_2.

The higher yield recorded with the application of 125 % RDNK in differential dosageas per crop coefficient curve (F_4) might be due to applying lower rates of fertiliser during initial stages and higher rates at flowering and boll formation stages met the crop nutrient requirement which made the crop to uptake more nutrients thereby resulting in producing more yield attributes finally resulting in higher seed cotton yield when compared to other fertigation levels (F_3, F_2 and F_1). On the other hand, F_3 and F_2 were also at par with each other which shows that applying the nutrients according to the crop growth needs in a more scientific way (Kc curve based) can also save the amount of fertilisers (25%) used.Further, the higher seed cotton yield under the treatments F_3 and F_4 over F_2 and F_1 might be due to the increased nutrient availability and absorption by the crop at the optimum moisture supply coupled with frequent and higher nutrient supply by fertigation and consequent better formation and translocation of assimilates from source to sink. Increase in the seed cotton yield with the increase in N and K levels were also earlier reported by Kakade *et al.* (2017), Bhaskar (2014), Jayakumar *et al.* (2014), Aladakatti *et al.* (2012) and Hadole *et al.* (2012).

There was no significant interaction effect between different drip irrigation and fertigation levels during both the years on seed cotton yield.

Stalk yield (kg ha^{-1})

An overview of data (Table 5) indicated that the irrigation levels did not show any significant influence on stalk yield of cotton crop during both the years and in means. Among the fertigation levels, application of 125 % RDNK in differential dosage as per crop coefficient curve (F_4) produced significantly higher stalk yield which was at par with the application of 125 % RDNK in differential dosage as per recommendation (F_3). While application of 100 % RDNK in differential dosage as per recommendation (F_1) resulted in lower stalk yield which was comparable with the application of 100 % RDNK in differential dosageas per crop coefficient curve (F_2) during 2019. Higher stalk yield with the application of 125 % RDNK over 100 % RDNK in both the fertigation patterns was due to higher availability of both the two major nutrients (N and K) in the soil solution which led to higher uptake and better crop growth which also gave maximum plant height, LAI and ultimately produced more biological yield. These results are in accordance with the findings of Magare *et al.* (2018). Fertigation in differential dosage as per crop coefficient curve (F_2, F_4) has met the crop growth needs without much loss, when compared to other fertigation in differential dosage as per recommendation (F_1, F_3) which produced higher dry matter production thus resulting in higher stalk yield.

Interaction effect of irrigation and fertigation levels on stalk yield was found non-significant during 2019, 2020 and in means.

Green cob yield (kg ha^{-1})

Data presented in Table 6 indicated that, among the three irrigation regimes, drip irrigation scheduled at 1.0 Epan(I_3) has recorded significantly higher cob yield over other two irrigation levels (I_2 and I_1), while the lowest

Table 1: Differential dosage of fertilizer application based on growth stage of cotton crop as per recommendation by PJTSAU

Crop stage	Nutrient dose (kg ha^{-1} day^{-1})	
	N	K_2O
After sowing 35 days (10-45 DAS)	0.56	0.29
Squaring 20 days (45-65 DAS)	1.50	0.58
Flowering and boll formation stage 20 days (65-85 DAS)	1.03	0.78
Boll development 30 days (85-115 DAS)	0.75	0.29

Table 2: Differential dosage of fertilizer application based on growth stage of cotton crop as per crop coefficient curve

Crop stage	Kc values	Nutrient dose (kg ha^{-1} day^{-1})	
		N	K_2O
10-25 days	0.45	0.54	0.29
26-31	0.49	0.59	0.31
32-37	0.53	0.64	0.34
38-43	0.57	0.69	0.36
44-49	0.61	0.74	0.39
50-55	0.65	0.79	0.42
56-61	0.69	0.83	0.44
62-67	0.73	0.94	0.47
68-73	0.78	1.00	0.50
74-79	0.83	1.07	0.53
80-85	0.88	1.11	0.57
86-91	0.92	1.17	0.59
92-97	0.97	1.17	0.62
98-103	1.02	1.24	0.66
104-110	1.06	1.28	0.68
Average =	0.74		

Table 3: Differential dosage of fertilizer application based on growth stage of sweet corn crop as per recommendation

Crop stage	Nutrient dose (kg ha^{-1} day^{-1})	
	N	K_2O
After sowing 20 days (10-30 DAS)	1.31	0.56
Grand growth period 20 days (30-50 DAS)	4.39	1.18
Reproductive stage 20 days (50-70 DAS)	3.30	0.75

cob yield was recorded under drip irrigation scheduled at 0.6 Epan (I_1).

The reason for higher cob yield in I_3 (1.0 Epan) can be attributed to favourable soil moisture conditions maintained throughout the crop growth period which enhanced the photosynthetic rate, biomass accumulation and partition into economic parts. The lowest yield under I_1 (0.6 Epan) might be due to the fact that moisture is not sufficient to absorb the nutrients by the crop as water is medium for nutrient absorption found to reduce leaf area, photosynthesis, biomass production and consequently cob yield. Robel *et al.* (2019), Brar *et al.* (2018), Bibe *et al.* (2017), Kada Siddappa *et al.* (2013) and Islam *et al.* (2012) also reported higher yields under higher irrigation regimes.

Among four fertigation levels, 125 % RDNK in differential dosage as per crop coefficient curve (F_4) registered significantly higher cob yield over 100 % RDNK in differential dosage as per recommendation (F_1) and 100% RDNK in differential dosage as per crop coefficient curve (F_2) during both the years and in means. However, it was statistically at par with the application of 125 % RDNK in differential dosage as per recommendation (F_3). While the lower fresh cob yield was recorded with the 100 % RDNK in differential dosage as per recommendation (F_1) during both the

Table 4: Differential dosage of fertilizer application based on growth stage of sweet corn as per crop coefficient curve

Crop stage	Kc values	Nutrient dose (kg ha^{-1} day^{-1})	
		N	K_2O
10-20 days	0.4	1.54	0.42
21-26	0.51	2	0.53
27-31	0.62	2.4	0.65
32-37	0.74	2.8	0.77
38-43	0.84	3.2	0.88
44-49	0.90	3.5	0.95
50-55	0.98	3.8	1.03
56-61	1.05	4.03	1.10
62-67	1.13	4.3	1.18
68-70	1.15	4.4	1.20
Average =0.83			

years. In particular, cob yield obtained through F_1 and F_2 were at par with each other and cob yield obtained with $F_3$was also comparable to F_2 but was statistically higher over F_1, where in 25 % of the nutrients can be saved with recommendation based sustainable approach like crop coefficient curve.

According to the crop coefficient curve (F_4), the higher yield recorded with 125 per cent RDNK in differential dosage could be due to lower fertiliser rates during the early stages and higher fertiliser rates during the grand growth period and reproductive stage meeting crop growth needs, causing the crop to uptake more nutrients, resulting in a higher cob yield. When compared to F_1 and F_3 treatments, nutrients were delivered more accurately and scientifically under F_4 and F_2 treatments. Increased fertiliser levels (N and K) attributed to adequate nutrient supply under higher density planting were also responsible for the higher cob yield under F_3 and F_4 fertigation levels over F_1 and F_2, which improved all growth and yield contributing features. Khanna (2013) and Sharana (2012) all reported similar findings of increased output with increased fertiliser rates.

Green fodder yield (kg ha^{-1})

A scrutiny of data (Table 6) indicated that irrigation scheduled at 1.0 Epan (I_3) registered significantly higher green fodder yield over 0.8 Epan (I_2) and 0.6 Epan (I_1) during both the years and in means, while the fodder yield recorded under 0.6 Epan (I_1) remained significantly inferior to 0.8 Epan (I_2) and 1.0 Epan (I_3) during both the seasons and in means. Lower fodder yield under 0.6 Epan (I_1) might be due to moisture stress conditions that resulted in reduced cell expansion, photosynthetic leaf area, reducing the crop growth and total dry matter accumulation. The optimum quantity of water at desired depth led to minimizing the stress felt by the crop and helped in realizing higher fodder yield under I_3 irrigation level. Sharana (2012) also found maximum green fodder yield under drip irrigation scheduled at 100% Epan over 60 and 80% Epan. Similar findings were also reported by Bibe *et al.* (2017), Kada Siddappa *et al.* (2013) and Shivakumar *et al.* (2011)

Among fertigation levels, significantly higher green fodder yield was realised with the 125 % RDNK in differential dosage as per crop coefficient curve (F_4) over 100% RDNK in differential dosage as per recommendation (F_1) and 100 % RDNK in differential dosage as per crop coefficient curve (F_2) andwas statistically on par with the fodder yield obtained with the 125% RDNK in differential dosage as per recommendation (F_3)during both the years and in means. F_1 had a lower green fodder yield in both years and in a mean that was comparable to F_2, F_2 had a higher green fodder yield in both years and in a mean that was comparable to F_2. Furthermore, F_3 yielded green fodder yields that were comparable to F_2 and statistically superior to F_1. When comparing the two fertigation patterns, F_1, F_3 and F_2, F_4, the nutrients were supplied more precisely to the crop under the F_2, F_4 patterns, *i.e.* the quantity of fertilisers applied per fertigation event were in accordance with the plants nutrient needs, resulting in higher dry matter production and thus higher fodder yield (F_1, F_3). Higher yields with 125 per cent RDNK above 100 per cent RDNK in all fertigation patterns were attributed to higher availability of all two key nutrients (N and K) in the soil solution, which resulted in higher absorption and improved crop growth, maximum plant height, LAI and ultimately produced more biological yield. Similarly, Sharana (2012), Fanish *et al.* (2011) also recorded higher fodder yield under increased levels of fertilisers.

Table 5. Seed cotton and stalk yield of cotton as influenced by drip irrigation and fertigation levels

Treatments	Seed cotton yield (kg ha^{-1})			Stalk yield (kg ha^{-1})		
	2019	**2020**	**Mean**	**2019**	**2020**	**Mean**
Irrigationlevels (I)						
I_1: Drip irrigation 0.60 Epan throughout crop growth period	2237	2046	2141	5897	5788	5843
I_2: Drip irrigation 0.80 Epan throughout crop growth period	2248	2060	2154	5917	5831	5874
I_3: Drip irrigation 1.0 Epan throughout crop growth period	2252	2090	2171	5935	5857	5896
SEm(±)	**81**	**50**	**-**	**166**	**187**	**-**
LSD (0.05)	**NS**	**NS**	**-**	**NS**	**NS**	**-**
Fertigation levels (F)						
F_1:100 % RDNK (differential dosage of N & K as per recommendation)	2040	1953	1997	5551	5419	5485
F_2: 100 % RDNK (differential dosage of N & K as per crop coefficient curve)	2113	2000	2057	5666	5586	5626
F_3: 125 % RDNK (differential dosage of N & K as per recommendation)	2384	2129	2256	6241	6007	6124
F_4:125% RDNK (differential dosage of N & K as per crop coefficient curve)	2446	2178	2312	6287	6210	6248
SEm(±)	**94**	**58**	**-**	**192**	**216**	**-**
LSD (0.05)	**275**	**170**	**-**	**562**	**634**	**-**
Interaction (IXF)						
SEm(±)	**163**	**100**	**-**	**332**	**374**	**-**
LSD (0.05)	**NS**	**NS**	**-**	**NS**	**NS**	**-**

Table 6: Green cob yield, green fodder yield (kg ha^{-1}) of sweet corn as influenced by drip irrigation and fertigation levels

Treatments	Green cob yield (kg ha^{-1})			Green fodder yield (kg ha^{-1})		
	2020	**2021**	**Mean**	**2020**	**2021**	**Mean**
Irrigationlevels (I)						
I_1: Drip irrigation 0.60 Epan throughout crop growth period	9967	9332	9650	27878	26551	27215
I_2: Drip irrigation 0.80 Epan throughout crop growth period	11734	11195	11465	33149	31559	32354
I_3: Drip irrigation 1.0 Epan throughout crop growth period	12870	12337	12604	36409	35044	35727
SEm±	**321**	**307**	**-**	**839**	**847**	**-**
CD (P=0.05%)	**941**	**899**	**-**	**2461**	**2485**	**-**
Fertigation levels (F)						
F_1:100 % RDNK (differential dosage of N & K as per recommendation)	10724	10156	10440	30117	28879	29498
F_2: 100 % RDNK (differential dosage of N & K as per crop coefficient curve)	11131	10593	10862	31423	29937	30680
F_3: 125 % RDNK (differential dosage of N & K as per recommendation)	11891	11300	11596	33600	32294	32947
F_4:125% RDNK (differential dosage of N & K as per crop coefficient curve)	12349	11769	12059	34776	33096	33936
SEm±	**371**	**354**	**-**	**969**	**978**	**-**
CD (P=0.05%)	**1087**	**1039**	**-**	**2842**	**2870**	**-**
Interaction (IXF)						
SEm±	**642**	**613**	**-**	**1678**	**1695**	**-**
CD (P=0.05%)	**NS**	**NS**	**-**	**NS**	**NS**	**-**

Table 7: System cost of cultivation and system gross returns as influenced by drip irrigation and fertigation levels

Treatments	System cost of cultivation (₹ ha^{-1})			System gross returns (₹ ha^{-1})		
	2019-20	**2020-21**	**Mean**	**2019-20**	**2020-21**	**Mean**
Irrigationlevels (I)						
I_1: Drip irrigation 0.60 Epan throughout crop growth period	98313	105961	102137	244439	233508	238973
I_2: Drip irrigation 0.80 Epan throughout crop growth period	99647	107233	103440	267960	257924	262942
I_3: Drip irrigation 1.0 Epan throughout cropgroGramene. www.gramene.org (Last accessed on 30 January, 2019).Gramene. www.gramene.org (Last accessed on 30 January, 2019).Gramene. www.gramene.org (Last accessed on 30 January, 2019).wthperiod 278639		101113	108565	104839	282764	274514
SEm(±)	**-**	**-**	**-**	**4841**	**4820**	**-**
LSD (0.05)	**-**	**-**	**-**	**14200**	**14138**	**-**
Fertigation levels (F)						
F_1:100 % RDNK (differential dosage of N & K as per recommendation)	96454	103775	100115	243949	238953	241451
F_2: 100 % RDNK (differential dosage of N & K as per crop coefficient curve)	96454	103775	100115	253153	246951	250052
F_3: 125 % RDNK (differential dosage of N & K as per recommendation)	102928	110731	106830	277064	263561	270313
F_4:125% RDNK (differential dosage of N & K as per crop coefficient curve)	102928	110731	106830	286050	271795	278923
SEm(±)	**-**	**-**	**-**	**5590**	**5565**	**-**
LSD (0.05)	**-**	**-**	**-**	**16397**	**16324**	**-**
Interaction (IXF)						
SEm(±)	**-**	**-**	**-**	**9683**	**9640**	**-**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 8: System net returns and system benefit cost ratio as influenced by drip irrigation and fertigation levels

Treatments	System net returns (₹ ha^{-1})			System benefit cost ratio		
	2019-20	**2020-21**	**Mean**	**2019-20**	**2020-21**	**Mean**
Irrigationlevels (I)						
I_1: Drip irrigation 0.60 Epan throughout crop growth period	146126	127548	136837	2.5	2.2	2.4
I_2: Drip irrigation 0.80 Epan throughout crop growth period	168313	150690	159502	2.7	2.4	2.6
I_3: Drip irrigation 1.0 Epan throughout crop growth period	181651	165949	173800	2.8	2.5	2.7
SEm(±)	**4134**	**3583**	**-**	**0.04**	**0.03**	**-**
LSD (0.05)	**12127**	**10509**	**-**	**0.12**	**0.09**	**-**
Fertigation levels (F)						
F_1:100 % RDNK (differential dosage of N & K as per recommendation)	147495	135178	141337	2.5	2.3	2.4
F_2: 100 % RDNK (differential dosage of N & K as per crop coefficient curve)	156699	143176	149938	2.6	2.4	2.5
F_3: 125 % RDNK (differential dosage of N & K as per recommendation)	174136	152830	163483	2.7	2.4	2.6
F_4:125% RDNK (differential dosage of N & K as per crop coefficient curve)	183122	161064	172093	2.8	2.5	2.7
SEm(±)	**4774**	**4137**	**-**	**0.05**	**0.03**	**-**
LSD (0.05)	**14003**	**12135**	**-**	**0.14**	**0.10**	**-**
Interaction (IXF)						
SEm(±)	**8269**	**7166**	**-**	**0.08**	**0.06**	
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 9: System productivity and profitability as influenced by drip irrigation and fertigation levels

Treatments	System productivity (kg $ha^{-1}day^{-1}$)			System profitability (₹ $ha^{-1}day^{-1}$)		
	2019-20	**2020-21**	**Mean**	**2019-20**	**2020-21**	**Mean**
Irrigationlevels (I)						
I_1: Drip irrigation 0.60 Epan throughout crop growth period	148.5	148.2	148.4	400.3	349.4	374.8
I_2: Drip irrigation 0.80 Epan throughout crop growth period	174.6	175.1	174.8	461.1	412.9	437.0
I_3: Drip irrigation 1.0 Epan throughout crop growth period	190.9	193.3	192.1	497.7	454.7	476.2
SEm(±)	**3.3**	**3.7**	**-**	**11.3**	**9.8**	**-**
LSD (0.05)	**9.6**	**10.8**	**-**	**33.2**	**28.8**	**-**
Fertigation levels (F)						
F_1:100 % RDNK (differential dosage of N & K as per recommendation)	158.8	160.1	159.5	404.1	370.4	387.3
F_2: 100 % RDNK (differential dosage of N & K as per crop coefficient curve)	165.4	166.1	165.7	429.3	392.3	410.8
F_3: 125 % RDNK (differential dosage of N & K as per recommendation)	177.3	178.6	177.9	477.1	418.7	447.9
F_4:125% RDNK (differential dosage of N & K as per crop coefficient curve)	183.6	183.7	183.6	501.7	441.3	471.5
SEm(±)	**3.8**	**4.3**	**-**	**13.1**	**11.3**	**-**
LSD (0.05)	**11.0**	**12.6**	**-**	**38.4**	**33.3**	**-**
Interaction (IXF)						
SEm(±)	**6.5**	**7.4**	**-**	**22.7**	**19.6**	**-**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

SYSTEM EVALUATION STUDIES

System economic analysis was carried by calculation of cost of cultivation for different operations for growing two crops. Influence of different irrigation and fertigation levels on economics of high density cotton-sweetcorn production system is presented in Table 7 and 8.

System cost of cultivation (₹ ha^{-1})

System cost of cultivation varied from . ₹96454 to 102928 ha^{-1} during 2019-20 and ₹103775 to 110731 ha^{-1} during 2020-21 among different treatments. Main variation in cost of cultivation was due to fertigation levels of N and K_2O, cost of water, fertilizers and man power required for irrigation, fertigation and other operations among treatments.

Results on economic analysis shows that among irrigation levels highest cultivation cost incurred with irrigation scheduled at 1.0 Epan (I_3) when compared to other irrigation regimes (I_2 and I_1) during 2019-20, 2020-21 and in mean. This variation in cultivation cost among irrigation levels is mainly due to cost of water and man power used for irrigation. Among four fertigation levels system cost of cultivation was higher with application of 125 % RDNK as per crop coefficient curve (F_4) and application of 125 % RDNK as per recommendation (F_3) when compared to application of 100 % RDNK as per crop coefficient curve (F_2) and application of 100 % RDNK as per recommendation (F_1)during 2019-20, 2020-21 and in mean. The deviation in system cost of cultivation among fertigation levels was mainly due to quantity of fertilisers used.

System gross returns (₹ ha^{-1})

System gross returns were product of marketable yield (seed cotton, cob and green fodder yield) and market price of seed cotton, cobs and fodder. The data related to system gross returns was presented in Table 7. Significantly higher system gross returns were obtained with drip irrigation scheduled at 1.0 Epan (I_3) when compared to 0.8 Epan and 0.6 Epan (I_2 and I_1) during both the seasons and in mean. While, lower gross returns were recorded with drip irrigation at 0.6 Epan during 2019-20 and 2020-21. Increased gross returns with I_3 was mainly due to high cob and fodder yield compared to other treatments (I_2 and I_1). However, the seed cotton produced was not significantly differed among irrigation levels.

Scrutiny of data indicated that system gross returns were significantly higher with application of 125 % RDNK as per crop coefficient curve (F_4) over application of 100 % RDNK as per crop coefficient curve (F_2) and application of 100 % RDNK as per recommendation (F_1) and was on par with application of 125 % RDNK as per recommendation (F_3) during 2019-20 and 2020-21. Lower gross returns were obtained from F_1 and was on par with F_2.The higher gross returns among F_3, F_4 was due to higher seed cotton, fresh cob and green fodder yield obtained over other fertigation levels F_1, F_2.

The interaction effect of irrigation and fertigation levels on system gross returns was found non-significant during 2019-20 and 2020-21.

System net returns (₹ ha^{-1})

The data pertaining to system net returns was depicted in Table 8. System net returns obtained from drip irrigated high density cotton and sweetcorn varied significantly among different irrigation regimes. Higher system net returns were recorded with drip irrigation scheduled at 1.0 Epan (I_3) which was significantly superior when compared to drip irrigation at 0.8 Epan and 0.6 Epan (I_2 and I_1) during both the seasons and in mean. Significantly lower net returns were recorded with drip irrigation at 0.6 Epan than drip irrigation at 0.8 and 1.0 Epan. Increased net returns under I_3 was mainly due to higher seed cotton, cob and fodder yield compared to other treatments (I_2 and I_1). Net returns were statistically higher with application of 125 % RDNK as per crop coefficient curve (F_4) and was on par with application of 125 % RDNK as per recommendation (F_3) during 2019-20, 2020-21 and in mean. While the lowest net returns were realised from application of 100 % RDNK as per recommendation (F_1) and was on par with application of 100 % RDNK as per crop coefficient curve (F_2) during both the years and in mean. The higher net returns among F_3, F_4 was mainly due to higher seed cotton, fresh cob and green fodder yield obtained over other fertigation levels F_1, F_2.

There was no significant interaction effect on system net returns due to irrigation regimes and fertigation levels during 2019-20 and 2020-21.

System benefit : cost ratio

The computed data on benefit : cost ratio of high density cotton- sweetcorn production system was presented in Table 8. System B:C ratios varied significantly among different irrigation regimes. B:C ratios were significantly higher under drip irrigation scheduled at 1.0 Epan (I_3) when compared to 0.8 Epan and 0.6 Epan(I_2 and I_1) during 2019-20, 2020-21 and in mean. Drip irrigation at 0.6 Epan (I_1) resulted in lower B:C ratios over other irrigation levels (I_2 and I_3). It is obvious that B: C ratio as well as net returns increased with increased in cob and fodder yield in sweetcorn crop. Treatments in which more irrigation water applied involved with higher system cost of cultivation over the treatments which received less amount of irrigation water, but supported to increase in production of cob and fodder yield resulting in the higher system benefit cost ratios.

B:C ratio was higher with the application of 125 % RDNK as per crop coefficient curve (F_4) when compared to application of 100 % RDNK as per recommendation (F_1) and application of 100 % RDNK as per crop coefficient curve (F_2) but was on par with application of 125% RDNK as per recommendation (F_3) during 2019 and 2020 and mean. The higher benefit cost ratio among F_4 andF_3 was due to higher seed cotton, green cob and fodder yield and net returns obtained over other fertigation levels F_1 and F_2.

The interaction effect between irrigation and fertigation levels on system benefit cost ratio was not significant during 2019-20 and 2020-21.

System productivity (kg ha^{-1} day^{-1})

The data related to system productivity was presented in Table 9. Significantly higher system productivity was obtained with drip irrigation scheduled at 1.0 Epan (I_3) when compared to 0.8 Epan and 0.6 Epan (I_2 and I_1) during both the seasons and in mean. While, lower system productivity was recorded with drip irrigation at 0.6 Epan during 2019-20 and 2020-21. Increased system productivity with I_3 was mainly due to higher production of cob and fodder yield compared to other treatments (I_2 and I_1). However, the seed cotton produced was not significantly differed among irrigation levels.

Data indicated that system productivity was significantly higher with application of 125 % RDNK as per crop coefficient curve (F_4) over application of 100 % RDNK as per crop coefficient curve (F_2) and application of 100 % RDNK as per recommendation (F_1) and was on par with application of 125 % RDNK as per recommendation (F_3) during 2019-20 and 2020-21. Lower system productivity was obtained from F_1 and was on par with F_2. The higher system productivity among F_3, F_4 was due to higher seed cotton, fresh cob and green fodder yield produced over other fertigation levels F_1, F_2.

The interaction effect of irrigation and fertigation levels on system productivity was found non-significant during 2019-20 and 2020-21.

System profitability (₹ ha^{-1} day^{-1})

The data pertaining to system profitability was furnished in Table 9. Significantly higher system profitability was obtained with drip irrigation scheduled at 1.0 Epan (I_3) when compared to 0.8 Epan and 0.6 Epan (I_2 and I_1) during both the seasons and in mean. While, lower system profitability was recorded with drip irrigation at 0.6 Epan during 2019-20 and 2020-21. Increased system profitability with I_3 was mainly due to higher net returns obtained when compared to other treatments (I_2 and I_1).

System profitability varied significantly among different fertigation levels. Data indicated that system profitability was significantly higher with application of 125 % RDNK as per crop coefficient curve (F_4) over application of 100 % RDNK as per crop coefficient curve (F_2) and application of 100 % RDNK as per recommendation (F_1) and was on par with application of 125 % RDNK as per recommendation (F_3) during 2019-20 and 2020-21. Lower system profitability was obtained from F_1 and was on par with F_2. The higher system profitability among F_3, F_4 was due to higher net returns obtained over other fertigation levels F_1, F_2.

The interaction effect of irrigation and fertigation levels on system profitability was found non-significant during 2019-20 and 2020-21.

Land use efficiency

The land use efficiency was 73.9% and 70.1% during 2019-20 and 2020-21 respectively.

CONCLUSION

Significantly higher system gross returns, system net returns, system B:C ratio, system profitability and system productivity were obtained under irrigation at 1.0 Epan over 0.6 and 0.8 Epan. Higher system gross returns, system net returns, system B:C ratio, system profitability and system productivity were recorded with application of 125 % RDNK in differential dosage as per crop coefficient curve (F_4) over application of 100 % RDNK in differential dosage as per recommendation (F_1) and application of 100 % RDNK in differential dosage as per crop coefficient curve (F_2) and were on par with 125% RDNK in differential dosage as per recommendation (F_3). The land use efficiency was 73.9% and 70.1 % during 2019-20 and 2020-21 respectively.

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REFERENCES

Aladakatti, Y.R., Hallikeri, S.S., Nandagavi, R.A., Shivamurthy, D. and Malik Rehan. 2012. Precision irrigation and fertigation to enhance the productivity and economic returns of bt cotton in vertisols. *Proceedings of Agro-Informatics and Precision Agriculture*, 341-343.

AnittaFanish, S., Muthukrishnan, P. and Santhi, P. 2011. Effect of drip fertigation on field crops- A review. *Agric. Review,* **32** (1): 14-25.

Bhaskar, P. 2014. Influence of crop geometry and drip fertigation on growth and yield of Bt cotton. *M.Sc. Dissertation,* Tamil Nadu Agricultural University, Coimbatore.

Bibe, S.M., Jadhav, K.T and Chavan, A.S. 2017. Response of irrigation and fertigation management on growth and yield of maize. *Int. J. Curr. Microbiol. Appl. Sci.,* **6** (11): 4054-4060.

Brar, H.S., Vashist, K.K. and Singh, K.G. 2018. Water saving in spring maize under different drip irrigation regimes and nitrogen levels. *Agric. Res. J.*, **55** (1): 162-165.

Directorate of Economics and Statistics. *Agriculture statistics at a Glance. 2016-17.* Ministry of Agriculture. Government of India.

Directorate of Economics and Statistics. *Agriculture statistics at a Glance. 2019-20.* Ministry of Agriculture. Government of India.

Directorate of Economics and Statistics. *Agriculture statistics at a Glance. 2020-21.* Ministry of Agriculture. Government of India.

Fanish, S.A., Muthukrishnan, P. and Jeyaraman, S. 2011. Effect of drip fertigation and intercrops on yield and water use efficiency of maize (*Zea mays*) under maize based intercropping system. *J. Crop Weed*, **7** (2): 41-45.

Gomez, K.A and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research (1st Edition), Jhon Wiley and Sons, Wiley and Sons, Wiley Inter Science Publication, New York, USA., 680.

Hadole, S.S., Bhagat, G.J., Nagone, A. H. and Thakur, V.R. 2012. Nutrient management through drip system of irrigation in cotton. *PKV Res. J.*, **36**(2):52-55.

Islam, M.R., Garcia, S.C and Horadagoda, A. 2012. Effects of irrigation and rates and timing of nitrogen fertilizer on dry matter yield, proportions of plant fractions of maize and nutritive value and in vitro gas production characteristics of whole crop maize silage. *Animal Feed Sci. Technol.*, **172** (4): 125-135.

Jayakumar, M., Surendran, U. and Manickasundaram, P. 2014. Drip fertigation effects on yield, nutrient uptake and soil fertility of Bt Cotton in semiarid tropics. *Int. J. Pl. Prod.*, **8** (3): 375-390.

Jha, B.K., Santosh, S. M., Sushanta K. N., Ajay Kumar and Arun, K.S. 2015. Optimal planting geometry and growth stage based fertigation in vegetable crops. Technical Bulletin No R-56/Ranchi-25.

Kada Siddappa, M., Praveen Rao, V., Yella Reddy, K and Tirupataiah, K. 2013. Yield, water use and water use efficiency of drip irrigated maize in southern Telangana region of AP. *Proceedings of NGWC 2013 on Problems, Challenges and Management of GW in Agriculture*. Coimbatore-Tamil Nadu. December 9-11 2013. pp. 372-376.

Kakade, S., Bhale, V., Deshmukh, J. and Wadatkar, S. 2017. Growth, nutrient uptake and seed cotton yield as influenced by split application of nutrients through fertigation in Bt Cotton. *Int. J. Curr. Microbiol. Appl. Sci.,* **6**(9): 2982-2990.

Kathage, J. and Matin, Q. 2012. Economic impacts and impact dynamics of Bt (*Bacillus thuringiensis*) cotton in India.*Proceedings of the National Academy of Sciences of the United States of America,* 109 **(29)**: 11652–11656.

Khanna, R. 2013. Effect of precision nutrient and water management with different sources and levels of fertilizers on maize production. *M.Sc. Thesis* submitted to University of Agricultural Sciences, Bengaluru.

Magare, P.N., Katkar, R.N and Jadhao, S.D. 2018. Effect of fertigation on yield, quality and soil fertility status under cotton grown in Vertisol. *Int.J. Chem. Studies*, **6**(2): 42-46.

Rao, P. V., Subbaiah, G. and Veeraraghavaiah, R. 2014. Agronomic responses of maize to plant population and nitrogen availability-a review. *Int. J. Pl. Animal and Environ. Sci.,* **4** (1): 107-116.

xRobel, A., Abraham, W.M. and Tilahun, H. 2019. Effect of moisture stress on maize (*Zea Mays* L.) yield and water productivity. *Int. J. Environ. Sci. & Nat. Res.,* **16** (4) : 83-85.

Sandya, N.R., Subbaiah, G. and Pulla Rao, C.H. 2016. Impact of different plant densities and nitrogen rates on growth and yield of sweet corn (*Zea mays saccharata*) during *rabi*. *Ecol. Environ. Conserv.*, **22** (3): 419-423.

Sharana, B., 2012. Performance of sweet corn hybrid under different levels of irrigation and nitrogen applied through drip system. *M.Sc. Thesis submitted to ANGRAU*, Hyderabad.

Shivakumar, H. K., Ramachandrappa, B.K., Nanjappa, H.V. and Mudulagiriyappa. 2011. Effect of phenophase based irrigation schedules on growth, yield and quality of baby corn (*Zea mays* L.). *Agric. Sci.*, **2** (3) : 267-272.

Spandana, P. B. 2012. Response of sweet corn hybrid to varying plant densities and nitrogen levels. *African J. Agric. Res.*,**7** (46): 6158-6166.

Veeraputhiran, R and Chinnusamy, C. 2009. Soil moisture and water use studies under drip and furrow irrigation methods in hybrid cotton. *J. Cotton Res. Dev*, **23** (1): 74-79.