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Cost Reduction Economical Drip Layout for Enhancing Productivity, Profitability and Soil Fertility in Maize and Cotton under Semi-arid Condition

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ABSTRACT

Background: Single economical cost reducing drip lay out for major annual crops with paired row geometry is an alternate solution to overcome constraints faced by the farmers and increase the income. Further to achieve high crop production and sustainable agricultural development, it is necessary to compare the effects of different dripline spacings and fertilization rates on maize and seed cotton yield.

Methods: A field experiment was carried out at Agricultural Engineering College and Research Institute, Tiruchirappalli to evaluate the suitability of single economical drip layout and to optimize the fertilizer level in modified geometries as well as to assess the impact of geometries in water and productivity of maize and cotton.

Result: The results revealed that, the economics was in favor with 1.20 m lateral spacing and application of 100% recommended N and K through drip fertigation and P as soil application (L_2F_2) having higher gross return, net return and BCR in maize and cotton. 1.2 m spacing between two laterals with 4lph emitter at 0.6 m interval with recommended dose of 100% N and K trough fertigation and P as soil application is recommended to achieve higher productivity and monetary return form cotton and maize.

Key words: Cotton, Drip layout, Fertilizer level, Maize, Productivity, Profitability.

INTRODUCTION

Maize (*Zea mays* L.) is considered to be vital and has the high productivity potential among the cereals crop and can be cultivated in different seasons and agro-climatic conditions. In India, maize is the important cereal crop next to rice and wheat (Erenstein *et al*., 2022). Cotton (*Gossypium hirsutum* L.) is an important commercial crop of India and it sustains the cotton textile industry which perhaps the largest segment of organized industries in the country (Zeng *et al*., 2022) and it is recognized as “white gold” since it is earning foreign exchange (Khan *et al*., 2020). For better root development and water requirement in cotton the time of application of irrigation is very much important and in order to maintain crop yield and quality fertilization is very much important**.** Among the different factors influencing the productivity of maize and cotton, water and nutrients occupy prime position since these responds very well to water and nutrient applications. Ever-increasing food requirement with declining water resources have poised a kind of pressure to find new technologies for proficient use of water and fertilizers in farming. Studies in many countries have shown that drip irrigation can save water use by 30% to 50% and raises crop yields by 20% to 90% depending on soil, climatic and crop characteristics and farmers practices if it is properly planned, installed and operated compared to surface irrigation and it can also enable increasing crop yields and crop quality (Çetin and Akalp, 2019).

At present, the fertigation method using drip fertigation systems has been widely used internationally in modern agriculture due to its large irrigation area coverage, high fertilizer utilization efficiency, high degree of automation, low labour demand and low environmental impacts (Ayars *et al.,* 2015, Chauhdary *et al.,* 2019, Wu *et al.,* 2019 and Harshad *et al.,* 2021). Maize and cotton crops under drip irrigation conditions with N fertilization have been widely tested and have shown successful results, exhibiting increased grain yield, seed cotton yield and economic benefits, improved utilization efficiency of fertilizers and water and reduced N loss (Ning *et al*., 2019 and Li *et al*., 2021). The spacing of the dripline and rate of fertilization are an important factor in achieving better crop productivity, nutrient and water use efficiency and production benefits. Research work of Lamm *et al.* (1997) and Bozkurt *et al.* (2006) identify that the changes in spacing of dripline resulted in significantly different yield. Chen *et al.* (2015) claimed that dripline spacing and layout affected the leaf area index, net photosynthetic rate, aboveground biomass, plant growth and grain yield as dripline spacing increased. Zhou *et al.*

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(2017) conducted an experiment to assess the effects of spacing in driplines over distributions of soil water and nitrate and conclude that a narrower dripline would enhance uniformity in distribution of NO_3-N concentration, relative chlorophyll content of leaves and crop yield. Further it can be said that, spacing of the dripline and crop yield is not universal since the fertigation efficiency varies in accordance with varying field conditions and agricultural measures such as fertilizer type, fertilization and irrigation rate, climatic factors and soil.

Even though drip irrigation system is a solution for farmers to solve their many of the problems in agriculture by improving efficiency and income in agriculture, it has some major constraints like drip layout of particular crop is not useful for other agricultural crops and it requires a new lay out, high initial investment cost due to different lay out for different crops and lack of capital to cover maximum holding under drip irrigation. Single economical cost reducing drip lay out for major annual crops with paired row geometry is an alternate solution to overcome these constraints faced by the farmers and increase the income. Further to achieve high crop production and sustainable agricultural development, it is necessary to compare the effects of different dripline spacings and fertilization rates on maize and seed cotton yield.

MATERIALS AND METHODS

Study area

A field experiment was conducted to study the effect of single economical drip layout with different geometries and fertilizer level on cotton and maize during 2021 and 2022 at Agricultural Engineering College and Research Institute, Kumulur, Tiruchirappalli. The soil in the experimental field is clay loam in texture. Climatic conditions that prevailed during the cropping period were 647 mm of rainfall with maximum and minimum temperatures of 31°C and 23°C and relative humidity of 82 and 58% was observed during morning and evening respectively. The chemical analysis of soil indicated that the soil was low in available nitrogen (201 kg/ha), medium in available phosphorus (14 kg/ha) and high in available potassium (327 kg/ha). It was moderately saline reaction (pH 7.98) with 0.72 dSm^{-1} electrical conductivity.

Experimental materials and design

A design of strip plot was adapted with three replications. Lateral spacings were adopted in the main plot *viz*., L_1: 0.90 m lateral spacing, L_2: 1.20 m lateral spacing, L_3: 1.50 m lateral spacing and L_4: Check (drip laterals laid out as per existing recommend plant spacing for cotton, maize). Two successive emitters spacing on the lateral is 0.60 m with discharge rate of 4 lph. Paired row geometry for different lateral spacings was adopted in maize and cotton as shown in the Fig 1. In subplot, different fertilizer levels were applied through drip fertigation as follows.F_1: 75 % of recommend N and K, F_2: 100 % of recommend N and K, F_3: 125% of recommend N and K. 75, 100 and 125 % P in F_1, F_2 and F_3, respectively directly applied to the soil. Drip irrigation was given once in two days and fertigation was as per the treatments. The observations of the crop yield were recorded and the data was subjected to statistical analysis.

Post-harvest samples were collected separately from each plot, the available NPK was estimated as per the procedures suggested by Subbiah and Asija (1956), Olsen *et al.* (1954) and Stanford and English (1949) respectively. The expenditure incurred from sowing to harvest was calculated and expressed in `/ha. Total income obtained from grain, seed cotton yield and stover yield were calculated for individual treatments. Cost of cultivation, gross return, net return and benefit cost ratio were calculated using the price of inputs and produce that prevailed during the crop season. Cost benefit analysis was computed for all the treatments using the following formula.

$$\text{Benefit cost ratio (B : C)} = \frac{\text{Gross return}}{\text{Total cost of cultivation}}$$

Statistical analysis

The statistical analysis was performed using the statistical method and strip plot design. Wherever the results were significant, the critical difference (CD) at the 5% level of significance was determined as given by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect of drip irrigation with different geometries and fertilizer level on productivity

Maize

Lateral spacing of 1.20 m (L_2) resulted significantly higher maize yield of 6675 kg/ha. This was followed by lateral spacing of 1.50 m (L_3) (Fig 2). The finding was supported by Li *et al.* (2021) who revealed that fertigation with one drip line per two rows of maize (*i.e*., dripline spacing was 1.2 m) was an economical and productive method of drip fertigation, saving approximately half the number of drip lines and obtaining higher yield compared to that of one drip line per row of maize and this was similar to the results observed by Bozkurt *et al.* (2006) who found that the optimum dripline spacing for maize is 1.2 m in sandy loam soil. Kruse and Israeli (1987) who examined subsurface drip irrigation using a 1.5 m dripline spacing for corn production in Colorado and found that considerable yield variation with distance from the dripline and concluded that it was important to center driplines (1.5 m) between corn rows to assure good production and yield. Manges *et al.* (1995) revealed that dripline spacing of 1.5 m significantly increased the corn yield at a plant population of approximately 80,000 plants/ha. Further, Lamm *et al.* (1997) advocated dripline spacing of 1.5 m obtained the highest yield and water use efficiency in the silt loam soil. Significantly lower yield of 5786 kg/ha was register with drip laterals laid out as per existing recommend plant spacing (L_4).

Application of 100% recommended N and K (F_2) through drip fertigation and P as soil application significantly recorded higher maize grain yield of 6440 kg/ha and this might be because of sufficient water and nutrients available in the root zone area that enhanced the maize grain yield. Further application of increased level of N and K resulted in vigorous root development, which promotes growth and development of plant leading to higher photosynthetic activity, which in turn results in better development of yield attributes and finally higher grain yield. This result is in agreement with the findings of Shruthi *et al.* (2018), who revealed that application of increased levels of recommended N and K through drip fertigation with four or eight-days interval resulted in higher kernel yield (86.85q/ha) and stover yield (103.73 q/ha) in hybrid maize.

Further the study revealed that, maize grain yield obtained with 100% recommended N and K (F_2) through drip fertigation and P as soil application was statistically on par with application of 125% recommended N and K (F_3) through drip fertigation and P as soil application. These results are close conformity with the findings of Ramulu *et al.* (2020) who opined that fertilizer application with 150% RDF (NPK) resulted in higher grain yield than the lower doses of NPK (75% and 100% RDF) in maize this might be due to increased nutrient dynamics in the root zone. Significantly lower yield (5973 kg/ha) was registered with 75% of

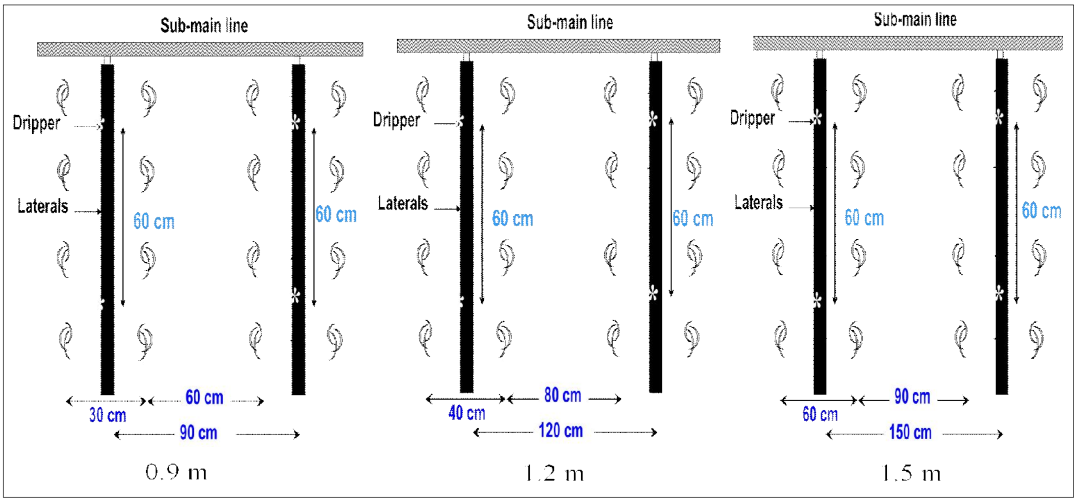

Fig 1: Lateral spacing.

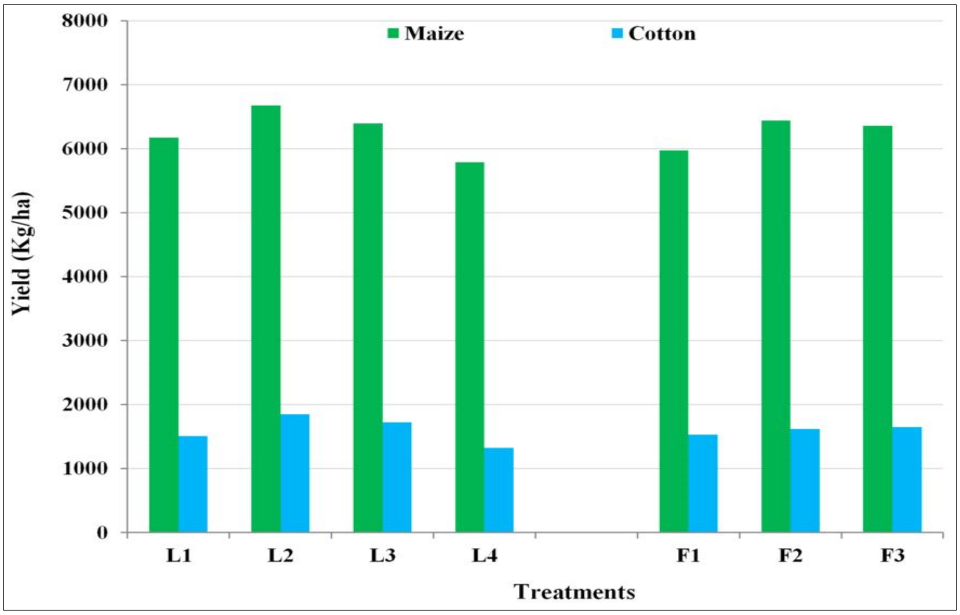

Fig 2: Effect of drip fertigation with different geometries on yield of maize and cotton.

recommended N and K (F_1) through drip fertigation and P as soil application in the present investigation. With regards to interaction, different lateral spacing and fertilizer level did not have any significant influence on the maize grain yield.

Cotton

Among the different geometries on lateral spacing, significantly higher seed cotton yield of 1848 kg/ha was recorded with lateral spacing of 1.20 m (L_2) (Fig 2). This is because in drip irrigation with optimum lateral spacing, water is applied in the vicinity of the root zone as per the demand of the crop which causes efficient utilization of added nutrients and translocation of photosynthates towards the reproductive part. This result agrees with the findings of Harshad *et al.* (2021) who opined that applying irrigation and fertigation through drip system (16 mm lateral of 1.2 m spacing × 4l ph × 0.6 m emitter spacing) and 100% RDF will have higher yield in cotton. In the treatment, lateral spacing of 1.50 m (L_3) recorded 1720 kg/ha seed cotton yield and it was statistically on par with lateral spacing of 1.20 m (L_2). Lower seed cotton yield of 1321 kg/ha was recorded with drip laterals laid out as per existing recommend plant spacing (L_4).

Application of 125% recommended N and K through drip fertigation and P as soil application (F_3) recorded significantly higher seed cotton yield (1646 kg/ha) and it was on par with 100% recommended N and K through drip fertigation and P as soil application (F_2). The increased level of fertilizer from 75 to 125% RDF might have increased the vegetative growth, photosynthetic rate, accumulation and translocation of metabolites from source to sink which directly expressed in the form of increased seed cotton yield. The seed cotton yield associated with drip fertigation is found to be increased linearly with increasing doses of fertilizer. Nalayini *et al.* (2012) and Kakade *et al.* (2017) have reported similar findings that fertigation with 125% recommended dose of N and K increased the yield attributes than other lower levels and soil application of fertilizers. These finding were further supported by Anusree *et al.* (2020). The lower yield of 1528 kg/ha was recorded with application of 75% recommended N and K (F_1) through drip fertigation and P as soil application in the study. Interaction between different plant geometries on lateral and fertilizer level did not have any significant influence on the seed cotton yield.

Effect of drip irrigation with different geometries and fertilizer level on profitability

Maize

In terms of profitability, lateral spacing of 1.20 m along with application of 100% recommended N and K through drip fertigation and P as soil application (L_2F_2) recorded higher gross return (`174,850/ha), net return (`103,085/ha) and B: C ratio (2.44) in maize (Table 1.).This was followed by 1.50 m lateral spacing, 4 lph at 0.6 m spacing along with application of 125% recommended N and K through drip fertigation and P as soil application (L_2F_3). This was similar with the findings of Li *et al.* (2021) who revealed that fertigation with one drip line per two rows of maize (*i.e.*, dripline spacing was 1.2 m) recorded higher gross return and net return in maize. Drip laterals laid out as per existing recommend plant spacing along with application of 75% recommended N and K through drip fertigation and P as soil application (L_4F_1) recorded lower gross return (`133,267/ha), net return (`49,368/ha) and B: C Ratio (1.59). Further lower cost of cultivation (`63,339/ha) was recorded with lateral spacing of 1.50 m and 75% of recommended N and K through drip fertigation and P as soil application ($L_3F_1$). This is mainly because of reduced drip lateral cost (`13,705/ha) when compared with drip laterals laid out as per existing recommend plant spacing (`28,555/ha). Reduction of 52 per cent of cost achieved in drip installation by adopting increased drip line spacing (1.50 m lateral spacing) for maize cultivation.

Cotton

Increasing the spacing between driplines and fertilizer levels has been recognized as the most significant factor in reducing the high initial costs of drip irrigation system

Table 1: Effect of single economical drip layout with different geometries and fertilizer level on maize profitability.

Treatments	Yield (kg/ha)	GR (`)	COC (`)	NR (`)	BCR
L_1F_1	6,034	150,850	72478	78,372	2.08
L_1F_2	6,230	155,758	77476	78,282	2.01
L_1F_3	6,250	156,258	82474	73,784	1.89
L_2F_1	6,392	159,792	66767	93,025	2.39
L_2F_2	6,994	174,850	71765	103,085	2.44
L_2F_3	6,639	165,983	76763	89,220	2.16
L_3F_1	6,135	153,375	63339	90,036	2.42
L_3F_2	6,547	163,675	68337	95,338	2.40
L_3F_3	6,510	162,750	73335	89,415	2.22
L_4F_1	5,331	133,267	83899	49,368	1.59
L_4F_2	5,987	149,667	88897	60,770	1.68
L_4F_3	6,042	151,050	93895	57,155	1.61

GR: Gross return; COC: Cost of cultivation; NR: Net return; BCR: Benefit cost ratio.

(Mubarak and Janat, 2020). The higher gross return (`152,533/ha), net return (`76,276/ha) and B: C ratio (2.0) was recorded when lateral spacing of 1.20 m with application of 100% recommended N and K through drip fertigation and P as soil application (L_2 F_2) (Table 2) This result was followed by 1.50 m lateral spacing, along with application of 125 % recommended N and K through drip fertigation and P as soil application (L_2 F_3). These findings were supported by Sorensen and Lamb (2008) and Singh *et al.* (2021) who revealed that cultivation cost has been statistically higher for 125% recommended dose of fertilizer, while 75% RDF incurred the least cost of cultivation. Drip laterals laid out as per existing recommend plant spacing along with application of 75% recommended N and K through drip fertigation and P as soil application (L_4F_1) recorded lower gross return (`1,00,027/ha), net return (`14,840/ha) and B: C ratio1.17. Further on cost of cultivation, lower cost cultivation of `70,337/ha was recorded with lateral spacing of 1.50 m and 75% of recommended N and K through drip fertigation and P as soil application (L_3F_1). These findings were supported by Lamm *et al.* (1997) who stated that increased dripline spacing reduce the overall drip investment costs in subsurface drip-irrigated corn.

Effect of drip irrigation with different geometries and fertilizer level on post-harvest soil available NPK (kg/ha)

Maize

Post-harvest soil available nitrogen and phosphorus were significantly influenced by fertigation levels whereas soil available potassium showed non-significant difference. Similarly lateral spacing also showed non-significant difference on soil available NPK.

Table 2: Effect of single economical drip layout with different geometries and fertilizer level on cotton profitability.

Treatments	Yield (kg/ha)	GR (`)	COC (`)	NR (`)	BCR
L_1F_1	1398	111,840	79476	32,364	1.41
L_1F_2	1523	121,867	81968	39,899	1.49
L_1F_3	1600	128,000	84460	43,540	1.52
L_2F_1	1789	143,093	73765	69,328	1.94
L_2F_2	1907	152,533	76257	76,276	2.00
L_2F_3	1847	147,733	78749	68,984	1.88
L_3F_1	1675	134,027	70337	63,690	1.91
L_3F_2	1760	140,800	72829	67,971	1.93
L_3F_3	1725	137,973	75321	62,652	1.83
L_4F_1	1250	100,027	85187	14,840	1.17
L_4F_2	1300	104,000	87679	16,321	1.19
L_4F_3	1414	113,147	90171	22,976	1.25

GR: Gross return; COC: Cost of cultivation; NR: Net return; BCR: Benefit cost ratio.

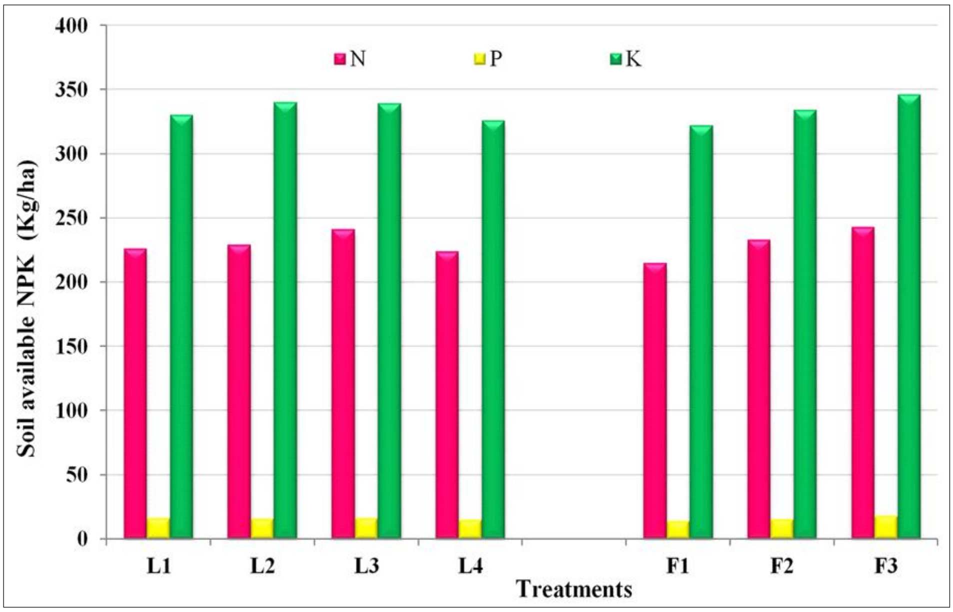

Fig 3: Drip fertigation with different geometries on post-harvest soil available NPK in maize.

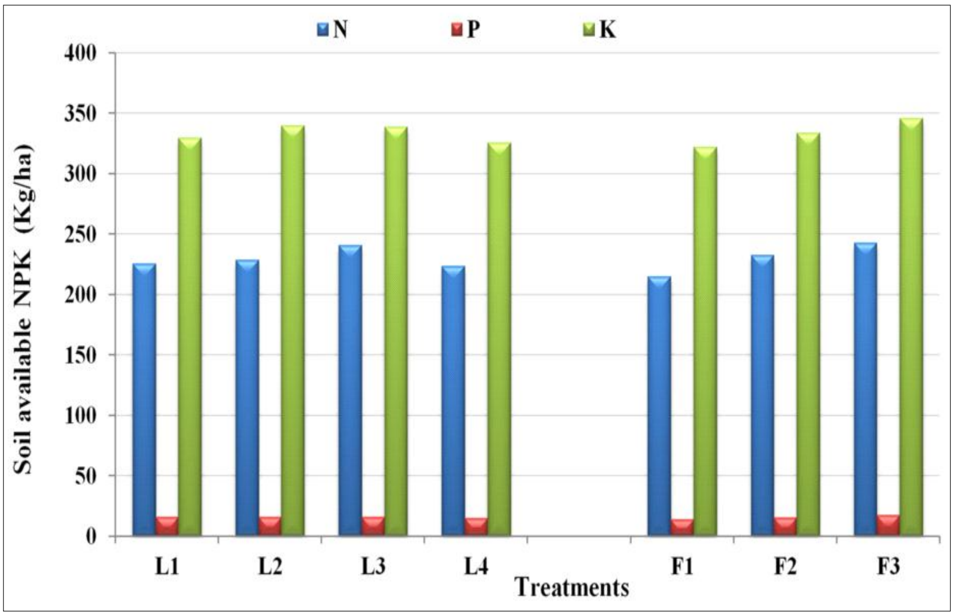

Fig 4: Drip fertigation with different geometries on post-harvest soil available NPK in cotton.

Application of 125% of recommend N and K through drip fertigation and P as soil application (F_3) recorded higher available nitrogen (243 kg/ha) and phosphorus (18 kg/ha) (Fig 3). This was followed by application 100% of recommend N and K through drip fertigation and P as soil application (F_2). The increase in level of NPK assured the availability of NPK to the crop plants in adequate amount and the excess is remained in the soil in substantial quantity. These findings were also confirmed by the findings of Saha and Mondal (2006), Felix *et al.* (2020) and Kiran *et al.* (2020) in maize. Available nitrogen (215 kg/ha) and phosphorus (14.3 kg/ha) was found to be lower with application of 75% recommended N and K through drip fertigation and P as soil application (F_1).

In interaction effect, there was no significant interaction on available nitrogen and potassium due different lateral spacing and fertilizer level in maize. But soil available phosphorus showed significant difference by dripline spacing and fertilizer levels. Significantly higher available phosphorus (18.8 kg/ha) was noticed with lateral spacing of 1.50 m with application of 125% recommended N and K through drip fertigation and P as soil application (L_3F_3). These findings was supported by Li *et al.* (2021) who opined that dripline spacing and fertilizer levels had no significant effect on the content of soil available N, P and K at the maize harvest.

Cotton

Lateral spacing showed significant difference on soil available nitrogen whereas soil available phosphorous and potassium showed non-significant difference. Higher available nitrogen (266 kg/ha) was recorded with1.50 m lateral spacing (L_3) and it was on par with 1.20 m lateral spacing (L_2). Drip laterals laid out as per existing recommend plant spacing recorded the lower available nitrogen (252 kg/ha)(Fig 4).

Application of 125% recommend N and K through drip fertigation and P as soil application higher available NPK. The reason for higher post-harvest available N, P and K in soil under 125 % of fertilizer levels could be due to reduction in leaching loss and better movement of nutrients in the soil under drip fertigation. Similar findings were also reported by Jayakumar *et al.* (2014) who stated that 150% of recommended dose of fertilizer recorded higher soil available nutrients in Bt cotton. Significantly available NPK was lower with application of 75% recommended N and K through drip fertigation and P as soil application (F_1). There was no significant interaction on available NPK due different lateral spacing and fertilizer level in cotton.

CONCLUSION

Lateral spacing of 1.20 m with 4 lph emitters at 0.60 m spacing on the lateral along with application of 100% recommended N and K through drip fertigation and P as soil application recorded higher yield with profitability both in maize and cotton and this gives solution to the farmers for major constraints like drip layout of particular crop is not useful for other agricultural crops and requires new lay out, high initial investment cost due to different lay out for different crops and lack of capital to cover maximum holding under drip irrigation. Hence, It was concluded that farmers have ample scope for adopting single economical cost reducing drip layout (1.20 m lateral spacing, 4 lph at 0.6 m spacing) with application of 100% of recommend N and K through drip fertigation and P as soil application in maize and cotton with paired row geometry for lesser cost of production, higher productivity, profitability and favourable impact on soil properties making way to sustainable agriculture.

The single economical drip layout (1.20 m lateral spacing, 4 lph at 0.6 m spacing) for maize and cotton is an alternate solution to overcome constraints faced by the farmers and increase the income in sustainable way under semi-arid condition.

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Conflict of interest

The authors declared no conflict of interest to this study.

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