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Productivity, Storability and Economics of Microsprinkler Fertigation for Winter Onion (*Allium cepa* L.) in Semi-arid Conditions

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Onion has very shallow root system that is frequently irrigated and fertilized with high fertilizer dose rates to maximize yield. Converting from furrow-fertigated to microsprinkler fertigated onion production may reduce fertilizer needs. The influence of fertigation sources and their levels, applied through microsprinkler irrigation on winter onion (*Allium cepa* L.) was evaluated for the years 2009-2011 under semi-arid region of India. The experiment was laid out in factorial randomized block design with nine treatments replicated thrice under microsprinkler system comprising three fertigation sources in main plots with three fertigation levels in sub plots. Fertigation by water soluble fertilizers sources improved plant height, neck thickness, polar and equatorial diameter, dry matter, bulb weight and green leaves weight. However, the differences in fertigation source urea+ urea phosphate + muriate of potash and urea+18:18:18 through microsprinkler was mostly non-significant. In fertigation levels, 100 % and 80 % recommended dose gave significantly higher values of growth and yield components than 60 % level. The marketable bulb yield decreased with decrease in level of fertigation from 100 to 60% but not decreased significantly showed potential saving of 40% fertilizer cost by use of fertigation. The bulb storage losses in microsprinkler fertigation did not differed; but was higher under when conventional fertilizer source was used. The bulb storage losses were reduced with fertigation 60 to 100%. Higher gross income, total net income, and the best benefit: cost ratio occurred with 60 and 100% microsprinkler fertigation. The treatment combination with application of 60% recommended dose of nutrients with urea+ urea phosphate + muriate of potash or urea+18:18:18 through microsprinkler in 10 weekly splits was optimum for growth, yield, storage and profit for winter onion cultivation.

Introduction

Onion (*Allium cepa* L.) is considered as one of the important commercial vegetable crops grown in India and the country ranks third among the onion producing countries in the world (Savitha *et al.,* 2010). Land area dedicated for onion cultivation in India is 1.04 million ha, producing about 15.7 million tonnes of bulbs. At present per hectare productivity of onion in India is very low (15.1 t/ha) compared with the leading onion growing countries, like Korean republic, USA, Spain and Netherland, where productivity is ranged from 49 to 67 t/ha (Tripathi *et al.*, 2010).

In onion water is a limiting factor for low productivity, and the common irrigation method is to flood the field which results in reduced water and fertilizer use efficiency due to different losses (Sankar *et al.*, 2008). It could be possible to increase its production and productivity by using improved irrigation methods. Use of microsprinkler irrigation coupled with appropriate irrigation scheduling have been found suitable over traditional irrigation methods in terms of water saving, higher productivity and economics for onion. Microsprinklers with better water application efficiency provide the opportunity to create optimum soil moisture regime for shallow rooted crop like onion for better maturity and yield (Sarkara *et al.*, 2008).

Onion bulb yield is affected by deficit supply of nutrients and therefore, irrigation and nutrients application should be delivered to provide the correct amount of nutrients and water required by onion (Rajput and Patel, 2006). In recent years greater importance has been focused to elevate productivity and efficiency of fertilizer through fertigation (Ajdary *et al.*, 2007). Longer shelf-life of onion bulbs is another issue for obtaining better remunerative prices and for exporting. Water and nutrient management for onion influences storage behavior of bulbs (Sharma *et al.*, 2010). Nitrogen adversely affects storability of onion bulb due to rotting and sprouting (Kumar *et al.*, 2006). There has been always apprehension about suitability of micro sprinkler fertigation for crops. However, very few studies indicated its superiority over soil application of fertilizer (Prabhakar *et al.*, 2011).

With microsprinkler, fertigation sources and fertigation levels are management variables which need to be investigated to enhance crop production. It is necessary to determine the economic viability of microsprinkler fertigation since water soluble fertilizers are more costly than conventional fertilizers. With this background, a study was under taken to characterize use of microsprinkler fertigation and contrast effects of different fertigation levels on growth, yield and economics of onion production.

Materials and Methods

Experimental site

The study was conducted at Mahatma Phule Krishi Vidyapeeth, Rahuri (19^0 47'N and $74^0$39' E; altitude 500 meters above mean sea level) located in Maharashtra state of India during *Winter* seasons (November to April) of 2009-2011. The site lies in semiarid area with mean rainfall of 520 mm which is mostly concentrated during the monsoon months from June to September. The soil type was silty clay loam. The soil was 60 cm deep, slightly alkaline in nature with pH of 7.8 and electrical conductivity of 0.28 dSm^{-1}. Soil nutrient status indicated low N (152.3 kg ha^{-1}), and P (21.7 kg ha^{-1}), but potassium was high (360 kg ha^{-1}). The soil had good drainage with infiltration rate of 3.24 cm hr^{-1} and organic carbon content as 0.63 %. Moisture contents at field capacity (32.2%) and permanent wilting point (20.7%) indicated available water capacity of 11.5%.

Experimental design

The experiment comprised of combinations of fertilizer sources: S_1-Urea+ Urea phosphate (17:44:0) + muriate of potash; S_2-Urea + diammonium phosphate + muriate of potash, and S_3-urea+18:18:18. and the fertigation regimes of 60 (D_1), 80 (D_2) and 100% (D_3)

recommended dose (RD) applied through microsprinkler.

The experiment was arranged in a split plot design. All treatments were replicated 3 times and repeated for 3 years. Urea (46:0:0), urea phosphate (17:44:0) and N18:P18: K18 are completely soluble in water (WSF); diammonium phosphate (DAP) is a cheap, conventional, fertilizer partially soluble in water. The soil was prepared by two harrowing and formed into on raised beds with 0.9 m top width and 1.20 m bottom width.

Onion seedlings (cv. N-2-4-1) were prepared in a nursery for transplanting in field. In nursery, the sowing of onion seeds was done on raised beds with 1.20 m top width and 1.50 bottom width. The nursery was irrigated by microsprinkler and after thirty days of raising nursery when seedlings attended the height of 25-30 cm, the onion seedlings were transplanted in field.

The nursery prepared seedlings was transplanted in 6 rows on each bed at spacing of 15 cm between rows and 7.5 cm between plants in rows. The experiment was arranged in a split plot design. All treatments were replicated 3 times and repeated for 3 years. The recommended fertilizer dose (100:50:50 $N:P_2O_5:K_2O$ kg ha^{-1}) was applied in 10 weekly uniform splits through microsprinkler fertigation from transplanting and continued up to 70 days after transplanting.

Microsprinkler system layout

The microsprinkler system was constructed from PVC pipes of 90 mm and 63 mm dia used for main and submains, respectively. A screen filter was used to avoid clogging of nozzles due to physical impurities in irrigation water and precipitates in fertilizer solution. The duration of fertigation was controlled with a control valve positioned at the inlet of each manifold for each plot. The microsprinklers were placed on 16 mm diameter laterals and spacing between 2 laterals, and microsprinklers, on each lateral was 1.2 × 1.2 m. The rotating nozzles of 26 lph capacity at a height of 75 cm were installed with an application rate of 3.1 mm h^{-1}. The system was operated at a constant pressure of 1.5 kg cm^{-2} maintained with a control valve. The average coefficient of uniformity for microsprinkler irrigation system was estimated as 82.5 % in all the treatments. The microsprinkler irrigation was applied twice in a week on the basis of pan evaporation rate (Allen *et al.,* 1998). The daily pan evaporation data was recorded from USWB class A Pan located at a site adjacent to the experimental area.

The recommended plant protection measures were performed as recommended by parent agricultural university. Irrigation was stopped 15 days before harvest. The bulbs were harvested after 16 weeks of planting at full maturity. After curing and neck cutting observations on yield contributing characters and bulb yield were recorded. A 10 kg sample of field cured onion bulbs were kept loose on a cement floor at 27℃ to study the storage losses. Storage data were recorded at 30-day interval up to 180 days after harvest for rotting, physiological and total loss in weight.

The data were subjected to analysis of variance (ANOVA) using DRYSOFT statistical package. If an interaction was significant it was used to explain the results. Least significant difference (LSD) test was used to determine whether differences exist between certain comparisons. If interactions were not significant means were separated with least significant difference at 5 % level of significance (P = 0.05). The pooled analysis was done for all important characters of the study (Panse and Sukhatme, 1995).

Results and Discussion

Growth characters

There was significant effect on growth characters of onion due to different fertigation sources and levels through microsprinklers. The 100 % fertigation with source S_1 (urea + urea phosphate and MOP) resulted highest plant height at 60 days after transplanting (34.63 cm) however, it was at par with fertigation source S_3 (18: 18: 18). The plant height is an important yield attribute in onion and it has a direct relationship with bulb yield. The percentages of unmarketable bulbs like bolter and twins were at higher side (0.58 % and 2.30 %) in source S_2 (Urea + Di ammonium phosphate + muriate of potash). The lesser bolter and twin bulbs in microsprinkler fertigated plots might be due to better availability of nutrients with reduction in leaching losses in water soluble fertilizer. The highest neck thickness was noticed in S_1 followed by S_3 however, the difference among fertigation sources was non-significant. Significant increase in bulb polar and equatorial diameter of bulbs were also obtained in S_1 (6.32 cm and 5.47 cm, respectively) and S_3 as compared to source S_2. This is in conformity with earlier findings of Kumar *et al.,* (2006) that fertigation increases the growth parameters of onion crop.

All the growth characters were found improved with fertigation levels, but the difference was non-significant in most of the parameters. The interaction effect between fertigation sources and fertigation doses for all growth contributing character was found non-significant.

Yield characters

The dry matter, bulb weight, bulb yield, weight of leaves and bulb to leave ratio (Table 3 and 4) were significantly improved under microsprinkler fertigation. The higher dry matter (12.86 gm) and weight of onion bulb (86.72 gm) was obtained in 100 % fertigation with S_1 source but was at par with S_3. Comparison of fertigation levels showed a consistent increase in yield contributing parameters with increasing fertigation level from 60% to 100% but the difference was non-significant. More nutrient availability might have increased the translocation of photosynthates to storage organ of bulb resulting in increased weight of bulb. Prabhakar *et al.*, (2011) also reported decrease in bulb weight with decreased nutrient concentration through fertigation. Almost similar trend was observed in other yield contributing characters. The source S_1 noticed highest weight of green leaves, followed by S_3. The fertigation of water-soluble fertilizers might have made nutrients available in adequate proportion, which resulted in triggering the weight of green leaves.

The interaction effect between fertigation sources and fertigation levels for all yield contributing characters were found non-significant.

Marketable bulb yield

The marketable bulb yield was observed higher in S_1 fertigated plots among all sources studied however, it was on par with source S_3. In fertigation levels bulb yield increased from 36.14 $t.ha^{-1}$ under 60 % fertigation to a maximum of 38.97 $t.ha^{-1}$ under 100 % fertigation but did not differed significantly. The increased bulb yield in fertigation was mostly due to favorable effects of nutrients throughout the crop period, its utilization and higher uptake (Sankar *et al.*, 2008). However, fertigation sources and fertigation levels interaction effect on onion bulb yield was found non-significant.

Table.1 Growth contributing characters of onion as influenced by different treatment

Sr. No	Plant height at 60 days				Bolting, %				Twin bulbs (%)			
	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean
Fertigation source												
S_1	33.15	37.85	32.90	34.63	0.46	0.53	0.55	0.51	2.05	1.98	1.88	1.97
S_2	31.63	36.40	31.45	33.16	0.56	0.61	0.58	0.58	2.37	2.31	2.23	2.30
S_3	32.50	37.04	32.40	33.98	0.52	0.56	0.55	0.54	2.12	2.08	2.00	2.06
C.D.at 5%	0.75	1.01	0.6	1.41	0.03	0.02	0.01	0.02	0.3	0.2	0.25	0.2
Fertigation level												
D_1	31.56	36.78	30.85	33.06	0.52	0.59	0.56	0.56	2.03	1.96	1.91	1.97
D_2	32.57	37.01	32.15	33.91	0.51	0.56	0.55	0.54	2.18	2.13	2.06	2.12
D_3	33.15	37.49	33.75	34.80	0.51	0.56	0.56	0.54	2.33	2.26	2.14	2.24
C.D.at 5%	1.29	NS	NS	NS	NS	NS	NS	NS	0.1	0.06	0.05	0.07
Interaction												
C.D.at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table.2 Neck thickness, polar and equatorial diameter of onion as influenced by different treatment

Sr. No	**Neck thickness (cm)**				**Polar diameter (cm)**				**Equatorial diameter (cm)**			
	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean
Fertigation source												
S_1	1.37	1.46	1.45	1.42	5.78	6.62	6.56	6.32	5.44	5.60	5.36	5.47
S_2	1.25	1.37	1.50	1.37	5.45	6.72	6.41	6.19	5.12	5.35	5.26	5.24
S_3	1.31	1.37	1.47	1.38	5.63	6.45	6.61	6.23	5.54	5.20	5.31	5.35
C.D.at 5%	NS	NS	NS	NS	0.18	0.12	0.06	0.09	0.18	0.27	NS	0.22
Fertigation level												
D_1	1.24	1.37	1.41	1.34	5.54	6.64	6.44	6.21	5.28	5.40	5.18	5.29
D_2	1.31	1.37	1.44	1.37	5.62	6.69	6.51	6.27	5.35	5.51	5.28	5.38
D_3	1.37	1.47	1.57	1.47	5.70	6.45	6.64	6.26	5.47	5.23	5.48	5.39
C.D.at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction												
C.D.at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table.3 Effect of micro sprinkler fertigation on TSS, dry matter and average bulb weight of onion

Sr. No	**TSS (%)**				**Dry matter (gm)**				**Average bulb weight (gm)**			
	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean
Fertigation source												
S_1	11.28	11.30	11.40	11.32	13.63	13.39	11.57	12.86	90.30	70.70	99.17	86.72
S_2	10.98	11.00	10.95	10.98	13.00	13.00	11.07	12.35	77.19	64.96	91.97	78.04
S_3	11.14	11.19	11.18	11.17	13.17	13.22	11.32	12.57	83.60	67.99	97.82	83.14
C.D.at 5%	0.10	NS	0.09	0.09	0.56	NS	0.34	0.49	6.1	5.7	6.9	7.9
Fertigation level												
D_1	11.07	11.13	11.23	11.14	13.08	13.02	11.10	12.40	81.66	65.74	92.72	80.04
D_2	11.17	11.18	11.18	11.17	13.19	13.21	11.30	12.57	83.21	67.51	97.79	82.84
D_3	11.16	11.19	11.13	11.16	13.54	13.36	11.55	12.82	86.21	70.41	98.45	85.02
C.D.at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction												
C.D.at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table.4 Yield and yield contributing parameters of onion under different fertigation sources and their levels

Sr. No	**Bulb yield (t ha^{-1})**				**Wt. of green leaves (t ha^{-1})**				**Bulb to leaves ratio**			
	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	Mean
Fertigation source												
S_1	47.34	31.45	39.23	39.07	6.80	4.25	5.23	5.43	6.76	7.42	7.43	7.20
S_2	42.56	27.93	37.07	35.86	6.57	3.60	4.85	5.01	6.61	7.56	7.56	7.24
S_3	44.62	29.21	38.41	37.69	6.74	3.84	5.08	5.22	6.63	7.60	7.70	7.31
C.D.at 5%	2.90	2.44	1.82	2.89	0.12	0.42	0.20	0.25	NS	NS	NS	NS
Fertigation level												
D_1	42.93	28.24	37.24	36.14	6.67	3.70	4.78	5.05	6.56	7.60	7.86	7.34
D_2	44.62	29.75	38.13	37.50	6.70	3.95	5.08	5.24	6.64	7.49	7.51	7.21
D_3	46.97	30.61	39.34	38.97	6.74	4.05	5.30	5.36	6.80	7.50	7.31	7.20
C.D.at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction												
C.D.at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table.5 Water use by onion as influenced by different treatments

Sr. No	**Water depth (mm)**				**FWUE (kg ha^{-1} mm)**			
	2009	2010	2011	Mean	2009	2010	2011	Mean
Fertigation source								
S_1	375.0	428.0	404.3	402.4	126.2	73.5	95.0	98.2
S_2					113.5	65.3	91.7	90.2
S_3					119.0	68.2	97.0	94.8
Fertigation level								
D_1	375.0	428.0	404.3	402.4	114.5	66.0	92.1	90.9
D_2					119.0	69.5	94.3	94.3
D_3					125.3	71.5	97.3	98.0

Table.6 Storage loses in onion as influenced by different treatments (Average of 3 years)

Sr. No.	Treatments	Rooting losses (%)				Total loss (%)	Physiological weight loss (%)						Total loss (%)
Days after harvesting		90	120	150	180		30	60	90	120	150	180	
Fertilizer source													
S_1	Urea phosphate + Urea + MOP	2.29	2.51	2.98	4.04	11.82	2.0	3.17	4.13	6.25	8.08	11.42	35.05
S_2	DAP + Urea + MOP	2.41	2.84	3.36	4.56	13.17	2.82	3.71	4.58	6.85	8.96	12.47	39.39
S_3	18:18:18 + Urea	2.36	2.66	3.17	4.27	12.46	2.15	3.36	4.37	6.55	8.80	12.22	37.45
	LSD @ 5%	0.07	0.13	0.17	0.09	--	0.13	0.17	0.17	0.26	0.07	0.14	--
Fertigation levels													
D_1	60% Fertigation	2.33	2.65	3.38	4.11	12.47	2.21	3.01	4.24	6.27	7.93	11.15	34.81
D_2	80% Fertigation	2.36	2.67	3.67	4.82	13.52	2.35	3.40	4.62	6.54	8.29	12.36	37.56
D_3	100% Fertigation	2.37	2.69	3.95	4.94	13.95	2.53	3.69	4.84	6.88	8.62	12.51	39.07
	LSD @ 5%	0.07	0.13	0.17	0.09	--	0.13	0.17	0.17	0.26	0.07	0.14	--
	Interaction												
	LSD @ 5%	**N.S.**	**N.S.**	**N.S.**	**N.S.**	--	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	--

Table.7 Cost economics as influenced by different treatments

Sr. No	**Total seasonal cost Rs. ha^{-1}**				**Net seasonal income, Rs. ha^{-1}**				**Benefit cost ratio ha^{-1}**			
	2009	2010	2011	Mean	2009	2010	2011	Mean	2009	2010	2011	**Mean**
Fertigation source												
S_1	52385	61414	61414	58404	184298	190186	130653	168379	3.52	3.10	2.13	2.91
S_2	47677	57374	57374	54142	165123	166092	127992	153069	3.46	2.90	2.23	2.86
S_3	57187	70342	70342	65957	165913	163365	125791	151690	2.90	2.33	1.79	2.34
Fertigation level												
D_1	50875	60593	60593	57354	163758	165301	125624	151561	3.23	2.74	2.08	2.68
D_2	52300	63081	63081	59487	170800	174919	127586	157768	3.28	2.80	2.04	2.71
D_3	54074	65456	65456	61662	180776	179424	131227	163809	3.37	2.78	2.03	2.73

Field water use efficiency

The total water applied to onion crop through microsprinkler was 402 mm which is almost half to water applied through reported conventional irrigation (800 mm) The maximum field water use efficiency (FWUE) of 98.2 kg $ha^{-1}mm^{-1}$ was observed under S_1 source whereas minimum water use efficiency observed with application of conventional fertilizers (90.2 kg $ha^{-1}mm^{-1}$). In fertigation levels, the FWUE was highest in 100 % dose (98 kg $ha^{-1}mm^{-1}$). Lowest FWUE of 90.9 kg $ha^{-1}mm^{-1}$ was recorded in microsprinkler 60% fertigation (Table 5). This is in confirmation with the findings of Sarkara *et al.,* (2008) that microsprinkler can increase the water use efficiency by increasing crop yield.

Storage losses

Rotting percentage

Rotting losses decreased under fertigation with water soluble fertilizers as compared to control. The rooting losses were found in increasing trend with the increase in storage period (Table 6). It was significantly higher in source S_2 (13.17 %) whereas least losses were observed in fertigation source S_1 (11.82 %) and it did not differ significantly with source S_3 (12.46 %). Similar trend of loss in weight was observed in three years.

The increasing trend for rotting loss was observed with increase in fertigation from 60 to 100 % for microsprinkler fertigated onion. Maximum losses were recorded in 100 % fertigation (13.95 %) followed by 80 % (13.52 %) and 60 % fertigation (12.47 %). The higher weight loss during storage with 100 % fertigation may be attributed to higher nutrient application. Higher nutrient dose may ensure greater uptake of nitrogen by the crop which caused spoilage of bulb due to rotting. Kumar *et al.,* (2006) reported that high doses of nitrogen fertigation had adverse effect on storability of onion bulb due to rotting. However, interaction between fertigation sources and levels was found non-significant.

Physiological loss in weight

Physiological loss increased with conventional fertilizer application (Table 6). The least physiological loss in weight was observed in fertigation source S_1 (35.05%) and it did not differ significantly with source S_3 (37.45%), while source S_2 resulted in significantly higher losses (39.39 %).

Physiological loss in bulb storage was found very responsive to nutrient applied. The highest dose of fertigation i.e. 100% recorded maximum physiological loss (39.07 %) followed by 80 % (37.56%) and 60 % fertigation (34.81%). Higher loss with higher fertility level might be due to the fact that higher nitrogen availability to crop during production phase might be accelerated the losses during storage. Woldetsadik *et al.,* (2003) also observed that high level of nitrogen fertilization promotes losses in onion. However, interaction between fertigation sources and levels was found non-significant.

Cost economics

In terms of three years pooled economics, the total seasonal cost computed by adding the seasonal cost of microsprinkler system and onion cultivation cost considering 4 months crop period (Table 7). The seasonal cost of microsprinkler system for onion was estimated as Rs. 7192/ considering depreciation cost, interest on capital investment and cost towards repairs and maintenance. The higher cost of cultivation in fertigation could be attributed to high market cost of water-soluble fertilizers.

The beneficial effect of higher yield through microsprinkler fertigation is attributed to the higher seasonal income. Among different sources and fertigation levels, source S_1 (Rs. 168379 ha^{-1}) and 100 % fertigation (Rs. 163809 ha^{-1}) recorded higher seasonal income. Higher productivity resulted into B:C ratio of 2.91 in S_1 however, it was almost equal with S_2 due to lower prices of conventional fertilizers.

In conclusion, foliar application of fertilizers through microsprinkler significantly improved the growth, yield and economic benefits of closely spaced onion. Among the various sources tested over 3 years, foliar application of fertilizers with source S_1 (urea + urea phosphate + MOP) and S_3 (Urea + 18:18:18) were found suitable in improving the productivity and economics returns from onion cultivation. Among different fertigation levels tested, no significant difference in growth, yield and economical parameters was noticed and 60 % fertigation through microsprinkler was observed as optimum option. The storage losses were significantly lower in foliar application of fertilizers however, 100 % fertigation level recorded higher storage losses. There is a marked increase in economic parameters under microsprinkler fertigation. The overall results of study revealed that 60 % foliar application of water-soluble fertilizers through microsprinkler is advisable to farmers for improved growth, yield, economics and storage behavior of onion in semi-arid regions of India.

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