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Neelam Patel
Principal Scientist, Water Technology Centre, ICAR-Indian Agricultural Research Institute, New Delhi, India

TBS Rajput
Principal Scientist, Water Technology Centre, ICAR-Indian Agricultural Research Institute, New Delhi, India

Correspondence
Neelam Patel
Principal Scientist, Water Technology Centre, ICAR-Indian Agricultural Research Institute, New Delhi, India

Micro irrigation technology for increasing water and fertilizer use efficiency of kharif onion

Neelam Patel and TBS Rajput

Abstract
Onion is an important vegetable crop and occupies 1.087 million ha area with a total production of 17.51 million ton (2011-12) in India. In north India, onion is cultivated mainly in rabi season which is harvested in April-May. The yield of onion varies from 25 to 35 t/ha under irrigated condition in rabi season whereas it is only 15-20 t/ha in kharif season. Low productivity of kharif onion is mainly because of lack of awareness of the farmers about its production technology namely drip fertigation technology. Keeping the above point in mind, a new crop production technology was developed with the objectives of assessing the potential of kharif onion in remunerative replacement of rice in water deficit areas of north India. Study was conducted at Water Technology Centre during 2011 and 2012 to develop production technology for growing kharif onion under drip fertigation system. Onion (var. N 53) was sown during the last week of July to first week of August at a plant to plant spacing of 10 cm and row to row spacing's of 15.0 cm. Spacing between two laterals was 1.***2*** m, accommodating 6 rows of onions per bed, per lateral. Water requirement of kharif onion was estimated as 30 cm under drip and 45 cm in flood irrigation. The highest water productivity of 7.4 kg/m^3 was obtained under drip fertigation technology while in flood it was 2.8 kg/m^3. This technology needs large scale adoption in north India known for rice production for the saving of water secondly farmers may have much profit by growing onion in kharif season in place of paddy.

Keywords: Drip irrigation, kharif onion yield, fertigation, Water and fertilizer use efficiency

Introduction
In India, paddy is the most popular crop during the kharif season. About 25% of net cultivable area is under paddy cultivation producing 90-95 million tones. Only 2% area is covered by onion during the kharif season in comparison of paddy therefore onion can be an optional crop for kharif season since kharif onion is an off season crop in north India and fetches good market price making it profitable in comparison to paddy. Onion is mainly a rabi crop but in some states it is produced in kharif and late kharif season also. Maharashtra is the highest onion producing state in India after Karnataka and both the states together produce almost 90% of kharif onion. All other Indian states depend on these two states namely Maharashtra and Karnataka for the supply of onion during October to March. In north India, major onion is produced in rabi season harvested in April-May. The rabi season produce is mainly stored, which lasts up to the end of September. This results in the comparatively higher price of onion during winter season therefore onion cultivation in kharif season has price advantage.
Mohanty and Prusti [1] and Pavlovic*et al.* [2] evaluated different varieties of onion for kharif season over two years. Mohanty and Prusti observed that Agrifound Dark Red and N 53 were high yielders produced 18.06 and 17.85 t/ ha, respectively**.** While Pavlovic*et al.* evaluated two genotypes i.e. MB and HZ, which have highest adaptability. They also reported that rabi varieties if grown in kharif season could confer equally good bulb yield as that of kharif varieties. Kumar*et al.* [3] explored the possibility of cultivation of kharif onion as a substitute crop to upland paddy. Cultivation of kharif onion resulted in the highest B:C ratio of 2.17 and 2.0 as sole crop and intercrop with radish, respectively as against upland paddy gives B:C ratio of 1.73. They concluded that the paddy equivalent yield of 9.6 to 12.67 t/ha may be obtained by replacement of paddy with the kharif onion in the cropping system. Giri*et al.* [4] conducted study in West Bengal, revealed that kharif onion has the potentiality in the state particularly in the new alluvial and red and laterite zone if care is taken during seedling raising. They evaluated the different cultivars of onion during kharif season in the plains of new alluvial zone of the state. Agrifound Dark Red, Baswant-780, Agrifound Light Red and N-53 among other cultivars were reported having better potentialities for cultivation as a kharif crop. The highest bulb yield (17.30 t/ha) was obtained in Agrifound Dark Red followed by Baswant-780 (15.40 t/ha).

The yield of onion varies from 25-35 t/ha under irrigated condition in rabi season whereas it is only 15-20 t/ha in kharif season. Several biotic, abiotic and socio-economic constraints inhibit exploitation of the yield potential of onion and these needs to be addressed [5] The low productivity of onion in kharif season can be improved significantly. Unawareness of the farmers about suitable varieties, climate, soil and improved cultivation techniques are the main reasons responsible for low production and productivity of kharif onion.[6] Keeping the above point in mind, field experiment was conducted on kharif onion for development of new crop production technology with the objectives of assessing the potential of kharif onion in remunerative replacement of rice in water deficit areas of north India.

Materials and methods

Experimental layout

An experiment was conducted during 2011 and 2012 on a sandy loam soil following split plot design having 3 replications. Monthly weather data recorded during the study period are shown in Table 1. The climate of the study area is semi-arid monsoonal subtropical type. More than 70% of the annual rainfall is received during the monsoon period from July to September. Humidity is generally high during July to September and starts decreasing during October and November. Minimum temperature was varied from 8.9 to 27.5 ^{0}C. Maximum temperature during the crop season was varied from 27 to 36 ^{0}C. The amount of rain received as 469.8 mm and 470.8 mm from July to September during 2011 and 2012, respectively. The weather data during the crop period are presented in Table 1.

Table 1: Weather conditions during field experimentation period

Months	Rainfall (mm)		Max. temp. (°C)		Min. temp. (°C)		Avg. RH (%)	
	2011	2012	2011	2012	2011	2012	2011	2012
July	33.8	139.8	34.4	36.0	26.0	27.5	77.2	69.5
August	272.4	274.0	34.2	35.0	27.0	25.0	69.0	79.0
September	163.6	57.0	35.0	32.9	27.6	20.8	71.3	69.1
October	0.0	11.0	31.9	32.3	15.7	14.7	68.3	59.7
November	0.0	0.0	29.3	26.9	11.8	8.9	74.2	57.2

Installation of the drip fertigation system commenced in 2010 with head works, which included a pump, a sand media filter (flow rate 25 m^3 h^{-1} and silica sand size 0.7 mm), a disc filter, back flush mechanism and a fertilizer injection system (25.4 mm venturi having 1800 lph injection rate) equipped with two pressure gauges and control valves. The tests for uniformity of water application of the drip system were carried out. Coefficient of variation, application efficiency and statistical uniformity were estimated to be 3, 98.2 and 95%, respectively therefore system performance was considered acceptable as per the guidelines of ASAE [7, 8]

Crop sowing and other crop management measures

Sowing/ transplanting on raised beds having furrows on both sides of each bed are better for kharif or rainy season crops. Field was ploughed to a fine tilth using disc plough, cultivator and rotavator. The ploughing depth was kept shallow as most of the onion roots penetrate to a depth of not more than 15 cm. The normal width and height of a bed were kept as 0.90 m and 0.15 m, respectively leaving 30 cm furrow for drainage.

Onion (var. N 53) was sown during the last week of July to first week of August at a plant to plant and row spacing of 10 cm x 15 cm in 2011 and 2012. Spacing between two laterals was 1.2 m accommodating 6 rows of onions per bed per lateral. Sowing of crop was done by using 1.5-2.0 cm sized bulblets in different crop geometry in broad based furrows system. Stomp @ 2.5 litres/ha and one hand-weeding after 25-30 days of sowing was done to make crop weed free. Foliar spray of water soluble fertilizers NPK-19:19:19 @ 1% were done 15, 30 and 45 days after sowing (DAS) followed by NPK-13:0:45 @ 1% spray at 60 DAS were applied as recommended for getting quality bulb and higher yield. The foliar applications of zinc @ 3 ppm, copper @ 1ppm and boron @ 0.5 ppm were applied for enhancement of plant growth, bulb yield and quality. The foliar application of wettable sulphur @ 1% during 15, 30, 45 and 60 DAS was done for higher bulb yield with less disease and pest load.

Fertigation

The requirement of nutrients depends on soil type, region of growing, varieties and removal of major nutrients. To meet the nutritional requirement of onion crop, 160 kg ha^{-1} nitrogen (N), 115 kg ha^{-1} phosphorous (P_2O_5) and 95 kg ha^{-1} potassium (K_2O) were applied throughout the crop season. Urea, muriate of potash and single super phosphate (SSP), mono potassium phosphate (MKP) were used to supply N, K_2O and P_2O_5, respectively. Thirty per cent (30%) N, 60% P_2O_5 and 40% K_2O were applied as basal dose at the time of sowing of crop. Phosphorous was applied in the form of SSP in basal dose and remaining 40% was applied in the form of MKP with fertigation. MKP is having 34% K therefore 30.1 Kg K_2O was met through MKP and remaining 26.9 kg was met through KCl. Whole quantity of phosphorus, potassium and half of nitrogen was applied as basal dose in flood irrigation before sowing of crop. Remaining half of nitrogen was given as top dressing in single dose in bulblet method of planting at 20-25 days after sowing. The top dressing must be completed before initiation of bulbing as delayed application results in thick neck or doubles.

Fertigation was started 21 days after sowing and was stopped 15 days prior to the harvest of crop. During the remaining 68 days of the crop duration, fertigation was done weekly with irrigation in drip fertigation. Total fertigation events in the crop season were 8. One HDPE plastic tank of 200 litres capacity was filled with water for preparation of stock solution. Urea, MKP and KCl are compatible with each other therefore all three dissolved in the same tank. Fertilizers were dissolved in 100 litres of water and applied by using venturi mixing with irrigation water.

Results and discussion

Irrigation water requirement of crop

Onions is a shallow-rooted crop and needs frequent and light irrigation resulting in good bulb development and consequently high yield. Frequent irrigation is possible only through drip irrigation. Onion root system is normally restricted to top 30 cm and roots penetrate seldom deeper (30 cm). The water requirement at initial growth is less but requires one irrigation after sowing particularly in rainy season in Northern India when temperature at the time of sowing/ transplanting is very high. Rabi onion has cropping cycle of 150-155 days but kharif onion gets harvested in 90-100 days.

The reference crop evapotranspiration (ET_o) was estimated using the daily data from an automatic weather station. The crop duration of onion (90 days) was divided into four stages, namely, initial (1st) 15 days, developmental (2nd) 45 days,

middle (3rd) 20 days and maturity (4th) 10 days. The crop water requirements were calculated by multiplying the ET_0 values with the onion crop coefficients (Kc) given by Allen*et al*. [9] as 0.7 for the 1st; 0.90 for the 2nd, 1.0 for the 3rd and 0.75 for the 4th growth stages.

Irrigation was started after September 18 and was stopped 10 days prior to harvesting. In kharif season, depending upon the rainfall 8-10 irrigations through drip are enough. In case of dry spells in 2nd and 3rd stage of crop growth, irrigation is necessary and moisture stress at these stages of crop growth results in low yield. The field should not be kept dry for long otherwise this results in splitting and forced maturity therefore drip irrigation is only technology through which farmers can apply very less amount of water as and when there is dry spell during the crop season. Total crop water requirement of kharif onion was estimated as 30 cm in drip and 45 cm in flood irrigation considering 90% and 60% irrigation efficiencies, respectively. Rainfall of August and September months was more than the estimated crop water requirement but crop was not able to utilize it fully and excess rainfall produced runoff that got safely disposed off through furrows. Water is needed for fertigation therefore about 13-15 cm water was applied throughout the cropping season and remaining was met from rainfall. Water requirement varied from 2.5 to 3.5 Litres/m^2 based on Kc and reference crop evapo-transpiration (ET_0). Water requirement in different growth stages is given in Table 2.

Table 2: Water requirement estimated for kharif onion in different growth stages

Growth stages	No. of days	Crop coefficient (Kc)	Water requirement (Litres / m^2)
Initial stage (1st)	15	0.7	2.5
Developmental stage (2nd)	45	0.85	3.0
Middle stage (3rd)	20	1.0	3.5
Maturity stage (4th)	10	0.90	2.9
Total crop duration	90		

Yield of onion

Onion crop was harvested in 90 days, when the color of leaves changes to slightly yellow and tops started drying but did not fall and red pigmentation on bulbs developed. The leaves are cut leaving about 2-2.5 cm tops above the bulb after complete drying. Early harvesting results in sprouting of bulbs while late harvesting results in formation of secondary roots during storage. In kharif season, late harvesting results in doubles and bolting also. Highest yield (22.2 t/ha) was observed in drip irrigation (Table 3). In conventional irrigation and fertilization about 10-12 t/ha kharif yield was harvested. About 30.8% saving of water and 50.7% enhancement in yield was observed in drip fertigation technology in comparison to flood. Fertigation reduced fluctuation in nutrient concentrations in soil in the course of growing season. Better distribution and higher uniformity of plant nutrients throughout the root zone or soil profile enhanced crop yield. Frequent applications of water and fertilizers in small doses not only increases their availability but also reduces losses from soil through leaching.

Water productivity and fertilizer use efficiency

Water productivity is defined as the relationship between onion bulb produced and volume of irrigation water applied. Water productivity values are used to evaluate the effectiveness of the irrigation practices on water utilization by onion crops. Fig. 8 shows the water productivity values expressed as tons of fresh bulb weight produced per cubic meter of water applied through irrigation and rainfall from sowing to harvesting. Highest yield of 22.2 t/ha was observed with 30.8% saving of water and 50.7% enhance in yield was observed in drip fertigation technology in comparison to flood. The highest water productivity of 7.4 kg/m^3 was obtained under drip fertigation technology with B: C ratio of 1.72 (Income Rs. 1.75 lakh per ha per year). On the other hand, in conventional irrigation, an average water productivity of 2.4 kg/m^3 was obtained. Fertigation with drip irrigation gave proportionally higher FUE in drip (54%) in comparison to flood.

Table 3: Kharif onion yield recorded under drip-fertigation technology

Onion yield observed in different methods of irrigation		Water productivity, kg/ m^3		FUE, kg of bulb per kg of macro nutrients applied	
Drip with fertigation	Flood irrigation	Drip with fertigation	Flood irrigation	Drip with fertigation	Flood irrigation
22.2	10.9	7.4	2.4	60.0	29.5

The fertilizer use efficiency (FUE) values were affected by method of water application and fertilization. Lower value of FUE for the flood method during both the years can be attributed to reduced yields but also to higher irrigation water and fertilizer use. Fertigation with drip irrigation gave proportionally higher FUE in drip (50%) in comparison to flood irrigation.

Fertigation through drip reduces leaching losses of nutrients, which is common in high rainfall occurring during August to September. To produce 1 ton of bulb in kharif season amount of nutrients (N, P_2O_5 and K_2O) required were estimated and are given in Table 4. It was observed from the Table 4 that nutrients requirement under flood is almost double than in drip with fertigation. Thus, more than 50% fertilizers can be saved in drip in comparison to flood without reducing the production (Table 4). This technology is having enormous potential in terms of nutrients saving besides water saving in the farmers' field. Kharif onion plays an important role in supply chain management from October to January all over the country. This technology offers potential for large scale adoption in north India known for rice production during this period.

Table 4: Nutrients requirement and savings of fertilizer in kharif onion

Crop geometry	Nutrients requirement (kg of macro nutrients per ton of onion bulb produce)						Savings of fertilize in drip irrigation in comparison to flood irrigation with conventional fertilizer application,%		
	Drip irrigation with fertigation			Flood irrigation					
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
10 cm x 15 cm	7.2	5.2	4.3	14.7	10.6	8.7	51.0	59.4	50.6

Conclusions

Highest yield (22.2 t/ha) was observed with 30.8% saving of water and 50.7% enhancement in yield under drip fertigation technology in comparison to flood. Water requirement for onion was estimated as 300 mm while for paddy it is 1200 mm that is almost 3 times higher than that of onion. Presently only 2% area is covered by onion during the kharif season in comparison of paddy. Distribution of rainfall during the monsoon is quite erratic and more than 80% of irrigation water requirement of paddy is normally met by groundwater pumping. If 25% of paddy growing area is replace by kharif onion in major paddy growing northern state, more than 50000 million cubic meter water can be saved therefore onion can be considered as a potential optional crop for kharif season.

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