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Research Paper

Effect of yield target-based fertigation levels on productivity and economics of maize (*Zea mays*)–onion (*Allium cepa*) cropping sequence

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ABSTRACT

A field experiment was carried out during 2015–16 and 2016–17 on clay-loam soil of Rahuri, Maharashtra, to study the effect of drip fertigation as per soil test crop response (STCR) equation on system productivity and economics of maize (*Zea mays* L.)–onion (*Allium cepa* L.) cropping sequence. The experiment was laid in a split-plot design with 3 replications. The treatment consisted of 4 main plot treatments of fertigation levels based on STCR equation for 10 t/ha yield target [(100%, 75%, 50% of STCR and general recommended dose fertilizers) GRDF] for the rainy season (*kharif*) maize (grain) and same set of treatments based on STCR equation for 0.5 t/ha yield target (100%, 75%, 50% of STCR and GRDF) was applied for winter (*rabi*) onion (seed) as subplot treatments. Fertigation of N and K as per 100%, of STCR equation for 10 t/ha yield target with FYM to *kharif* maize followed by fertigation of N and K as per 100%, of STCR equation for 0.5 t/ha yield target with FYM in 4 equal splits at 15 days interval up to 60 DAS to *rabi* onion recorded significantly maximum maize grain yield (9.84 t/ha) during the rainy season and onion seed yield (0.54 t/ha) during *rabi* season. The system productivity (57.50 t/ha), production efficiency (190.96 kg/ha/day) and net monetary returns (541.82 × 10^3 ₹/ha) were also higher under fertigation of N and K as per 100% of STCR equation to *kharif* maize, followed by fertigation of N and K as per 100% of STCR equation in 4 equal splits at 15 days interval up to 60 DAS to *rabi* onion.

Key word: Fertigation, GRDF, Maize, Nutrient uptake, Onion, STCR equation, Yield target

Maize or Indian corn is one of the most important cereal crops. It ranks 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 27.14 million tonnes and an average productivity of 2,476 kg/ha during 2017–18.

Onion is one of the leading vegetable crops worldwide, grown for its culinary purposes and medicinal values. India ranks first in area and second in production with production of 189.27 million tonnes and area of 11.73 million ha after China. Degradation of soil health has also been reported due to long-term imbalanced use of nutrients. This imbalance nutrient use has resulted in wide gap between crop removal and fertilizer application. Location-specific fertilizer recommendations are possible for soils of varying fertility, resource conditions of farmers and levels of targeted yield for similar soil classes and environment. The soil test crop response (STCR) approach for targeted yield is unique in indicating both soil test-based fertilizer dose and the level of yield that can be achieved with good management practices.

In order to fulfil the domestic requirement of ever-increasing population of India, it is essential to increase the maize grain as well as onion 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 rainy season (*kharif*) maize and winter season (*rabi*) onion, the effort was made to conduct research on system productivity and economics in maize–onion cropping sequence as influenced by drip-fertigation levels based on STCR yield target equation. Onion experiment was conducted on bulb to seed only.

Based on a part of Ph.D. thesis of the first author submitted to the MPKV, Rahuri, in 2018 (unpublished)

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MATERIALS AND METHODS

A field experiment was carried out during 2015–16 and 2016–17 at the Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar Maharashtra (India) at fixed site between 19°23' and 19°38' N and between 74°39' and 74°65' 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 (197.3 mm in 31 rainy days), while it was higher during second year (625.8 mm in 36 rainy days). The maximum and minimum temperature range was 28.7°C–40°C and 9.3°C–24.4°C during the first year, respectively while, 26.5°C–41.3°C and 8.7°C–23.6°C during the second year. The relative humidity at morning hours was 34–81% and 31–87%, whereas at evening it was 17–65% and 11–77% during first and second year, respectively. The bright sunshine hours range was almost similar (2–10 hr) during both the years. The wind velocity range was 0.2–11.4 kmph and 0.3–8.3 kmph during first and second year, respectively. In general, weather was suitable for growing maize during *kharif* and onion during *rabi* season.

The soil was clay loam in texture with low in available nitrogen (203.84 kg/ha), medium in available phosphorus (15.82 kg/ha) and high in available potassium (582.4 kg/ha) and the organic carbon content was 0.58%. The soil was slightly alkaline in reaction (*p*H 8.05) with 0.34 dS/m electric conductivity (EC_e). The soil physical properties, viz. bulk density (1.27 g/cm^3), field capacity (34.67%) and permanent wilting point (18.54%) indicated that the soil was moisture retentive.

High-yielding variety of maize Dicalp 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* onion (seed) variety 'Phule Samarth', (early maturity) developed at the Mahatma Phule Krishi Vidyapeeth, Rahuri, having controlled vegetative growth, natural top fall, thin bulb neck, less twins, lustrous dark red and globular bulb, 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 5 July 2015 and 30 June 2016, whereas *rabi* season onion bulbs were planted on 21 December 2015 and 21 December 2016 at both the sides of ridges with spacing of 60 cm × 30 cm. The experiment was laid out in a split-plot design with 3 replications. The experiment comprised 4 main plot treatments for *kharif* maize (grain), viz. T_1, Fertigation (N and K) as per 100% of soil test crop response (STCR) equation with FYM up to 60 days after sowing (DAS); T_2, fertigation (N and K) as per 75% of STCR equation with FYM up to 60 DAS; T_3, fertigation (N and K) as per 50% of STCR equation with FYM up to 60 DAS; and T_4, general recommended dose of fertilizer (GRDF) (120 : 60 : 40 N, P_2O_5, K_2O kg/ha), and 4 subplot treatments for *rabi* onion (seed), viz. F_1, Fertigation (N and K) as per 100% of STCR equation with FYM up to 60 days after planting (DAP); F_2, fertigation (N and K) as per 75% of STCR equation with FYM up to 60 DAP; F_3, fertigation (N and K) as per 50% of STCR equation with FYM up to 60 DAP; and F_4, GRDF (100 : 50 : 50 N, P_2O_5, K_2O kg/ha). The fertigation of nitrogen and potassium was done by using the urea (46% N) and muriate of potash (60% K_2O) with help of Automatic Fertigation Unit in 4 equal splits at an interval of 15 days up to 60 days to the yield-target treatments of maize (10 t/ha) and onion (0.5 t/ha) during both the seasons. The 100% recommended dose of phosphorus was applied by band method through single superphosphate (16% P_2O_5) at the time of sowing/planting as a basal dose to both the crops. The fertilizer prescription equation with FYM used for *kharif* maize were: FN = 3.88 T – 0.56 SN – 3.19 FYM, FP_2O_5 = 1.91 T – 0.99 SP – 1.46 FYM and FK_2O = 2.09 T – 0.13 SK – 1.08 FYM and for *rabi* onion FN = 0.55 T – 0.65 SN – 2.42 FYM, FP_2O_5 = 0.28 T – 3.01 SP – 1.20 FYM and FK_2O = 0.28 T – 0.11 SK – 0.80 FYM, where FN, FP_2O_5, FK_2O = Fertilizer N, P_2O_5 and K_2O (kg/ha), T = yield target (kg/ha), SN, SP and SK = soil-available N, P and K (kg/ha) and FYM = Farmyard manure (t/ha). The yield target-based fertilizer equations for maize was developed by Kadlag and Ghodake (2013) and for onion by Sonar and Kadam (2002).

The scheduling of irrigation was done through drip at every 2 alternate day on the basis of pan evaporation data and crop coefficient (K_C) to all the treatments during both the years. In order to keep the experimental plot free from weeds, 3 hand-weedings in *kharif* maize and 2 hand-weedings in *rabi* onion were carried out during the first and second year of experiment, respectively. The maize cobs were harvested on 3 November 2015 and 18 October 2016 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. Matured onion umbels were harvested on 21 April 2016 and 26 May 2017 during the first year and on 05 May 2017 and 11 May 2017 during second year, respectively, when more than 50% of black seeds are exposed from the umbel.

RESULTS AND DISCUSSION

System productivity and production efficiency

Residual effect of fertigation: Based on 2 years pooled mean data (Table 1), it revealed that fertigation of N and K as per 100% of STCR equation for 10 t/ha yield target with

FYM in 4 equal splits at 15 days interval up to 60 DAS to preceding crop of *kharif* maize resulted in significantly higher maize–grain-equivalent yield of onion seed (47.66 t/ha), system productivity (57.50 t/ha) and production efficiency (190.96 kg/ha/day) at par with fertigation as per 75% of STCR equation with FYM. The system productivity recorded by 100% of STCR equation for 10 t/ha yield target was 31.45 and 27.17% more than 50% of STCR equation and general recommended dose of fertilizers (GRDF) applied through band placement. As application of full dose of fertilizers during both the years in treatment of 100% of STCR equation might have increased the easy availability of nutrients for proper growth and development of crop. These ultimately resulted in higher crops leading to higher system productivity.

Direct effect of fertigation: Fertigation of N and K as per 100% of STCR equation for 0.5 t/ha yield target with FYM in 4 equal splits at 15 days interval up to 60 DAP to *rabi* onion for seed resulted in significantly higher maize–grain-equivalent yield of onion seed (48.16 t/ha), system productivity (56.67 t/ha) and production efficiency (192.98 kg/ha/day) and at par with fertigation of N and K as per 75% of STCR equation with FYM (Table 1). The system productivity registered under 100% of STCR equation for 0.5 t/ha yield target was 34.85 and 13.34% higher than fertigation as per 50% of STCR equation and GRDF on pooled mean basis. The higher system productivity might be because of higher yield of maize grain and onion seed in respective season. These results are in agreement with those reported by Manea *et al*. (2015) and Kolage (2017).

Water-use efficiency for kharif maize

Fertigation of N and K as per 100% of STCR equation for 0.5 t/ha yield target with FYM in 4 equal splits at 15 days interval up to 60 DAP to *kharif* maize registered significantly higher water-use efficiency (25.33 and 33.24 kg/ha-mm) and at par with fertigation as per 75% of STCR equation (23.61 and 30.27 kg/ha-cm) with FYM during both the years (Table 2). This might be because of higher yield of maize grain with fertigation of N and K as per 100% of STCR equation during both the years. These results are in agreement with those reported by Fanish and Muthukrishnan (2011).

Water-use efficiency for rabi onion

Residual effect of fertigation: The fertigation of N and K as per 100% of STCR equation for 10 t/ha yield target with FYM in four equal splits at 15 days interval up to 60 DAS to preceding crop *kharif* maize registered significantly higher water use efficiency in onion (0.97 and 0.76 kg/ha-mm) and at par with fertigation as per 75% of STCR equation (0.89 and 0.69 kg/ha-mm) during both the years (Table 2). As application of full dose of fertilizers during both the years in treatment of 100% of STCR equation might have help increased the seed yield of onion with same quantity of available water which resulted in higher water use efficiency.

Direct effect of fertigation: Fertigation of N and K as per 100% of STCR equation for 0.5 t/ha yield target with FYM in 4 equal splits at 15 days interval up to 60 DAP to *rabi* onion for seed registered significantly higher water-use efficiency in onion (0.97 and 0.77 kg/ha-mm), being at par

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

Treatment	Maize yield (t/ha)	Onion seed yield (t/ha)	MGEY (t/ha)	System productivity (t/ha)	Production efficiency (kg/ ha/day)
Residual effect of fertigation as per STCR equation (10 t/ha yield target) to kharif maize (grain)					
T_1, Fertigation as per 100% of STCR equation	9.84	0.54	47.661	57.50	190.96
T_2, Fertigation as per 75% of STCR equation	9.07	0.49	43.27	52.34	173.36
T_3, Fertigation as per 50% of STCR equation	7.24	0.41	36.50	43.74	146.21
T_4, GRDF (control)	8.43	0.43	38.25	46.69	153.28
SEm±	3.94	0.23	24.34	27.44	9.35
CD (P=0.05)	11.03	0.72	75.01	84.56	28.81
Direct effect of fertigation as per STCR equation (0.5 t/ha yield target) to rabi onion (seed)					
F_1, Fertigation as per 100% of STCR equation	–	5.41	48.16	56.67	192.98
F_2, Fertigation as per 75% of STCR equation	–	4.87	43.20	51.57	173.10
F_3, Fertigation as per 50% of STCR equation	–	3.77	33.39	42.02	133.50
F_4, GRDF (control)	–	4.61	40.99	50.00	164.24
SEm±	–	0.25	24.51	22.94	9.33
CD (P=0.05)	–	0.71	69.69	65.23	26.52
Interaction (A × B)	–	NS	NS	NS	—

STCR, Soil test crop response; GRDF, general recommended dose of fertilizer

with fertigation of N and K as per 75% of STCR equation with FYM during 2015–16 and 2016–17 respectively. The higher water-use efficiency might be because of higher yield onion seed in respective years. These results are in the line of Dingre *et al*. (2012).

Economics

Residual effect of fertigation: Fertigation of N and K as per 100% of STCR equation for 10 t/ha yield target with FYM in 4 equal splits at 15 days interval up to 60 DAS resulted in significantly maximum gross monetary returns (832.09 × 10³₹/ha), net monetary returns (541.82 × 10³/ha) and economic efficiency (2,171₹/ha/day) than fertigation as per 50% of STCR equation for 100 q/ha yield target with FYM and GRDF (control) treatments. However, it was at par with fertigation as per 75% of STCR equation for 10 t/ha yield target with FYM (Table 3). The higher benefit: cost (B:C) ratio (2.85) was also recorded with fertigation as per 100% of STCR equation for 10 t/ha yield target with FYM to preceding crop *kharif* maize (grain). This might be because of higher yield and higher rate obtained for crops during both the seasons. These results are in the line of Patil *et al*. (2011) and Sharma *et al*. (2015).

Direct effect of fertigation; Fertigation of N and K as per 100% of STCR equation for 0.5 t/ha yield target with FYM

Table 2. Water-use efficiency as influenced by different treatments in *kharif* maize and *rabi* onion

Treatment	Water-use efficiency (kg/ha-mm)			
	Kharif maize		*Rabi* onion	
	2015	2016	2015–16	2016–17
Residual effect of fertigation as per STCR equation (10 t/ha yield target) to kharif maize (grain)				
T_1, Fertigation as per 100% of STCR equation	25.33	33.24	0.97	0.76
T_2, Fertigation as per 75% of STCR equation	23.61	30.27	0.89	0.69
T_3, Fertigation as per 50% of STCR equation	19.00	23.99	0.75	0.58
T_4, GRDF (control)	21.81	28.31	0.80	0.60
SEm±	0.63	1.05	0.02	0.03
CD (P=0.05)	1.80	3.03	0.08	0.12
Direct effect of fertigation as per STCR equation (0.5 t/ha yield target) to rabi onion (seed)				
F_1, Fertigation as per 100% of STCR equation	–	–	0.97	0.77
F_2, Fertigation as per 75% of STCR equation	–	–	0.89	0.68
F_3, Fertigation as per 50% of STCR equation	–	–	0.70	0.52
F_4, GRDF (control)	–	–	0.84	0.65
SEm±	–	–	0.03	0.03
CD (P=0.05)	–	–	0.10	0.09

Table 3. Effect of yield target-based fertigation levels on economics of maize (grain)–onion (seed) cropping sequence (pooled data of 2 years)

Treatment	Gross monetary returns (×10³₹/ha)	Cost of cultivation (×10³₹/ha)	Net monetary returns (×10³₹/ha)	Benefit: cost ratio	Economic efficiency (₹/ha/day)
Residual effect of fertigation as per STCR equation (10 t/ha yield target) to kharif maize (grain)					
T_1, Fertigation as per 100% of STCR equation	832.09	290.27	541.82	2.85	2171
T_2, Fertigation as per 75% of STCR equation	757.23	285.80	471.44	2.64	1889
T_3, Fertigation as per 50% of STCR equation	632.75	282.22	350.53	2.23	1404
T_4, GRDF (control)	675.16	279.70	395.46	2.41	1584
SEm±	38.72	-	38.72	-	154.93
CD (P=0.05)	119297	-	119297	-	477.38
Direct effect of fertigation as per STCR equation (0.5 t/ha yield target) to rabi onion (seed)					
F_1, Fertigation as per 100% of STCR equation	820.16	286.74	533.42	2.84	2,137
F_2, Fertigation as per 75% of STCR equation	746.00	284.54	461.46	2.61	1,849
F_3, Fertigation as per 50% of STCR equation	607.68	282.55	325.13	2.14	1,303
F_4, GRDF (control)	723.39	284.15	439.24	2.54	1,760
SEm±	36.70	-	36.70	-	146.90
CD (P=0.05)	104340	-	104340	-	417.70
Interaction (A × B)	NS	-	NS	-	NS

STCR, Soil test crop response; GRDF, general recommended dose of fertilizer

in 4 equal splits at 15 days interval up to 60 DAP resulted in significantly gross monetary returns (820.16 × 10³₹/ha), net monetary returns (533.42 × 10³₹/ha) and economic efficiency (2,137₹/ha/day) and was at par with fertigation as per 75% of STCR equation for 0.5 t/ha yield target with FYM and general recommended dose treatment (Table 3). Fertigation as per 100% of STCR equation for 0.5 t/ha yield target with FYM registered higher B: C ratio than rest of the treatments. Availability of favourable condition and sufficient amount of nutrients on time through 100% STCR equation might have led to more and quality production of maize grain and onion seed and also helped in getting high market rate for produce. These results are in conformity to Patil *et al*. (2011), Sharma *et al*. (2015) and Manea *et al*. (2015).

It could be concluded that, fertigation of nitrogen and potassium (with phosphorus as a basal dose) through straight fertilizers as per 75% of STCR equation with FYM (based on 10 t/ha yield target) to *kharif* maize (grain), followed by *rabi* onion for seed with 75% of STCR equation with FYM (based on 0.5 t/ha yield target) in 4 equal splits at 15 days interval up to 60 DAP found suitable to achieve yield target with 25% saving of fertilizer by increasing the productivity and economics of system.

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