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Research Article

GROWTH, YIELD, ECONOMICS, WATER AND NUTRIENT USE EFFICIENCY OF POTATO AS INFLUENCED BY DIFFERENT METHODS OF DRIP FERTIGATION AND VARIETIES

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Abstract- Field experiments were conducted during *rabi* season in 2011-12, 2012-13 to 2014-15 to study the effect of different methods of drip fertigation and varieties on growth, yield, water and nutrient use efficiency and economics of potato. Results showed that drip fertigation of 100% of recommended dose of N and K at 9, 16, 23, 30, 37 43, 51, 58 and 65 days after planting markedly increased growth attributes like plant emergence and plant height and ultimately gave significantly higher>75 g grade and total tuber yield of potato over conventional method. Further, this method had improved crop productivity, water and nutrient use efficiency along with more net return and benefit-cost ratio, which was much higher than conventional method. Although, Kufri Pukhraj registered highest total tuber yield, with slightly higher crop productivity, water and nutrient use efficiency, net return and benefit-cost ratio, the difference between varieties of potato was non-significant.

Keywords- Drip fertigation, Net return, Nutrient use efficiency, Varieties, Water use efficiency.

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Introduction

Water is one of the most important inputs of agriculture, which is becoming scarce day by day due to booming population and rapid urbanization. Further the water scarcity has been predicted to worsen globally due to extreme weather events like drought and floods and reduction in water quality due to global warming [10]. Therefore, there is an urgent need for economizing water use by replacing conventional system of furrow irrigation by more water efficient irrigation system such as drip irrigation, which has reportedly saved water up to 40% compared to conventional system of furrow irrigation. Fertigation of water soluble fertilizers through drip ensures even distribution of nutrients and water to plant with precise timing to meet crop nutrient demand, while minimizing nutrients losses through leaching [4], reduces environmental pollution and soil erosion [7]. However, response of different varieties varies with management practices such as methods of nutrient application and irrigation. Keeping these points in view the present investigation was planned to study the effect of different methods of drip fertigation and varieties on growth, yield, economics, water and nutrient use efficiency of potato.

Materials and Methods

Field experiments were conducted at Potato Research Station, SDAU, Deesa (Gujarat) during *rabi* season in 2011-12, 2012-13 to 2014-15. The soil of the experimental site was loamy sand in texture, low in organic carbon (0.37%), pH (7.18), available nitrogen (178.12 kg N/ha), medium in available phosphorus (19.20 kg P/ha) and available potassium (235.11 kg K_2O/ha). The experiment was laid out in split plot design with four methods of fertilization i.e; 25% recommended dose of N and K(RD_{NK})as basal + 75%RD_{NK} through drip fertigation at 23, 30, 37, 43, 51, 58 and 65 days after planting (DAP),50% RD_{NK} as basal + 50% RD_{NK} through drip fertigation at 23, 30, 37 43, 51, 58 and 65 DAP,100% RD_{NK} through drip fertigation at 9,16, 23, 30, 37, 43, 51, 58 and 65 DAP and conventional method in main plots and three varieties of potato namely, Kufri Badshah, Kufri Pukhraj and Kufri Pushkarin sub-plots and replicated thrice. Recommended dose of fertilizers for conventional method was 275:140:275 kg N: P_2O_5: K_2O/ ha with irrigation through furrows and that ofdrip fertigation was 75% of the conventional RDF (i.e.; 220:110:220 kg N: P_2O_5: K_2O/ ha). Full dose of P_2O_5 was applied basally during final land preparation in both drip fertigation and conventional method. In conventional method, half dose of N and full dose of K_2O were applied as basal dose at the time of planting and the remaining dose of N was applied at 30 DAP. Doses of N and K_2O were given through venturi in drip fertigation. In the drip fertigation crop, each lateral line was laid out in the middle of inter-row space of pair rows. The distance between two drippers was 60 cm and the drippers were of discharge rate 4 litres per hour. Drip system was operated every alternate day and in conventional method furrow irrigation was given at 0.8 pan evaporation with total number of 14 irrigations at 50 mm depth.

Healthy and well-sprouted tubers were sown as paired rows with spacing of 75 cm x 20 cm in the third week of November during all the years of experimentation. Sources of nitrogen, phosphorus and potassium were urea, single super phosphate and muriate of potash Recommended package of practices were followed for raising the crop. Haulms were cut at 105th days after planting and at harvested 15 days after haulm cutting. *In-situ* green manuring of sunn hemp (*Crotolaria juncea*) was done before planting of potato. Growth attributes of potato like plant emergence (%) at 30 DAP, plant height and number of shoots/hill at 50

DAP were recorded. Grade wise (0-25 g, 25-50 g, 50-75g, >75g) and total tuber yield of potato were recorded at harvest from net plot and then expressed in t/ha.

Crop productivity was calculated by using formula:

$$\text{Crop productivity (kg/ha/day)} = \frac{\text{Total yield (kg/ha)}}{\text{Total crop duration (days)}}$$

Total duration of crop was 105 days during all the years of experimentation. Water use efficiency (WUE) was estimated by using formula:

$$\text{WUE} = \frac{\text{Total yield (kg/ha)}}{\text{Total amount of irrigation water applied (mm)}}$$

Total amount of irrigation water used in drip fertigation and conventional method of planting and irrigation were 425 and 700 mm, respectively. Nutrient use efficiency (NUE) of N, P and K was determined by using formula as given by Dobermann [3]:

$$\text{NUE(N, P and K)} = \frac{\text{Total yield (kg/ha)}}{\text{Nutrient(N, } P_2O_5, K_2O\text{)applied (kg/ha)}}$$

Economics like cost of cultivation and net return were worked out by using prevailing market prices of inputs during the period of investigation. Net return was estimated by subtracting total cost of cultivation from gross return. Benefit-cost ratio (BCR)was worked out by using the formula

$$\text{Benefit-cost ratio (BCR)} = \frac{\text{Net return (₹/ha)}}{\text{Total cost of cultivation (₹/ha)}}$$

Three years data on growth, yield, crop productivity, water and nutrient use efficiency and economics were pooled and then statistical analysed using OPSTAT software designed by CCSHAU, Hisar.

Results and Discussion

Growth attributes

Perusal of data presented in [Table-1] showed that drip fertigation methods promoted plant growth as evidenced by better plant emergence at 30 DAP and plant height at 50 DAP than conventional method. However, number of shoots/hill at 50 DAP was not significantly influenced by drip fertigation methods. Higher uniformity of water supply in drip irrigation system might be attributed to higher emergence of plant over conventional method. Moreover frequent irrigation and higher availability of soil moisture and nutrients in drip fertigation enhanced effective absorption and utilization of available nutrients and better root development [9] which ultimately lead to vigorous plant growth.

Among different varieties of potato, all growth attributes namely, plant emergence at 30 DAP and number of shoots/hill at 50 DAP were unaffected except plant height at 50 DAP, in which Kufri Badshah was significantly tallest (57.84 cm) [Table-1].

Tuber Yield

Different fertilization methods did not significantly influenced grade-wise tuber yields of potato except >75 g grade tuber yield, in which 50% RD_{NK} as basal + 50% RD_{NK} through drip fertigation at 23, 30, 37 43, 51, 58 and 65 DAP recorded highest >75 g grade tuber yield(18.16 t/ha), which was statistically at par with 100% RD_{NK} through drip at 9, 16, 23, 30, 37, 43, 51, 58 and 65 DAP but was significantly higher than 25% RD_{NK} as basal + 75% RD_{NK} through drip fertigation at 23, 30, 37 43, 51, 58 and 65 DAP and conventional method [Table-1]. In case of total tuber yield, all drip fertigation treatments had superior advantage over conventional method. Application of 100% RD_{NK} through drip at 9, 16, 23, 30, 37, 43, 51, 58 and 65 DAP recorded maximum value of total tuber yield (42.83 t/ha) which was 19.43% higher than conventional method. The better performance of drip fertigation might be ascribed to accurate supply of water and nutrients to root zone of individual plant with minimum loss to surrounding environment. Besides this, split application of fertilizers in drip fertigation could have matched the nutrient demand by crop thus enhanced its absorption and utilization by the crop. Thus, the cumulative effect of all these factors contributed in higher plant stand, growth and photosynthesis for developing tuber and ultimately resulted in higher tuber yield. Similar findings were reported under different crops like banana [9] and cotton [6] in drip fertigation had significantly higher yield than surface irrigation with soil application of recommended dose of fertilizers.

Tuber yield of potato (both grade wise and total tuber yield) was not statistically influenced by different varieties [Table-1]. However, highest 0-25,25-50 and 50-75g grade-wise and total tuber yield were recorded under Kufri Pukhraj (4.35, 8.08, 13.25 and 41.36 t/ha, respectively) among all varieties.

Table-1 *Effect of drip fertigation methods and varieties on growth and tuber yields of potato (pooled data of three years)*

Treatment	Plant Emergence (%) at 30 DAP	Plant height at 50 DAP	No. of shoots/hill at 50 DAP	Grade wise tuber yield (t/ha)				Total tuber yield (t/ha)
				0-25g	25-50g	50-75g	>75g	
Drip fertigation methods								
25% RD_{NK}(basal) + 75% RD_{NK} drip fertigation at 23, 30, 37, 43, 51, 58 and 65 DAP	92.69	48.71	3.44	4.08	8.54	13.52	15.63	41.77
50% RD_{NK}(basal) + 50% RD_{NK} drip fertigation at 23, 30, 37 43, 51, 58 and 65 DAP	93.11	47.67	3.46	3.56	7.14	13.07	18.16	41.94
100% RD_{NK} drip fertigation at 9,16, 23, 30, 37, 43, 51, 58 and 65 DAP	92.99	48.57	3.49	4.10	7.70	13.74	17.27	42.83
Conventional method	91.51	45.61	3.60	4.57	7.54	11.61	12.15	35.86
SE(m)	0.33	0.64	0.15	0.30	0.28	0.71	0.71	0.61
C.D. (P=0.05)	1.18	2.27	NS	NS	NS	NS	2.51	1.58
Varieties								
KufriBadshah	92.63	57.84	3.52	3.69	8.06	12.90	15.40	40.05
KufriPukhraj	92.18	42.60	3.39	4.35	8.08	13.25	15.68	41.36
KufriPushkar	92.93	42.47	3.58	4.20	7.05	12.80	16.33	40.38
SE(m)	0.30	0.78	0.13	0.22	0.41	0.33	0.37	0.26
C.D. (P=0.05)	NS	2.34	NS	NS	NS	NS	NS	NS

Crop productivity

Highest crop productivity (407.85 kg/ha/day) was noted under 100% RD_{NK} through drip fertigation at 9, 16, 23, 30, 37, 43, 51, 58 and 65 DAP, which was significantly higher than conventional method but was statistically on par with other drip fertigation treatments [Table-2]. The increment in crop productivity due to 100% RD_{NK} through drip fertigation at 9, 16, 23, 30, 37, 43, 51, 58 and 65 DAP was at the tune of 19.41% over the conventional method. This could be attributed to significantly higher total tuber yield in 100% RD_{NK} through drip fertigation at 9, 16, 23, 30, 37, 43, 51, 58 and 65 DAP over conventional method under same crop duration. Ali and Al-Juthery [2] observed much higher increment in total tuber yield

under 100 % drip fertigation of mineral fertilizer than furrow method at 100% soil application of mineral fertilizer.

In case of different varieties of potato, no variety emerged out as significantly superior among them with respect to crop productivity [Table-2]. However, highest crop productivity was recorded under Kufri Pukhraj, which was followed by Kufri Pushkar and Kufri Badshah, respectively.

Water and nutrient use efficiency

All drip fertigation treatments had statistically equivalent water use efficiency (WUE) and they markedly improved WUE over conventional method [Table-2]. Application of 100% RD_{NK} through drip fertigation at 9, 16, 23, 30, 37, 43, 51, 58 and 65 DAP recorded highest WUE (100.76 kg/ha/mm), which had 96.68% higher WUE than conventional method. Sasani *et al*. [13] also observed that higher WUE under drip irrigation than conventional irrigation method. Limited water supply in drip irrigation minimizes the leaching loss of nutrients especially N, which enabled shallow rooted potato to utilizes nutrients more rapidly and efficiently for its growth, development and yield. Consequently, higher total tuber yield under reduced water consumption could be ascribed as possible reason for higher water use efficiency in drip fertigation. Many researchers were of the similar views and reported drip irrigation as one of the methods of optimizing water for crop production with greater yield per unit area and yield per unit volume of water than conventional furrow irrigation [5,11,15]. Similar trend was also observed in case of nutrient use efficiency (NUE) of N, P and K, in which all drip fertigation methods registered statistically higher NUE than conventional method, highest being recorded under 100% RD_{NK} through drip fertigation at 9, 16, 23, 30, 37, 43, 51, 58 and 65 DAP (77.86 kg tuber/kg of nutrients applied). Uniform distribution and increased availability of water and nutrients directly at root zone through drip fertigation could have led to better growth and uptake of nutrients. This might have led to markedly higher tuber yield under 25% lower dose of fertilizers than conventional method, thus ultimately gave higher NUE. Shedeed *et al.*[14] supported the findings and reported highest NUE under 100% fertigation of fertilizers in tomato.

Table-2 *Effect of drip fertigation methods and varieties on crop productivity, water and nutrient use efficiency and economics of potato (pooled data of three years)*

Treatment	Crop productivity (kg/ha/day)	WUE (kg/ha/mm)	NUE (kg tuber yield/kg nutrient applied)	Net return (₹/ha)	BCR
Drip fertigation methods					
25% RD_{NK} (basal) + 75% RD_{NK} drip fertigation at 23, 30, 37, 43, 51, 58 and 65 DAP	397.78	98.28	75.94	113,371	1.28
50% RD_{NK} (basal) + 50% RD_{NK} drip fertigation at 23, 30, 37 43, 51, 58 and 65 DAP	399.39	98.67	76.25	114,192	1.29
100% RD_{NK} drip fertigation at 9,16, 23, 30, 37, 43, 51, 58 and 65 DAP	407.85	100.76	77.86	118,486	1.34
Conventional method	341.55	51.23	51.97	85,634	0.98
SE(m)	3.49	0.84	0.55	-	0.02
C.D. (P=0.05)	11.40	2.97	1.94	-	0.05
Varietiess					
KufriBadshah	381.41	85.97	69.52	105265	1.19
KufriPukhraj	393.93	88.93	71.85	111619	1.26
KufriPushkar	384.59	86.81	70.15	106877	1.21
SE(m)	2.88	0.86	0.91	-	0.03
C.D. (P=0.05)	NS	NS	NS	-	NS

WUE of potato did not varied significantly due to different varieties [Table-2]. However, highest WUE was recorded under Kufri Pukhraj (88.93 kg/ha/mm), which was followed by Kufri Pushkar (86.81 kg/ha/mm), and Kufri Badshah (85.97 kg/ha/mm). Highest total tuber yield under same amount of irrigation water consumption could have resulted in highest water use efficiency in Kufri Pukhraj. Similarly, variation in NUE due to varieties was non-significant [Table-2]. Among varieties, Kufri Pukhraj had highest NUE (71.85 kg tuber/kg of N, P_2O_5 and K_2O applied), while Kufri Badshah registered lowest NUE. Different varieties of potato exhibit variable responses to same or different nutrient and other input managements. Kufri Pukhraj had been reported for its high NUE by many researchers [8,16].

Economics

All drip fertigation methods had higher net return than conventional method with range of ₹ 27737-32852/ha, respectively [Table-2]. Supply of 100% RD_{NK} through drip fertigation at 9, 16, 23, 30, 37, 43, 51, 58 and 65 DAP had highest net return (₹ 118486/ha) among all fertilization methods. Increment in net return due to drip fertigation of 100% RD_{NK} at 9, 16, 23, 30, 37, 43, 51, 58 and 65 DAP, 50% RD_{NK} as basal + 50% RD_{NK} through drip fertigation at 23, 30, 37 43, 51, 58 and 65 DAPand 25% recommended dose of N and K (RD_{NK}) as basal + 75% RD_{NK} through drip fertigation at 23, 30, 37, 43, 51, 58 and 65 DAP were in the tune of ₹ 32852/ha, ₹ 28558/ha and ₹27737/ha, respectively over the conventional method. Similarly, marked increase in benefit-cost ratio (BCR) was recorded due to drip fertigation treatments over the conventional method [Table-2]. Maximum value of BCR (1.34) was observed under application of 100% RD_{NK} through drip fertigation at 9, 16, 23, 30, 37, 43, 51, 58 and 65 DAP, which was significantly superior over rest of treatments. Significant increase in total tuber yield with much higher net return under drip fertigation might have resulted in higher BCR over conventional method. Patel *et al*. [12] also corroborated the findings and reported higher net return under drip fertigation of potato than other methods.

On comparing different varieties of potato, Kufri Pukhraj had with maximum value of net return (₹ 111619/ha) under same total cost of cultivation, which was followed by Kufri Pushkar and Kufri Badshah, respectively [Table-2]. Highest total tuber yield in Kufri Pukhraj could have maximum net return under same cost of cultivation among all varieties. However, non-significant difference in BCR was observed among various varieties of potato [Table-2]. Maximum value of BCR was observed under Kufri Pukhraj, which was slightly higher than Kufri Pushkar and Kufri Badshah, respectively.

Based on above findings, it can be concluded that application of 100% recommended dose of N and K through drip at 9,16, 23, 30, 37, 43, 51, 58 and 65 DAP in potato should be followed to enhance growth, tuber yield, crop productivity, water and nutrient use efficiency thus ultimately maximizing net return and benefit-cost ratio. Also, adoption of drip fertigation will ensure higher profitability with opportunity to lower nutrient and water requirements of potato over conventional method. Since all three-potato varieties were equivalent in terms of yield, crop productivity, water and nutrient use efficiency and economic remuneration, anyone of them can be used for profitable potato production under drip fertigation.

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