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Effect of fertigation levels and schedules on productivity and economics of maize (*Zea mays*)-chickpea (*Cicer arietinum*) cropping sequence

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Abstract
A field experiment was carried out during 2016-17 and 2017-18 on clay-loam soil of Rahuri, Maharashtra, to study the effect of fertigation levels and schedules on system productivity and economics of maize (*Zea mays* L.)- Chickpea (*Cicer ariatium* L.) cropping sequence. The experiment consists of four main plot treatments of fertigation levels (T_0-control, T_1-50% RDF, T_2-75% RDF and T_3-100% RDF) and four fertigation schedules (S_1-Fertigation of 100% N and K upto 75 DAS, S_2- Fertigation of 100% N and K upto 90 DAS, S_3-Fertigation of 50% N and K upto 75 DAS and 50% N and K between 75 DAS to 90 DAS and S_4- Fertigation of 100% NPK upto 90 DAS) for maize crop during *kharif* season and for *rabi* season each main plot treatments were split into two sub plot treatments of L_1-75% RDF and L_2-100% per cent recommended dose of fertilizer for chickpea replicated three times in split plot design. The fertigation of 100 per cent recommended dose of fertilizer through drip fertigation in 8 equal splits at weekly interval to *kharif* maize registered significantly higher grain yield (83.66 q ha^{-1}) and the fertigation schedules of 100 per cent recommended dose of N and K up to 75 DAS with P as basal dose registered significantly higher grain yield (75.17 q ha^{-1}) than rest of the fertigation schedules during both the years. Maize grain equivalent yield of chickpea (73.61 q ha^{-1}), system productivity (157.26 q ha^{-1}) and production efficiency (43.09 kg ha^{-1} day^{-1}) and economic efficiency (305.54 ₹ ha^{-1} day^{-1}) were also higher under application of 100 per cent recommended dose of nitrogen and potassium through drip fertigation in eight equal splits at weekly interval up to 75 days after sowing with phosphorus as basal dose to preceding crop *kharif* maize followed by *rabi* chickpea with 100 per cent recommended dose of nitrogen and potassium through drip fertigation in three equal splits @ 33.33 per cent each at 15 DAS, at branching and at flowering with phosphorus as basal dose recorded significantly higher growth, yield and quality of grains in maize-chickpea cropping sequence.

Keywords: Fertigation levels, schedules, RDF, maize, chickpea

Introduction
Maize is one of the most important cereal crop having third position among the cereal crops after wheat and rice. With changing global food demands and consumer choices, maize is now becoming the wonder crop for many countries, especially in developing countries like India. In India, maize is grown over an area of 8.38 million ha with annual production of 30.24 million tonnes with an average productivity of 2476 kg ha^{-1} during 2020-21 (Anon, 2021).

Chickpea, one of the major pulse crop cultivated and consumed in India, it is the third most important pulse crop, after peas, produced in the world, it accounts for 20% of the world pulses production. In India chickpea is grown over an area of 9.69 million ha with annual production of 11.07 million tonnes with an average productivity of 1142 kg ha^{-1}. India is the largest producer of chickpea with about 63% of the total area under chickpea production lying in India, contributing for over 75% of total production in the world.

In order to fulfil the domestic requirement of ever-increasing population of India, it is essential to increase the maize grain as well as chickpea production to large extent. The productivity is depends on use of optimum fertilizer doses, the imbalance fertilizer reported considerable yield reduction as well as adverse effect on crop physiology, soil health and environment. In order to study the effect of drip fertigation on improving the yield and quality on sustainable basis in respect of (*kharif*) maize and (*rabi*) chickpea, the effort was made to conduct research on system productivity and economics in maize-chickpea cropping sequence as influenced by fertigation levels and schedules.

Materials and Methods

A field experiment was carried out during 2016-17 and 2017-18 at the Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar Maharashtra (India) at fixed site between 19º23'and 19º38' N and between 74º39' and 74º65'E, 511 m above sea level, with the average annual rainfall of 520 mm. The weather situation during experimentation indicated that, the total rainfall received during first year was less than average (726.0 mm in 32 rainy days), while it was less during second year (625.8 mm in 24 rainy days). The maximum and minimum temperature range was 26.5 ^{0}C- 41.3 ^{0}C and 8.7 ^{0}C-24.8 ^{0}C during the first year while, 25.2 ^{0}C- 40.6 ^{0}C and 8.3 ^{0}C- 25.2 ^{0}C during the second year, respectively. The relative humidity at morning hours was 41-87% and 11-77%, whereas at evening it was 30-87% and 13-73% during first and second year, respectively. The bright sunshine hours range was almost similar (1.6-10.7 hr) during both the years. The wind velocity range was 0.3-8.4 kmph and 0.3-10.9 kmph during first and second year, respectively. In general, weather was suitable for growing maize during *kharif* and chickpea during *rabi* season.

The soil was clay loam in texture with low in available nitrogen (206.53 kg/ha), medium in available phosphorus (11.85 kg/ha) and high in available potassium (465.73 kg/ha) and the organic carbon content was 0.56%. The soil was slightly alkaline in reaction (pH 8.10) with 0.27 dS/m electric conductivity (ECe). The soil physical properties, *viz*. bulk density (1.18 g/cm3), field capacity (35.32%) and permanent wilting point (17.46%) indicated that the soil was moisture retentive. High-yielding variety of maize Dicalb Pinnacle was used, having high shelling percentage and high number of rows, tolerant to foliar diseases like leaf blight, charcoal rot and late wilt. It is highly responsive to high input management and suitable for irrigated condition in *kharif* season. *Rabi* chickpea variety "Phule krupa", developed at the Mahatma Phule Krishi Vidyapeeth, Rahuri, having high responsive to fertilizer, extra bold seeds, milky white grain and tolerant to wilt disease was used. The maize seeds were sown on both the sides of ridges by keeping the distances of 60 cm × 20 cm in the *kharif* season on 12 July 2016 and 15 July 2016, whereas in *rabi* season chickpea crop was sown by using paired row planting technique during *rabi* season as the lateral spacing for previous crop was 120 cm, the sowing of chickpea was done at spacing of 45 cm-75 cm x 7.5 cm and maintain the recommended plant population. The sowing was done on 29-11-2016 and 04-12-2017 during first and second year respectively. The experiment was laid out in a split-plot design with 3 replications. The experiment comprised 4 main plot treatments of fertigation levels *viz*., F_0-Control, F_1- 50% of RDF, F_2- 75% of RDF, F_3- 100% of RDF and four fertigation schedules for *kharif* maize *viz*., S_1- Fertigation of 100% N and K upto 75 DAS, S_2- Fertigation of 100% N and K upto 90 DAS, S_3- Fertigation of 50% N and K upto 75 DAS + 50% N and K between 75 to 90 DAS and S_4- Fertigation of 100% NPK upto 90 DAS and for *rabi* season each main plot treatments were split into two sub plot treatments of L_2- 100% RDF and L_1-75% RDF for chickpea.

The recommended dose of phosphorus was applied as a basal dose by band placement method by using Single Super Phosphate (16% P_2O_5) for preceding crops *kharif* maize and succeeding crop *rabi* chickpea. Fertigation of N and K was started at 15 days after sowing of *kharif* maize and there after applied as per treatment at weekly interval and for *rabi* chickpea fertigation of N and K was done in three splits, first at 15 DAS @ 33.3%, at branching @ 33.3% and at flowering @ 33.3%.

The scheduling of irrigation for maize was done through drip at every alternate day on the basis of pan evaporation data and crop coefficient (KC) to all the treatments during both the years. In *rabi* Chickpea irrigation was applied at every week interval based on a pan evaporation data**.**

In order to keep the experimental plot free from weeds, 3 hand-weddings in *kharif* maize and 2 hand weddings in *rabi* chickpea were carried out during the first and second year of experiment, respectively. The maize cobs were harvested on 9 November 2016 and 14 November 2017 during first and second year, respectively, as it showed maturity signs like brown silky hairs, formation of black lines at the point of attachment on the cobs, formation of hard and yellowish kernels. Chickpea crop was harvested on 17 March 2017 and 21 March 2018 during first and second year, respectively when maturity of pods was judged from their fully drying and golden brown color of the pods.

Results and Discussion

System productivity and production efficiency

Residual effect of fertigation levels

Based on 2 years pooled mean data (Table 1), it revealed that the fertigation of 100 per cent recommended dose of fertilizer through drip fertigation in 8 equal splits at weekly interval to preceding crop *kharif* maize registered significantly higher maize grain equivalent yield of chickpea (73.61 q ha^{-1}), system productivity (157.26 q ha^{-1}) and production efficiency (43.09 kg ha^{-1} day^{-1}) of maize-chickpea cropping sequence than rest of the fertigation levels. The residual effect of higher level of fertigation and capacity of chickpea crop to fix atmospheric nitrogen fulfill the nutritional requirement of crop hence both crops were produce higher grain yield resulted in higher system productivity in higher level of fertigation to preceding maize. These results are in corroborated with Gawai and Pawar (2007) [2] and Jnanesha (2012) [4].

Residual effect of fertigation schedules

The fertigation of 100 per cent recommended dose of N and K up to 75 DAS with P as basal dose registered significantly higher system productivity (139.87 q ha^{-1}), production efficiency (38.32 kg ha^{-1} day^{-1}) in maize-chickpea cropping sequence than rest of the fertigation schedules. However, it was at par with fertigation of 100 per cent recommended dose of NPK up to 90 DAS. These results are in line of those reported by Hiremath *et al.*, (2016) [3] and Snehal (2019) [11].

Direct effect of fertigation levels to *rabi* chickpea

The fertigation of 100 per cent recommended dose of fertilizer through drip fertigation in 3 equal splits @33.33 per cent each at 15 days after sowing, at branching and at flowering with phosphorus as basal dose to *rabi* chickpea registered significantly higher maize grain equivalent yield of chickpea (68.16 q ha^{-1}), system productivity (137.73 q ha^{-1}) and production efficiency (37.74 kg ha^{-1} day^{-1}) of maize-chickpea cropping sequence than fertigation of 75 per cent recommended dose of fertilizer during both the years and on pooled mean. This might be due to application of fertilizer through fertigation as per the peak demand of crop and capacity of crop to fix atmospheric nitrogen not only meet nutritional requirement of crop but helps to increase the fertility status of soil for succeeding crop, therefore both the

crop produced higher yield resulted in higher system productivity. These results are in accordance with Shreenivas *et al.*, (2017) [9] and Kawade (2018) [6].

Water use efficiency

Water-use efficiency for kharif maize

Effect of fertigation levels

Fertigation of 100 per cent recommended dose of fertilizer through drip fertigation in 8 equal splits at weekly interval to preceding crop *kharif* maize registered higher water use efficiency (24.05 and 21.76 kg ha-mm^{-1}) than rest of the fertigation levels and control treatment during both the years. This might be due to higher grain yield with higher fertigation level as the irrigation water applied was same in all fertigation level. These results are accordance with Fanish *et al.* (2011) [11].

Table 1: Effect of fertigation levels and schedules on maize–grain-equivalent yield (MGEY), system productivity and production efficiency (pooled data of 2 years)

Treatment	Grain yield (q ha^{-1})	Chickpea yield (q ha^{-1})	MGEY (q ha^{-1})	System productivity (q ha^{-1})	Production efficiency (kg ha^{-1} day^{-1})
F. Residual effect of fertigation levels (*kharif* maize)					
F_0 -Control	46.50	19.79	52.87	98.96	27.11
F_1 - 50% of RDF	69.37	22.82	60.85	130.22	35.68
F_2 - 75% of RDF	79.61	27.00	67.79	147.40	40.38
F_3 - 100% of RDF	83.66	29.69	73.61	157.26	43.09
SEm(±)	1.27	0.59	1.66	1.88	0.51
CD at 5%	3.92	1.81	5.10	5.79	1.58
S. Residual effect of fertigation schedules (*kharif* maize)					
S_1 - Fertigation of 100% N and K upto 75 DAS	75.17	25.31	65.10	139.87	38.32
S_2 - Fertigation of 100% N and K upto 90 DAS	69.41	24.70	63.45	132.86	36.40
S_3 - Fertigation of 50% N and K upto 75 DAS + 50% N and K bet^n 75 to 90 DAS	63.06	24.26	62.21	125.27	34.32
S_4 - Fertigation of 100% NPK upto 90 DAS	71.49	25.03	64.35	135.84	37.22
SEm(±)	1.52	0.41	1.12	2.11	0.58
CD at 5%	4.33	NS	NS	6.00	1.64
L. Direct effect of fertigation levels to *rabi* chickpea					
L_1- 75% of RDF	-	23.20	59.40	129.18	35.39
L_2- 100% of RDF	-	26.45	68.16	137.73	37.74
SEm(±)	-	0.26	0.70	0.71	0.19
CD at 5%	-	0.73	1.98	2.00	0.55
Interaction (F X S)					
SEm(±)	-	0.82	2.25	4.22	1.16
CD at 5%	-	NS	NS	NS	NS
Interaction (F X L)					
SEm(±)	-	0.51	1.40	1.41	0.39
CD at 5%	-	NS	NS	NS	NS
Interaction (S X L)					
SEm(±)	-	0.51	1.40	1.41	0.39
CD at 5%	-	NS	NS	NS	NS
Interaction (F X S X L)					
SEm(±)	-	1.03	2.80	2.83	0.77
CD at 5%	-	NS	NS	NS	NS
General mean	-	24.82	63.78	133.46	36.56

Effect of fertigation levels

The fertigation of 100 per cent recommended dose of N and K up to 75 DAS with P as basal dose registered higher water use efficiency (21.85 and 19.35 kg ha-mm^{-1}), during both the year of experimentation might be due to higher grain yield. The fertigation of 100 per cent NPK up to 90 DAS found second in rank in respect of water use efficiency. The higher water use efficiency might be because of higher grain yield due to frequent and split application of required quantity of nutrients up to reproductive phase of crop. These results are in line with shruthi *et al.*, (2018) [10].

Water-use efficiency for *rabi* chickpea

Residual effect of fertigation levels

Fertigation of 100 per cent recommended dose of fertilizer through drip fertigation in 8 equal splits at weekly interval to preceding crop *kharif* maize registered higher water use efficiency (13.23 and 15.11 kg ha-mm^{-1}) than rest of the fertigation levels and control treatment during both the years. The higher water use efficiency might be due to higher grain yield with higher fertigation level as the irrigation water applied was same in all fertigation level. These results are in line of Vimalendram and Latha (2014) [12].

Residual effect of fertigation schedules

The fertigation of 100 per cent recommended dose of N and K up to 75 DAS with P as basal dose registered higher water use efficiency (11.68 and 12.49 kg ha-mm^{-1}), during both the year of experimentation might be due to higher grain yield. The fertigation of 100 per cent NPK up to 90 DAS found second in rank in respect of water use efficiency. These results are in line of those reported by Nagesh and Hemant (2017).

Table 2: Water use efficiency as influenced by different treatment in *kharif* maize and *rabi* chickpea

Treatment	Water-use efficiency (kg/ha-mm)			
	Kharif maize		*Rabi* chickpea	
	2016	2017	2017	2018
F. Residual effect of fertigation levels (*kharif* maize)				
F_0 -Control	13.55	11.94	9.27	9.63
F_1 - 50% of RDF	19.91	18.06	10.60	11.19
F_2 - 75% of RDF	22.56	20.98	12.79	13.01
F_3 - 100% of RDF	24.05	21.76	13.23	15.11
S. Residual effect of fertigation schedules (*kharif* maize)				
S_1 - Fertigation of 100% N and K upto 75 DAS	21.85	19.35	11.68	12.49
S_2 - Fertigation of 100% N and K upto 90 DAS	20.07	17.95	11.39	12.20
S_3 - Fertigation of 50% N and K upto 75 DAS + 50% N and K bet^n 75 to 90 DAS	17.46	16.97	11.27	11.90
S_4 - Fertigation of 100% NPK upto 90 DAS	20.70	18.46	11.55	12.35
L. Direct effect of fertigation levels to *rabi* chickpea				
L_1- 75% of RDF	-	-	10.63	11.52
L_2- 100% of RDF	-	-	12.31	12.95
General mean	20.02	18.19	11.47	12.23

Direct effect of fertigation levels to *rabi* chickpea

The fertigation of 100 per cent recommended dose of fertilizer through drip fertigation in 3 equal splits @33.33 per cent each at 15 days after sowing, at branching and at flowering with phosphorus as basal dose to *rabi* chickpea registered maximum water use efficiency (12.31 and 12.95 kg ha-mm^{-1}) than fertigation of 75 per cent recommended dose of fertilizer during both the years. These results are in accordance with Kakade *et al.*, (2018) [5].

Economics

Residual effect of fertigation levels: Based on 2 year pooled mean data, fertigation of 100 per cent recommended dose of fertilizer through drip fertigation in 8 equal splits at weekly interval to preceding crop *kharif* maize registered higher gross monetary returns (238031 ₹ ha^{-1}), net monetary returns (111521 ₹ ha^{-1}), B:C ratio (1.77) and economic efficiency (305.54 ₹ ha^{-1} day^{-1}) than rest of the fertigation levels and control treatment during both the years. This might be because of higher yield and higher rate obtained for crops during both the seasons. These results are in accordance with Kawade (2018) [6].

Table 3: Effect of fertigation levels and schedules on economics of maize-chickpea cropping sequence (pooled data of 2 years)

Treatment	Gross monetary return	Cost of cultivation	Net monetary returns	B:C ratio	Economic efficiency (₹ ha^{-1} day^{-1})
F. Residual effect of fertigation levels (*kharif* maize)					
F_0 -Control	157126	129080	28045	1.19	76.84
F_1 - 50% of RDF	205444	132795	72648	1.51	199.04
F_2 - 75% of RDF	232537	134653	97885	1.69	268.18
F_3 - 100% of RDF	248031	136510	111521	1.77	305.54
SEm(±)	2873	-	2873	-	7.87
CD at 5%	8853	-	8853	-	24.26
S. Residual effect of fertigation schedules (*kharif* maize)					
S_1 - Fertigation of 100% N and K upto 75 DAS	220837	132172	88665	1.63	242.92
S_2 - Fertigation of 100% N and K upto 90 DAS	209825	132172	77653	1.55	212.75
S_3 - Fertigation of 50% N and K upto 75 DAS + 50% N and K bet^n 75 to 90 DAS	197936	132172	65764	1.46	180.18
S_4 - Fertigation of 100% NPK upto 90 DAS	214539	136523	78017	1.53	213.74
SEm(±)	3268	-	3268		8.95
CD at 5%	9293	-	9293		25.460
L. Direct effect of fertigation levels to *rabi* chickpea					
L_1- 75% of RDF	204250	132841	71408	1.50	195.64
L_2- 100% of RDF	217319	133678	83641	1.59	229.15
SEm(±)	1080	-	1080	-	2.96
CD at 5%	3050	-	3050	-	8.36
Interaction (F X S)					
SEm(±)	6536	-	6536	-	17.91
CD at 5%	NS	-	NS	-	NS
Interaction (F X L)					
SEm(±)	2159	-	2159	-	5.92
CD at 5%	NS	-	NS	-	NS
Interaction (S X L)					
SEm(±)	2159	-	2159	-	5.92
CD at 5%	NS	-	NS	-	NS
Interaction (F X S X L)					
SEm(±)	4319	-	4319	-	11.83

CD at 5%	NS	-	NS	-	NS
General mean	210784	133259	77525	1.55	212.40

Residual effect of fertigation schedules

The fertigation of 100 per cent recommended dose of N and K up to 75 DAS with P as basal dose recorded higher gross monetary returns (220837 ₹ ha^{-1}), net monetary returns (88665 ₹ ha^{-1}) B:C ratio (1.53) and economic efficiency (242.92 ₹ ha^{-1} day^{-1}) than rest of the fertigation levels and control treatment during both the years. Similar results are also reported by Nemade *et al*., (2020).

Direct effect of fertigation levels to *rabi* chickpea

The fertigation of 100 per cent recommended dose of fertilizer through drip fertigation in 3 equal splits @33.33 per cent each at 15 days after sowing, at branching and at flowering with phosphorus as basal dose to *rabi* chickpea registered higher gross monetary returns (217319 ₹ ha^{-1}), net monetary returns (83641 ₹ ha^{-1}) B:C ratio (1.59) and economic efficiency (229.15 ₹ ha^{-1} day^{-1}) than rest of the fertigation levels and control treatment during both the years These results are in accordance with Kakade *et al.*, (2018) [5].

It could be concluded that fertigation of 100 per cent recommended dose of nitrogen (120 kg N ha^{-1}) and potassium (40 kg K_2O ha^{-1}) through drip fertigation in 8 equal splits at weekly interval up to 75 days after sowing with phosphorus (60 kg P_2O_5 ha^{-1}) as a basal dose to *kharif* maize followed by *rabi* chickpea with 100 per cent recommended dose of nitrogen (25 kg N ha^{-1}) and potassium (30 kg K_2O ha^{-1}) through drip fertigation in 3 equal splits @33.33 per cent each at 15 days after sowing, at branching and at flowering with phosphorus (50 kg P_2O_5 ha^{-1}) as a basal dose found most suitable in maize-chickpea cropping sequence for obtaining higher productivity, monetary benefits and sustaining soil health.

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