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Subsurface Drip Fertigation, Irrigation Regimes and Short Duration Pulses on Productivity of Cotton-Maize Cropping Sequence

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Fertigation, a latest technology wherein nutrients are applied along with irrigation water. Fertigation opens new possibilities for controlling water and nutrient supplies to crops besides maintaining the desired concentration and distribution of water and nutrients to the soil. Research works on drip fertigation under intercropping situation is very limited. Input information on optimal schedules for micro-irrigation and fertigation to cotton and maize with intercropping of pulses will have to be generated, thus enabling the option of micro irrigation under intercropping situation. The experiment was laid out in split split plot design with three replications. The main plot consists of two irrigation levels *viz.,* 75 and 100 % PE reading, sub plot contains three drip fertigation levels *viz.,* 75, 100 and 125 % and sub sub plot consist intercropping with short duration pulses *viz.,* sole crop of maize/cotton, intercrop with cow pea, blackgram and cluster bean. The result revealed that no significant differences were noticed in number of bolls, boll weight under different irrigation

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regimes. Among the fertigation level, 125% RDF recorded higher number of bolls plant^{-1} and boll weight. The cotton equivalent yield of 3860 kg ha^{-1} with water saving of 24 per cent was accrued under cotton intercropped with blackgram and irrigation regime of 100% PE with application of 125% RDF (150:75:75 kgs NPK/ha) and it was followed by irrigation regime at 75% PE it increased 18.9% cotton yield compared to control (2099 kg ha^{-1}) with water saving of 40.6%. Regarding maize based intercropping system, maize + black gram intercropping with irrigation regime of 100% PE and 100% RDF (250: 75: 75 kg NPK/ha) gave higher maize equivalent yield of 7735 kg/ha. In cotton – maize sequence, intercropping of black gram found to be best suitable system with the irrigation level of 100% PE and 125% RDF (150:75:75 kg NPK/ha) for cotton and 100% RDF (250: 75: 75 kg NPK/ha) for maize is recommended to get higher yield.

Keywords: Fertigation; recommended dose of fertilizer; inter cropping; cotton-maize.

1. INTRODUCTION

Cotton and maize based cropping systems is commonly practiced in India. Irrigation water and nutrient management are the two most important hands of modern agricultural activity. The research on these areas under different cropping system is driven by the need to intensify production to obtain higher yields and effective utilization resources [1]. For that every attempt is necessary for achieving the objective of higher use efficiency of water and fertilizer. Under these circumstances drip irrigation is one such hi-tech system and reported that water use efficiency is as high as 70-90 percent. Drip irrigation has proved its superiority over other methods of irrigation due to the direct application of water and nutrients in the vicinity of root zone. Addressing these issues requires an integrated approach of soil-water-plant nutrient management in the plant-rooting zone.

Fertigation, a latest technology wherein nutrients are applied along with irrigation water. Fertigation opens new possibilities for controlling water and nutrient supplies to crops besides maintaining the desired concentration and distribution of water and nutrients to the soil. Research works on drip fertigation under intercropping situations are very limited. Input information on optimal schedules for micro-irrigation and fertigation to cotton and maize with intercropping of pulses will have to be generated, thus enabling the option of micro irrigation under intercropping situation. The drip system installed for cotton and maize crop can be used for intercrops too simultaneously which helps to reduce the payback period.

Crop diversification through intercropping has been shown to improve crop productivity and profitability, conservation of resources and provide a kind of biological insurance against risks particularly in rainfed condition [2]. Intercropping of pulses increases the soil nitrogen availability through biological nitrogen fixation. The available more nitrogen is more beneficial to the base crop also the addition of synthetic fertilizers also reduced. Intercropping is one of the potential areas to achieve sustainability with respect to soil fertility and productivity of maize growing areas [3]. Intercropping of suitable genotypes of pulses with maize not only provide nutritional security and improve the productivity but also improves soil quality. It has been well documented that legumes favorably improve the physical, chemical and biological aspects of the soil. Intercropping cause improvement in soil structure, as judged from the decrease in the bulk density, hydraulic conductivity, and available water besides increasing organic carbon content compared to pure maize cropped soils [3,4]. The beneficial effects must be perhaps due to root exudates, root and shoot residue addition and their decay. Inclusion of legumes in the cropping system benefits through nitrogen fixation by them and improves the soil fertility. These benefits are largely due to increased total biomass production, amount of N fixed, amount of N added to soil through root nodules, increased biological activity and increased availability of nutrients other than N. Considering the above points in view, the present study was undertaken to assess the feasibility of drip fertigation in maize based inter cropping system.

2. MATERIALS AND METHODS

The field investigations were carried in field Number D 42 of AICRP on Water Management Research block, Agricultural College and Research institute, Tamil Nadu Agricultural University, Madurai. The experiment was carried at consecutive two years (2016 and 2017) during *kharif* season in cotton and *rabi* season in maize to evaluate the subsurface drip fertigation, irrigation regimes along with growing short duration pulses as intercrop.

The experimental farm is geographically located at 9°54' N latitude and 78°54' E longitude at an elevation of 147 m above mean sea level located in the Southern Agro climatic zone of the Tamil Nadu. The normal weather condition of the location is as follows. The mean annual rainfall is 856 mm, out of which 39.8 per cent is distributed during South West Monsoon, 42 per cent during North East Monsoon, 2.1 per cent during winter and 16.2 per cent during summer. The daily mean maximum and minimum temperature are 35.5°C and 25.3oC during SWM, 30.90 °C and 21.1 °C during NEM, 30.9 °C, and 20.8 °C during winter and 36.4°C and 24.7°C during summer respectively. The experimental field soil was sandy clay loam in texture with the pH of 7.25. The nutrient status was medium in available nitrogen (264.0 kg ha^{-1}) and phosphorus (18.5 kg ha^{-1}) and high in available potassium (372.0 kg ha^{-1}).

The experiment was laid out in split split plot design with three replications. The main plot consist as tow irrigation levels 75 and 100 per cent based pan evaporation (PE) reading, sub plot contains three drip fertigation levels of 75, 100 and 125 per cent and sub sub plot consist intercropping with short duration pulses viz., C1 – sole crop of maize/cotton, C2 – intercrop with cow pea, C3-intercrop with blackgram and C4-intercrop with cluster bean.

The experimental field was ploughed with mould board plough twice followed by two pass of cultivator and finally rotovator was passes for obtaining fine tilth. The seed bed ridges and furrows were formed than seeds were sown according to the spacing. Immediately after sowing the filed was irrigated uniformly than third day lifesaving irrigation was given uniformly to entire field irrespective of irrigation regimes. Subsequent irrigations were scheduled as per the assigned PE ratios with once in three days based on PE. The daily pan evaporation data were obtained from standard USWB Class A pan evaporimeter located at AC&RI, Madurai agromet observatory. Recommended dose of fertilizer for cotton is 120:60:60 kg NPK ha^{-1} and for maize is 250:75:75 kg NPK ha^{-1}. Fertigation was given as per the treatment schedule. Fertigation was scheduled once in days starting from 15 DAS to 120 days after sowing for cotton and from 15 DAS to 90 DAS for maize. The required quantity of N, P and K are given in the form of urea (46 % N), MAP (12 % N and 61 % P_2O_5) and SOP (50 % K_2O). Each plot consists of laterals for fertigation and irrigation. A tap was provided at the beginning of each lateral for giving controlled fertigation. Short duration pulses were grown as intercrop with ratio of 1:1 in between two main crops. For comparing the performance of intercrop the sole maize / cotton plot also maintained.

The yield attributes of cotton *viz.,* number of bolls, boll weight, seed cotton yield and cotton equivalent yield were recorded. The observations on maize cob length, cob girth, grain and stover yield and maize equivalent yield were recorded at different stages of crop growth. The crop equivalent yield (CEY) was calculated using the following formulae.

Crop equivalent yield (CEY) = (Intercrop yield (kg ha^{-1}) × Price of Intercrop (Rs kg^{-1})) / (Price of cotton / maize)

Prevailing market price of different crops were used for CEY calculation.

The data were subjected to statistical scrutiny as per method suggested by Gomez [5]. Whenever the results were significant, the critical difference was arrived at five per cent probability level. Treatment differences that were non-significant are denoted as NS in the tables.

3. RESULTS AND DISCUSSION

3.1 Number of Bolls and Boll Weight

Among the irrigation regimes 75 and 100 % PE had no significant difference in the number of bolls and boll weight (Table 1). The mean values of 2016 and 2017 data on number of bolls and boll weight of 48.04 and 45.48 and 3.59 and 3.40 g $boll^{-1}$ recorded at 100 and 75 % PE, respectively. With respect to sub surface drip fertigation had significant influence on the number of bolls and boll weight. Sub surface drip fertigation at 125 % RDF (recommended dose of fertilizer) has recorded higher number of bolls (50.09 and 47.98) and boll weight (3.52 and 3.85) 2016 and 2017, respectively. However, it was followed by application of 100 % RDF which recorded 47.98 and 45.78 and boll weight of 3.36 and 3.66 g at 2016 and 2017, respectively.

It shows that maintenance nutrient supply with adequate amount of water was found to be beneficial in release of nutrients and thereby recorded greater uptake of nutrients and increased the number of bolls and boll weight. Similar results were obtained by Lamm and Trooien [6]. Short duration pulse of cowpea, blackgram and cluster bean had no significant influence on number of bolls and boll weight. Malik et al. [7] also reported that, number of bolls and boll weight was not significantly influenced by different intercropping systems.

3.2 Seed Cotton Yield

Irrigation regimes had no significant influence on the seed cotton yield (Table 1). The mean value of two years data shows 2749 and 2685 kg ha^{-1} recorded in irrigation given at 100 and 75 per cent PE, respectively. Sub surface drip fertigation had invariably increase in the seed cotton yield. Among fertigation levels application of 125 per cent RDF has recorded higher seed cotton yield of 2808 and 2987 kg ha^{-1} in 2016 and 2017, respectively. It was followed by the application 100 per cent RDF as fertigation recorded 2704 kg ha^{-1} in 2016 and 2645 kg ha^{-1} in 2017 respectively. It was followed by drip fertigation at 100 per cent RDF recorded 2704 kg ha^{-1} in 2016 and 2645 kg ha^{-1} in 2017 respectively. The increase in yield under 125 per cent RDF was due to the performance of all crop growth and yield attributing characters and due to better availability of soil moisture and nutrients throughout the crop growth period under drip fertigation system. Also, higher rates of nutrients resulted in better translocation of assimilates from source to sink. This was in concordance with the findings of Gutal [8].

Both the years of study the lower seed cotton yield was recorded in 75 per cent RDF as fertigation. The results obtained might be due to reduction in the yield attributes number bolls and boll weight in turn which reflected in the seed cotton yield of the cotton. Growing of pulses as intercrop there is no significant influence on the seed cotton yield, however the higher mean values were recorded cotton intercropped with cowpea which recorded 2682 kg ha^{-1} it was comparable with blackgram. Among the treatment combinations the interaction effect was found to be non-significant.

Table 1. Effect of irrigation regimes and fertigation levels on the growth attributes of cotton under sub surface drip irrigation in cotton-maize cropping sequence

Treatments	Number of bolls			Boll weight (g)/boll			Seed cotton Yield (kg/ha)		
Irrigation regimes									
	2016	**2017**	**Pooled mean**	**2016**	**2017**	**Pooled mean**	**2016**	**2017**	**Pooled mean**
I_1 – 75% PE	46.18	44.77	45.48	3.23	3.56	3.40	2584	2585	2585
I_2 – 100% PE	48.74	47.34	48.04	3.43	3.75	3.59	2737	2760	2749
SEd	0.962	0.967	0.992	0.07	0.076	0.072	54.30	43.53	50.312
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Fertigation levels									
F_1 – 75% RDF	44.31	41.66	42.99	3.24	3.46	3.35	2466	2382	2424
F_2 – 100% RDF	47.98	45.78	46.88	3.36	3.66	3.51	2707	2645	2676
F_3 – 125% RDF	50.09	49.62	49.86	3.52	3.85	3.69	2808	2987	2898
SEd	1.012	0.872	0.982	0.072	0.078	0.078	56.60	47.73	54.43
CD (P=0.05)	2.335	2.012	2.267	0.166	0.180	0.180	130.40	110.10	125.59
Intercrops									
C_1- Cotton	48.53	46.75	47.64	3.41	3.73	3.57	2732	2710	2721
C_2 -Cotton + cowpea	47.93	45.61	46.77	3.39	3.65	3.52	2704	2660	2682
C_3-Cotton+ black gram	47.05	45.45	46.25	3.36	3.63	3.50	2635	2665	2650
C_4-Cotton + Cluster bean	46.33	44.95	45.64	3.35	3.61	3.48	2570	2651	2610
Control	36.8	34.43	35.62	3.13	3.21	3.17	2086	2112.	2099
SEd	1.18	1.096	1.20	0.084	0.087	0.090	65.93	54.69	63.85
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

3.3 Cotton Equivalent Yield

The cotton equivalent yield was worked out for two different years, among the treatment combinations irrigation given at 100 per cent based PE and fertigation with 125 per cent RDF and intercropped with blackgram recorded higher cotton equivalent yield of 3693 kg ha^{-1} and 4028 kg ha^{-1} during the year 2016 and 2017, respectively (Fig. 1). The increase in yield under 125 per cent RDF might be due to the fact that fertigation at higher dose obviously resulted in higher availability of all the three major nutrients in the soil solution which led to higher uptake and better translocation of assimilates from source to sink thus in turn increased the yield. Similar linear response to higher doses of fertilizers was obtained in under drip fertigation by Sundar Raman et al., [9]. Increased in cotton equivalent is mainly because of higher cotton yield and blackgram and also good market price for both the crops as compared to rest of the crops. This is similar to the findings of Chellaiah and Gopalaswamy [10].

3.4 Maize Grain and Stover Yield

Among the irrigation regimes, maize grain and stover yield there was no significant difference between the treatments in both years 2016 and 2017 (Table 2). Whereas in 2017 irrigation based on 125 per cent PE recorded higher grain and stover yield of 7008 kg ha^{-1} and 15498 kg ha^{-1} respectively.

With respect to subsurface drip fertigation application of 125 per cent RDF recorded grain and stover yield of 6946 and 15705 kg ha^{-1}, respectively in 2016. However, it was significantly on par with fertigation at 100 per cent RDF. In the year 2017 also the similar trend of grain and stover yield was recorded. These results were attributed due to application of higher and optimum dose (125 and 100 per cent) of fertilizers through fertigation resulted in maximum uptake of nutrients at all the stages resulted in higher yield. The similar results were also reported by Tumbare and Nikam [11]. There was no significant difference were noted down in grain and stover yield when different pulses were grown as intercrop. However the mean values shows that higher growing blackgram as intercrop recorded higher grain and stover yield of 6706 and 14864 kg ha^{-1}, respectively.

3.5 Maize Equivalent Yield

The maize equivalent yield was worked out for two different years, among the treatment combinations irrigation given at 100 per cent based PE and fertigation with 125 per cent RDF and intercropped with blackgram recorded higher maize equivalent yield of 7872 and 8974 kg ha^{-1} in 2016 and 2017, respectively (Fig. 2). This may be assigned to the synergetic effect of maize and blackgram in utilization of natural resources. Addition of dry matter to the soil and nitrogen fixation by pulse intercrops with maize were also the cause for higher maize equivalent yield in these treatments. Similarly, Shivay et al. [12] have observed higher maize equivalent yield with maize + urdbean/soybean intercropping system over sole maize.

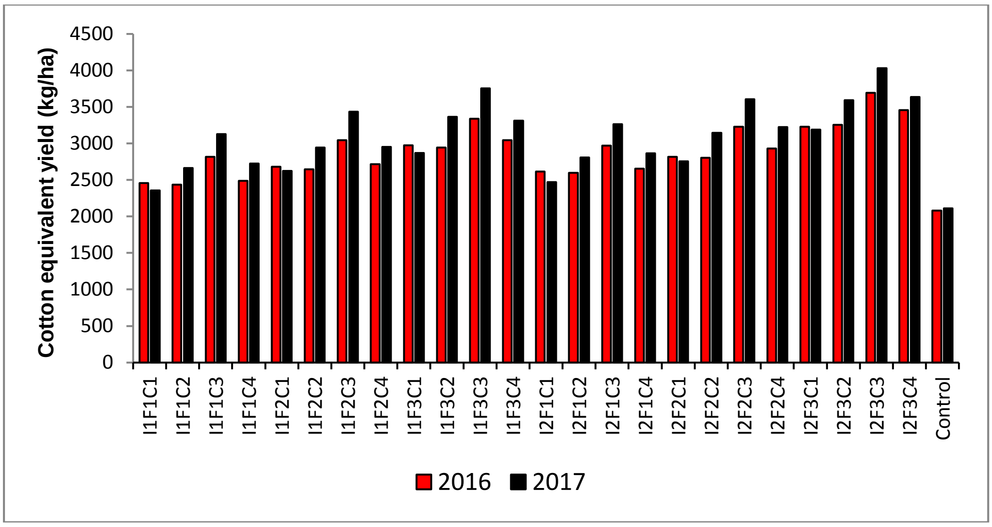

Fig. 1. Effect of irrigation regimes and fertigation levels on the cotton equivalent yield under sub surface drip irrigation in cotton-maize cropping sequence

Table 2. Effect of irrigation regimes and fertigation levels on the yield of maize under sub surface drip irrigation in cotton-maize cropping sequence

Treatments	Grain yield (kg/ha)			Stover yield (kg / ha)		
Irrigation regimes	**2016**	**2017**	**Pooled mean**	**2016**	**2017**	**Pooled mean**
I1 – 75% PE	6521	6385	6453	14663	14080	14372
I2 – 100% PE	6873	7008	6941	15096	15498	15297
S.Ed	139	141	144	304	304	312
CD (0.05%)	NS	606	NS	NS	1309	1327
Fertigation levels						
F1 – 75% RDF	6425	6419	6422	14062	13855	13959
F2 – 100% RDF	6719	6703	6711	14872	14789	14831
F3 – 125% RDF	6946	6967	6957	15705	15723	15714
S.Ed	143	144	148	317	318	331
CD (0.05%)	330	332	340	731	734	762
Intercrops						
C1- Maize	6785	6860	6823	14960	15024	14992
C2 -Maize + Cow pea	6704	6580	6642	14890	14554	14722
C3 -Maize + black gram	6687	6724	6706	14857	14870	14864
C4-Maize +Cluster bean	6612	6622	6617	14811	14708	14760
S.Ed	166	165	175	370	364	389
CD (0.05%)	NS	NS	NS	NS	NS	NS
Control (surface irrigation)	5678	5656	5667	12347	12571	12459

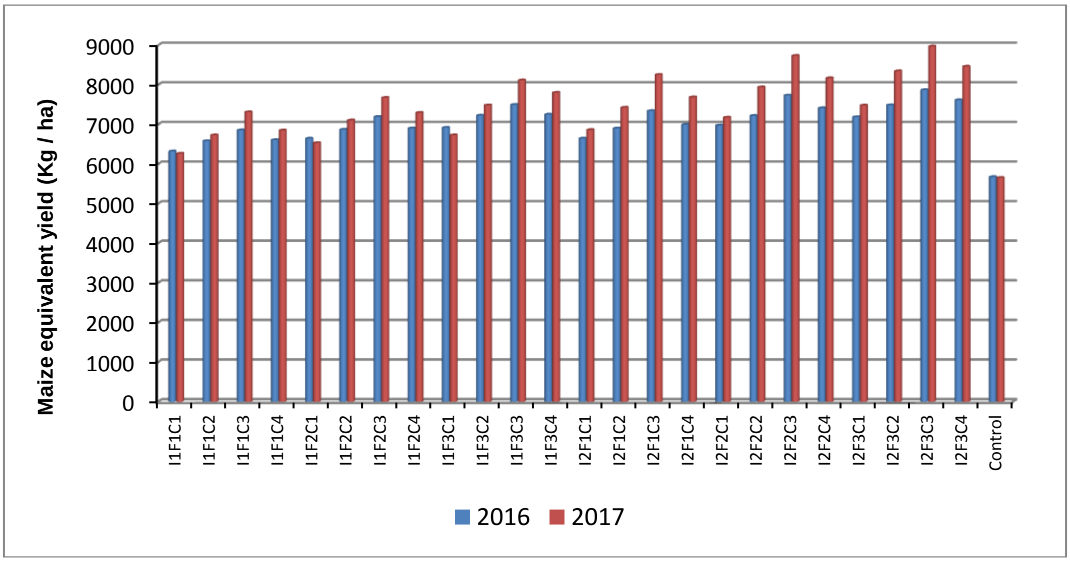

Fig. 2. Effect of irrigation regimes and fertigation levels on the Maize equivalent yield under sub surface drip irrigation in cotton-maize cropping sequence

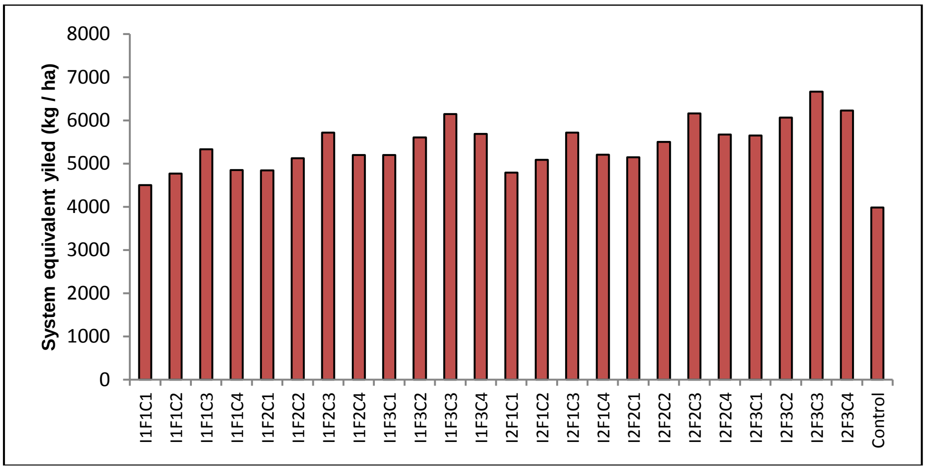

Fig. 3. Effect of irrigation regimes and fertigation levels on the cotton equivalent yield (system) under sub surface drip irrigation in cotton-maize cropping sequence

3.6 Cotton Equivalent Yield (System)

The cotton equivalent yield was worked out for two different years, among the treatment combinations irrigation given at 100 per cent PE and fertigation with 125 per cent RDF and intercropped with blackgram recorded higher cotton equivalent yield of 6668 kg ha^{-1} (Fig. 3). Generally, the production of a system depends not on the efficiency of individual component crop of the system but also how well these crops compliment with each other in time and space. Therefore, the overall productivity of maize based system depends partly on the efficiency of crop itself and partly on how well maize fits in with other intercrops and vice versa. Similar results were reported by Gangwar and Ram [13] and Katyal et al. [14].

4. CONCLUSION

From the experiment it could be concluded that cotton intercropped with blackgram and irrigation at 100% PE with fertigation of 125% RDF (150:75:75 kgs NPK/ha) resulted in higher cotton yield (3860 kg/ha cotton equivalent yield) with water saving of 24 per cent. Whereas, in maize based intercropping system, maize + black gram intercropping would be the best system. In this system irrigation at 100% PE with 100% RDF (250: 75: 75 kg NPK/ha) gave higher maize equivalent yield of 7735 kg/ha. From the pooled analysis of two years' data it was enlighten that in cotton – maize sequence, intercropping of black gram found to be best suitable system with irrigation regime of 100% PE and application of 125% RDF (150:75:75 kg NPK/ha) for cotton and 100% RDF (250: 75: 75 kg NPK/ha) for maize through fertigation is recommended to get higher yield in the system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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