International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(5): 604-611

Received: 09-07-2019
Accepted: 13-08-2019

Lavlesh
Ph.D. Scholar, Department of Vegetable Science, G.B. Pant University of agriculture and technology, Pantnagar, Uttarakhand, India

Manoj Raghav
Professor and Head, Department of Vegetable Science, G.B. Pant University of agriculture and technology, Pantnagar, Uttarakhand, India

PK Singh
Professor, Department of Irrigation and Drainage Engineering, G.B. Pant University of agriculture and technology, Pantnagar, Uttarakhand, India

Poonam Gautam
S.R.O., Department of Soil Science, G.B. Pant University of agriculture and technology, Pantnagar, Uttarakhand, India

Lalit Bhatt
J.R.O. Department of Vegetable Science, G.B. Pant University of agriculture and technology, Pantnagar, Uttarakhand, India

SB Bhardwaj
Statistician, Directorate of Experiment station, G.B. Pant University of agriculture and technology, Pantnagar, Uttarakhand, India

Sajal Debbarma
Ph.D. Scholar, Department of Vegetable Science, G.B. Pant University of agriculture and technology, Pantnagar, Uttarakhand, India

Correspondence
Lavlesh
Ph.D. Scholar, Department of Vegetable Science, G.B. Pant University of agriculture and technology, Pantnagar, Uttarakhand, India

Influence of fertigation system, fertigation scheduling and fertigation treatment on plant growth characters of potato (*Solanum tuberosum* L.)

Lavlesh, Manoj Raghav, PK Singh, Poonam Gautam, Lalit Bhatt, SB Bhardwaj and Sajal Debbarma

Abstract
In order to evaluate the influence of fertigation system and fertigation scheduling and fertigation treatment on plant growth characters of potato crop, a field experiment was conducted during the *rabi* season of 2016-17 and 2017-18 at Vegetable Research Centre, G.B. Pant University of Agriculture & Technology, Pantnagar, Udham Singh Nagar, Uttarakhand. The experimental field was laid out in Three Factorial Randomized Block Design with one additional treatment consisting of thirty seven treatment combinations with three replications. The Influence of fertigation system and fertigation scheduling and fertigation treatment on plant growth characters of Potato were studied. Growth characters like emergence per cent, plant height, fresh haulm weight, dry haulm weight, fresh root weight and dry root weight were significantly influence by fertigation system, different fertigation scheduling, different rates of fertigation treatment at 30 days after planting (DAP). Sub-surface fertigation system was found better in improving germination, plant height, fresh haulm weight, dry haulm weight, fresh root weight and dry root weight. Fertigation treatment T_1 (120% of RDF) was found to be better in improving plant growth characters.

Keywords: Drip fertigation, potato fertigation**,** fertigation scheduling, surface fertigation

Introduction

Potato (*Solanum tuberosum* L.) is among the most important food crop of the world. It is an important temperate crop which has been adopted well for cultivation under sub-tropical conditions. Potato was earlier thought to be confined mainly to the developed nations. Yet until the 16th century it was unknown to the people of Europe, Asia, Africa and North America. The world potato sector is undergoing major changes, until the early 1990, most potatoes were grown and consumed in developed countries like Europe, North America and countries of the former Soviet Union. Developing countries today produce around 58.84% of the world's potatoes (Anonymous, 2008) [1]. In India, potato is being cultivated on 2.14 million ha area with a total annual production of 51.31 million tonnes and productivity of 23.95 t/ha (Anonymous, 2018a) [3]. Yield of potato depends on the biogenetical potential of variety and the cultural practices to which crop plants are subjected. For balanced plant development and to realise the yield potential of a cultivar, it should be grown under ideal environmental condition. Out of the several constraints of potato production, water and nutrient management pose a serious threat. They not only hamper the crop plants growth but also significantly affects its yield potential. The limited groundwater resources are the major constraint for irrigation water supply.

The present status of groundwater in many States of India has reached to a level of crisis. The solutions of this serious issue are demanding an immediate attention at many fronts. The ground water level data for January 2016 indicate that out of the total 14974 wells analysed, 4958 (33 per cent) wells are showing water level in the depth range of 2-5 m bgl (metres below ground level), 5342 (36 per cent) wells are showing water level in the depth range of 5-10 m bgl, 2498 (17 per cent) wells are showing water level in the depth range of 10-20 m bgl (Annonymous, 2016a) [2]. Efficient use of fertilizer and water is highly critical to sustained agricultural production. Fertilizers applied under traditional methods are generally not utilized efficiently by the crop. In fertigation, nutrients are applied through emitters directly into the zone of maximum root activity and consequently fertilizer-use efficiency can be improved over conventional method of fertilizer application (Malik *et al*., 1994) [12].

Sanchita *et al.* (2010) [16] reported that plant height, branch number of tomato were highest with cent per cent fertigation of recommended dose of N & K at the rate of 75 and 60 kg/ha, respectively. Badr *et al.* (2010) [4] reported that in terms of soil water availability to plants, subsurface drip provided more favourable growth conditions for plant growth compared to surface drip irrigation.

Material and Methods

The present research work was carried out during the *rabi* season of 2016-2017 and 2017-2018 at Vegetable Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, District- Udham Singh Nagar, Uttarakhand.
The experiment was laid out in Three Factorial Randomized Block Design with one additional treatment consisting of thirty seven treatment combinations with three replications (details of treatment combinations shown in table 1).

Treatment details

A) Factor A: Fertigation system

S_1: Surface fertigation
S_2: Sub surface fertigation

B) Factor B: Fertigation Scheduling

Schedule 1: S_1

Crop growth stage	No of splits	Total nutrients supplied		
		N	P	K
Stage I (15-30 DAP)	4	15 percent of fertigation treatment	10 percent of fertigation treatment	10 percent of fertigation treatment
Stage II (30-45 DAP)	4	40 percent of fertigation treatment	40 percent of fertigation treatment	40 percent of fertigation treatment
Stage III (45-60 DAP)	4	40 percent of fertigation treatment	40 percent of fertigation treatment	40 percent of fertigation treatment
Stage IV (60 -75DAP)	4	15 percent of fertigation treatment	10 percent of fertigation treatment	10 percent of fertigation treatment

Schedule 2: S_2

Crop growth stage	No of splits	Total nutrients supplied		
		N	P	K
Stage I (15-30 DAP)	4	25 percent of fertigation treatment	25 percent of fertigation treatment	25 percent of fertigation treatment
Stage II (30-45DAP)	4	25 percent of fertigation treatment	25 percent of fertigation treatment	25 percent of fertigation treatment
Stage III (45-60 DAP)	4	25 percent of fertigation treatment	25 percent of fertigation treatment	25 percent of fertigation treatment
Stage IV (60-75 DAP)	4	25 percent of fertigation treatment	25 percent of fertigation treatment	25 percent of fertigation treatment

Schedule 3: S_3

Crop growth stage	No of splits	Total nutrients supplied		
		N	P	K
Stage I (15-30 DAP)	4	20 percent of fertigation treatment	20 percent of fertigation treatment	20 percent of fertigation treatment
Stage II (30-45DAP)	4	30 percent of fertigation treatment	30 percent of fertigation treatment	30 percent of fertigation treatment
Stage III (45-60 DAP)	4	30 percent of fertigation treatment	30 percent of fertigation treatment	30 percent of fertigation treatment
Stage IV (60-75 DAP)	4	20 percent of fertigation treatment	20 percent of fertigation treatment	20 percent of fertigation treatment

* The above fertilizer schedule is made after 10% of fertigation treatment applied as starter dose and considering rest 90% fertigation treatment as 100%.

C) Factor C: Fertigation treatment

1. T_1 : 120 per cent of RDF
2. T_2 : 100 per cent of RDF
3. T_3 : 80 per cent of RDF
4. T_4 : 60 per cent of RDF
5. T_5 : 40 per cent of RDF
6. T_6 : Without fertilizer

D) Additional treatment: 1

T_7 : Farmer's Practice at 100 per cent of RDF

Table 1: Detail of treatment combinations

S. No.	Treatment combination	Treatment detail	S. No.	Treatment combination	Treatment detail
1	$S_1L_1T_1$	Surface drip with 120% of RDF*	19	$S_2L_1T_1$	Sub-surface drip with 120% of RDF
2	$S_1L_1T_2$	Surface drip with 100% of RDF	20	$S_2L_1T_2$	Sub-surface drip with 100% of RDF
3	$S_1L_1T_3$	Surface drip with 80% of RDF	21	$S_2L_1T_3$	Sub-surface drip with 80% of RDF
4	$S_1L_1T_4$	Surface drip with 60% of RDF	22	$S_2L_1T_4$	Sub-surface drip with 60% of RDF
5	$S_1L_1T_5$	Surface drip with 40% of RDF	23	$S_2L_1T_5$	Sub-surface drip with 40% of RDF
6	$S_1L_1T_6$	Surface drip without fertilizer	24	$S_2L_1T_6$	Sub-surface drip without fertilizer
7	$S_1L_2T_1$	Surface drip with 120% of RDF	25	$S_2L_2T_1$	Sub-surface drip with 120% of RDF
8	$S_1L_2T_2$	Surface drip with 100% of RDF	26	$S_2L_2T_2$	Sub-surface drip with 100% of RDF
9	$S_1L_2T_3$	Surface drip with with 80% of RDF	27	$S_2L_2T_3$	Sub-surface drip with 80% of RDF
10	$S_1L_2T_4$	Surface drip with 60% of RDF	28	$S_2L_2T_4$	Sub-surface drip with 60% of RDF
11	$S_1L_2T_5$	Surface drip with 40% of RDF	29	$S_2L_2T_5$	Sub-surface drip with 40% of RDF
12	$S_1L_2T_6$	Surface drip without fertilizer	30	$S_2L_2T_6$	Sub-surface drip without fertilizer
13	$S_1L_3T_1$	Surface drip with 120% of RDF	31	$S_2L_3T_1$	Sub-surface drip with 120% of RDF
14	$S_1L_3T_2$	Surface drip with 100% of RDF	32	$S_2L_3T_2$	Sub-surface drip with 100% of RDF
15	$S_1L_3T_3$	Surface drip with 80% of RDF	33	$S_2L_3T_3$	Sub-surface drip with 80% of RDF
16	$S_1L_3T_4$	Surface drip with 60% of RDF	34	$S_2L_3T_4$	Sub-surface drip with 60% of RDF
17	$S_1L_3T_5$	Surface drip with 40% of RDF	35	$S_2L_3T_5$	Sub-surface drip with 40% of RDF
18	$S_1L_3T_6$	Surface drip without fertilizer	36	$S_2L_3T_6$	Sub-surface drip without fertilizer
			37	T_7	Farmer's Practice at 100 per cent of RDF

The fertilizers were applied through drip system on twice a week (i.e. at 4 days interval) basis using overhead tank system. Farmer's practice is the conventional method of cultivation and fertilizers were applied using band placement method with furrow irrigation. Different plant growth related parameters were recorded as below.

Emergence the number of plants emerged out in each plot were counted at 30 DAP and per cent was calculated by the following formula

$$\text{Emergence per cent} = \frac{\text{Number of tuber emergence}}{\text{Number of tuber planted}} \times 100$$

The height of each tagged plant was measured successively at 30 and 45 DAP from the base to the tip of longest leaf by stretching. It was measured with the help of meter scale and the data were recorded in centimeter (cm). The mean plant height was calculated by summing up the length of five plants and dividing by five. Fresh and dry weight of haulm and root was determined by uprooting two plants from sampling area of each plot at 30 DAP and weighed. Roots weighed after cleaning with water. The fresh weight was recorded in grams. The plant samples taken from each plot were then dried in sun for 7-8 hours/ day for 2-3 days and then dried in oven at about 55-60 ^{0}C temperature, till the samples attained a constant weight. After drying, the samples weighed and dry weight recorded in grams per plant.

The experimental data was analyzed using the "Analysis of Variance Technique" for Factorial Randomized Block Design (FRBD) with one extra treatment as per the procedures for factorial design with extra additional treatments given by Rangaswamy (2006) [15]. Wherever the effects exhibited significance at 5 per cent level of significance, critical differences were calculated.

Result and Discussion

Effect of fertigation system, fertigation scheduling and fertigation treatment on emergence per cent

Emergence count was done at 30 days after planting (DAP). The data pertaining to the emergence per cent have been presented in table 2.

It is evident from data (Table 2) that the effect of fertigation system was found significant on emergence per cent of potato in 2016-17 and 2017-18. The maximum emergence per cent (99.73) and (99.78) was recorded in sub-surface fertigation (S_2) in 2016-17 and 2017-18, respectively. The minimum emergence per cent (99.36) and (99.46) was recorded in surface fertigation (S_1) in 2016-17 and 2017-18, respectively.

The significant effect of fertigation scheduling on emergence per cent (Table 2) was observed in 2016-17 whereas, in 2017-18 it was found non-significant. In 2016-17, schedule 3 (L_3) found to have maximum emergence per cent (99.78) which was statistically at par with schedule 2 (L_2) and minimum emergence per cent (99.30) was recorded in schedule 1 ($L_{1,}$), respectively.

The effect of fertigation treatment on emergence per cent (Table 2) was found significant in 2017-18 whereas, it was found non-significant in 2016-17. In 2017-18 maximum emergence per cent (99.85) was observed in both treatment T_5 (40% of RDF) and T_3 (80% of RDF) which was statistically at par with treatments T_2 (100% of RDF) and T_4 (60% of RDF) whereas, minimum emergence value (99.19) was recorded in T_1 (120% of RDF) which was statistically at par with T_6 (Without fertilizer).

Significant differences was recorded in farmers practice v/s fertigation treatment with maximum emergence per cent (99.54) and (99.62) found in fertigation treatment in 2016-17 and 2017-18 whereas, minimum emergence per cent (94.67) and (95.56) recorded in farmer's practice (T_7) in 2016-17 and 2017-18, respectively.

The interaction effect of A×B viz., fertigation system × fertigation scheduling and interaction B×C *viz*., fertigation scheduling × fertigation treatment, A×C *viz*., fertigation system × fertigation treatment and A×B×C *viz*., fertigation system × fertigation scheduling × fertigation treatment on emergence per cent was found non- significant in 2016-17 and 2017-18.

Table 2: Effect of fertigation system, fertigation scheduling and fertigation treatment on emergence per cent and plant height of potato at 30 DAP

Factors	**Emergence %**		**Plant height (cm)**	
A : Fertigation system	**2016-17**	**2017-18**	**2016-17**	**2017-18**
Surface fertigation (S_1)	99.36	99.46	37.21	35.73
Sub-surface fertigation (S_2)	99.73	99.78	38.07	36.16
S.Em.±	0.09	0.10	0.25	0.25
C.D. at 5%	0.26	0.29	0.72	NS
B : Fertigation scheduling				
Schedule 1 (L_1)	99.30	99.44	38.04	36.63
Schedule 2 (L_2)	99.56	99.67	38.16	36.35
Schedule 3 (L_3)	99.78	99.74	36.71	34.86
S.Em.±	0.11	0.12	0.31	0.31
C.D. at 5%	0.32	NS	0.88	0.87
C : Fertigation treatment				
120 per cent of RDF (T_1)	99.26	99.19	42.85	40.86
100 per cent of RDF (T_2)	99.56	99.78	41.33	39.46
80 per cent of RDF (T_3)	99.70	99.85	40.12	38.06
60 per cent of RDF (T_4)	99.70	99.70	37.94	36.16
40 per cent of RDF (T_5)	99.78	99.85	37.04	35.73
Without fertilizer (T_6)	99.26	99.33	26.56	25.42
S.Em.±	0.16	0.18	0.44	0.44
C.D. at 5%	NS	0.49	1.24	1.24
Farmer's practice vs Fertigation treatment				
Farmer's practice (T_7)	94.67	95.56	32.31	30.67
Fertigation treatment	99.54	99.62	37.64	35.95
S.Em.±	0.28	0.31	0.77	0.77

C.D. at 5%	0.80	0.87	2.18	2.17
Interaction effect				
A×B	0.16	0.18	0.44	0.44
C.D. at 5%	NS	NS	NS	NS
B×C	0.28	0.30	0.76	0.76
C.D. at 5%	NS	NS	NS	NS
A×C	0.28	0.30	0.62	0.62
C.D. at 5%	NS	NS	1.76	NS
A×B×C	0.39	0.43	1.08	1.07
C.D. at 5%	NS	NS	3.04	3.03

Although, the emergence of tubers takes place due to the food material already stored in the seed tuber which gave initial boost to the emerging plants, however, application of fertigation at 15 DAP might helped in creating optimum conditions in soil around the seed tubers which helps in increasing the emergence per cent in fertigation treatments. Kumar *et al.* 2018 [10] also reported higher emergence in fertigated treatment over furrow irrigation.

There was no clear trend observed under fertgation treatment effects on emergence per cent. Maan *et al.* (2018) [11] also reported an increase in emergence per cent with increasing the fertilizer dose upto 100% of recommended dose of nitrogen and thereafter it decreases.

Effect of fertigation system, fertigation scheduling and fertigation treatment on Plant height

Plant height (cm) as affected by different fertigation treatments have been presented in table 2. The various fertigation treatments significantly influence the plant height at 30 DAP. The effect of fertigation system on plant height (Table 2) was found significant in 2016-17 whereas, found non-significant in 2017-18. In 2016-17 the maximum plant height recorded in sub-surface fertigation (S_2) (38.07) cm whereas, minimum plant height (37.21) cm was recorded in surface fertigation (S_1).

The effect of fertigation scheduling on plant height (Table 2) was observed significant in 2016-17 and 2017-18. In 2016-17 the maximum plant height was found in schedule 2 (L_2) which was found statistically at par with schedule 1 (L_1) and minimum plant height was found in schedule 3 (L_3). In 2017-18 schedule 1 (L_1) found to have maximum plant height of 36.63 cm respectively and was found statistically at par with schedule 2 (L_2) while minimum height 34.86 cm was found in schedule 3 (L_3), respectively.

The effect of fertigation treatment on plant height (Table 2) was observed significant in 2016-17 and 2017-18. In 2016-17 and 2017-18 the maximum plant height 42.85 cm respectively was observed in Treatment T_1 (120% of RDF) which was statistically superior over other fertigation treatment whereas, minimum height 26.56 and 25.42 cm was recorded in T_6 (without fertilizer) in 2016-17 and 2017-18, respectively.

Farmers practice v/s fertigation treatment (Table 2) was found significant in 2016-17 and 2017-18 with maximum plant height (37.64) and (35.95) cm respectively found in fertigation treatment whereas, minimum (32.31) and (30.67) cm found in farmer's practice (T_7).

The interaction effect of A×B viz., fertigation system × fertigation scheduling (Table 2) and interaction B×C *viz*., fertigation scheduling × fertigation treatment on plant height was found non-significant in both the years.

Table 3: Effect of fertigation system × fertigation treatment interaction on plant height (cm) at 30 DAP

Fertigation treatment	2016-17		2017-18	
	Fertigation system		Fertigation system	
	S_1	S_2	S_1	S_2
120 per cent of RDF (T_1)	42.93	42.77	41.17	40.54
100 per cent of RDF (T_2)	41.12	41.55	39.72	39.19
80 per cent of RDF (T_3)	40.42	39.82	37.50	38.61
60 per cent of RDF (T_4)	37.91	37.97	36.04	36.28
40 per cent of RDF (T_5)	35.99	38.10	35.01	36.44
Without fertilizer (T_6)	24.91	28.20	24.92	25.92
S.Em.±	0.62		0.62	
C.D. at 5%	1.76		NS	

The interaction effect of A×C *viz*., fertigation system × fertigation treatment was found significant on plant height (Table 3) in 2016-17 but found non-significant in 2017-18. In 2016-17 the maximum plant height value (42.93) cm was observed in S_1T_1, which was found statistically at par with S_2T_1 (42.77) and S_2T_2 (41.55) whereas, the minimum height (24.91) cm was recorded in S_1T_6.

The interaction A×B×C *viz* fertigation system × fertigation scheduling × fertigation treatment (Table 4) on plant height (cm) was found significant in 2016-17 and 2017-18 with maximum value (45.29) and (43.63) cm in $S_2L_1T_1$ respectively. In 2016-17 maximum height was found $S_2L_1T_1$ which was found statistically at par with $S_1L_2T_1$ (43.16), $S_1L_3T_1$ (43.69) and $S_2L_2T_2$ (42.99) and minimum height (24.71) was found in $S_1L_1T_6$ which was statistically at par with $S_1L_2T_6$ (25.18), $S_1L_3T_6$ (24.86) and $S_2L_3T_6$ (26.29). In 2017-18, $S_2L_1T_1$ was found statistically at par with $S_1L_2T_1$ (41.58), $S_1L_3T_1$ (42.08) and $S_2L_2T_2$ (41.33) and minimum height (23.42) was found in $S_1L_2T_6$ which was statistically at par with $S_1L_1T_6$ (26.25), $S_1L_3T_6$ (25.08), $S_2L_1T_6$ (26.33) and $S_2L_3T_6$ (24.58).

Table 4: Effect of fertigation system × fertigation scheduling× fertigation treatment interaction on plant height (cm) at 30 DAP

Fertigation treatment	2016-17						2017-18					
	Fertigation system						Fertigation system					
	Surface fertigation (S_1)			Sub-Surface fertigation (S_2)			Surface fertigation (S_1)			Sub-Surface fertigation (S_2)		
	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3	L_1	L_2	L_3
T_1	41.96	43.16	43.69	45.29	41.23	41.79	39.83	41.58	42.08	43.63	39.50	38.50
T_2	41.49	41.29	40.58	41.39	42.99	40.27	39.75	40.25	39.17	38.50	41.33	37.75
T_3	40.89	40.12	40.24	40.17	40.13	39.17	39.08	39.58	33.83	39.83	38.50	37.50
T_4	39.56	39.92	34.26	39.42	36.93	37.57	38.08	36.83	33.20	37.83	35.00	36.00
T_5	34.33	38.17	35.46	39.28	38.59	36.42	32.75	36.50	35.78	37.67	36.83	34.83
T_6	24.71	25.18	24.86	28.06	30.27	26.29	26.25	23.42	25.08	26.33	26.83	24.58

S.Em.±	1.08	1.07
C.D. at 5%	3.04	3.03

Maximum plant height was observed under sub-surface fertigation system as compared to surface fertigation system could be attributed to the availability of better soil moisture and their retention due to reduced evaporation and better availability of nutrients due to placement of drip line within the crop root zone below the soil surface which enables crop to utilise water and nutrients effectively and therefore increased the plant height. Above findings was in agreement with Badr *et al.*, (2010) [4].

The higher plant height was obtained in fertigation scheduling 1 (L_1) and scheduling 2 (L_2) than scheduling 3 (L_3) at 30 DAP which might be due to the increased application of fertilizers through fertigation during the active plant growth period which results into higher plant height. The above findings are in agreement with Pooja (2017) [13].

Plant height increases with increasing the fertigation treatment may be due to the fact that availability of nutrients consistently increases through fertigation which favours the uptake of nutrients and subsequently promote the vegetative growth of plant in terms of height. The above findings are in agreement with Kumar *et al*. 2018 [10].

Effect of fertigation system, fertigation scheduling and fertigation treatment on fresh haulm weight

The data pertaining to fresh haulm weight (g) have been presented in table 5. It is evident from the table that the fresh haulm weight was affected significantly by different fertigation treatments at 30 DAP.

Table 5: Effect of fertigation system, fertigation scheduling and fertigation treatment on fresh haulm weight and dry haulm weight (g) at 30 DAP

Factors	Fresh haulm weight (g)		Dry haulm weight (g)	
A : Fertigation system	**2016-17**	**2017-18**	**2016-17**	**2017-18**
Surface fertigation (S_1)	79.94	79.69	3.38	3.87
Sub-surface fertigation (S_2)	96.75	98.67	4.12	4.40
S.Em.±	2.99	2.78	0.14	0.13
C.D. at 5%	8.42	7.84	0.39	0.37
B : Fertigation scheduling				
Schedule 1 (L_1)	83.28	84.18	3.66	4.01
Schedule 2 (L_2)	84.78	87.82	3.43	4.02
Schedule 3 (L_3)	96.97	95.54	4.16	4.39
S.Em.±	3.66	3.41	0.17	0.16
C.D. at 5%	10.31	NS	0.48	NS
C : Fertigation treatment				
120 per cent of RDF (T_1)	111.39	109.07	4.82	4.90
100 per cent of RDF (T_2)	103.56	104.13	4.17	4.72
80 per cent of RDF (T_3)	90.42	93.04	3.93	4.34
60 per cent of RDF (T_4)	86.67	89.18	3.72	4.04
40 per cent of RDF (T_5)	77.61	75.96	3.28	3.80
Total control (T_6)	60.43	63.70	2.58	3.03
S.Em.±	5.17	4.82	0.24	0.23
C.D. at 5%	14.58	13.58	0.68	0.65
Farmer's practice vs Fertigation treatment				
Farmer's practice (T_7)	98.17	100.71	3.99	4.44
Rest	88.34	89.18	3.75	4.14
S.Em.±	9.08	8.46	0.43	0.40
C.D. at 5%	NS	NS	NS	NS
Interaction effect				
A×B	5.17	4.82	0.24	0.23
C.D. at 5%	NS	NS	NS	NS
B×C	8.96	8.34	0.42	0.40
C.D. at 5%	NS	NS	NS	NS
A×C	7.31	6.81	0.34	0.33
C.D. at 5%	NS	NS	NS	NS
A×B×C	12.67	11.80	0.59	0.56
C.D. at 5%	NS	NS	NS	NS

At 30 DAP the effect of fertigation system (Table 5) on fresh haulm weight (g) was found significant in 2016-17 and 2017-18 in which the maximum fresh haulm weight (96.75) and (98.67) g was found in sub-surface fertigation (S_2) whereas, lowest was observed in surface fertigation (S_1) with (79.94) and (79.69) g respectively.

The effect of fertigation scheduling on fresh haulm weight (Table 5) was observed significant in 2016-17 whereas, in 2017-18 it was found non-significant. Schedule 3 (L_3) found to have maximum fresh haulm weight (96.97) g in 2016-17 whereas, minimum fresh haulm weight (83.28) g was found in schedule 1 (L_1) which was observed statistically at par with schedule 2 (L_2) (84.78).

The effect of different fertigation treatment on fresh haulm weight (Table 5) was observed significant in 2016-17 and 2017-18. In 2016-17 and 2017-18, the maximum fresh haulm weight observed in treatment T_1 (120% of RDF) (111.39) and (109.07) g respectively which was found statistically at par with T_2 (100% of RDF) (103.56) and (104.13)g, respectively whereas, treatment T_6 (without fertilizer) found to have minimum fresh haulm weight with (60.43) and (63.7) g in 2016-17 and 2017-18, respectively.

Farmers practice v/s fertigation treatment data was found (Table 5) non-significant in 2016-17, 2017-18 and pooled analysis over the years.
The interaction effect of A×B *viz*., fertigation system × fertigation scheduling, B×C *viz*., fertigation scheduling × fertigation treatment, A×C *viz*., fertigation system × fertigation treatment and A×B×C *viz* fertigation system × fertigation scheduling × fertigation treatment on fresh haulm weight (Table 5) was found non-significant in both the years as well as in pooled analysis over the years.
In early stages of crop, higher fresh haulm weight was recorded in sub-surface fertigation than surface fertigation which might be due to higher nutrient uptake and its translocation to shoots whereas, in later stage of crop the higher fresh haulm weight recorded in surface fertigation. It might be due to early nutrient translocation from source to the sink i.e., tubers under sub-surface. Darwish *et al*. (2004) [5] also resported potassium translocation from shoots to tubers at physiological maturity under fetigation.
Significantly higher fresh haulm weight was observed under schedule 3 in early stages of crop growth, which might be due to the optimum nutrient availability during 1st stage and 2nd stage of crop growth under schedule 3.
Fresh haulm weight increases with increase in the fertilizer dose under fertigation as it help in enhancing nutrients uptake by better root development in fertigation treatments than farmers practice. Above findings was in agreement with El-Abedin *et al.* 2017 [6].

Effect of fertigation system, fertigation scheduling and fertigation treatment on dry haulm weight
The data pertaining to dry haulm weight (g) have been presented in table 5. It is evident from the table that the dry haulm weight was affected significantly by different fertigation treatments at 30 DAP. The effect of fertigation system on dry haulm weight was found significant in 2016-17 and 2017-18 in which the maximum dry haulm weight (4.12) and (4.4) g found in sub-surface fertigation (S_2) whereas, lowest observed in surface fertigation (S_1) with (3.38) and (3.87) g, respectively.
The effect of fertigation scheduling on dry haulm weight (Table 5) was observed significant in 2016-17 whereas, in 2017-18 it was found non-significant. In 2016-17, schedule 3 (L_3) found to have maximum dry haulm weight (4.16) g whereas, minimum dry haulm weight (3.43) was recorded in schedule 2 (L_2).
The effect of different fertigation treatment on dry haulm weight (Table 5) was observed significant in 2016-17 and 2017-18. In 2016-17 and 2017-18, the maximum dry haulm weight observed in treatment T_1 (120% of RDF) (4.82) and (4.9) g whereas, treatment T_6 (without fertilizer) found to have minimum fresh haulm weight with (2.58) and (3.03) g in 2016-17 and 2017-18, respectively. In 2016-17 the maximum dry haulm weight of T_1 (120% of RDF) was found statistically at par with T_2 with values (4.17) g whereas, in 2017-18 the maximum dry haulm weight of T_1 (120% of RDF) was found statistically at par with T_2 (4.72) and T_3 (4.34) g.
Farmers practice v/s fertigation treatment data was found (Table 5) non-significant in 2016-17 and 2017-18.
The interaction effect of A×B *viz*., fertigation system × fertigation scheduling, B×C *viz*., fertigation scheduling × fertigation treatment, A×C *viz*., fertigation system × fertigation treatment and A×B×C *viz* fertigation system × fertigation scheduling × fertigation treatment (Table 5) on dry haulm weight was found non-significant in both the years.
In early stages of crop growth the higher dry haulm weight was recorded under sub-suraface fertigation, which might be due to better nutrient uptake by roots and its translocation to the plant shoots whereas, in later stage of crop growth higher dry haulm weight was observed under surface fertigation over the sub-surface fertigaion. It might be due to higher nutrient translocation to sink (tuber) as compared to source (haulm). Above findings was in agreement with Darwish *et al*. (2004) [5].
In early stage of crop growth 30 DAP higher dry haulm weight was recorded under schedule 3 which might be due to the balance application of nitrogen fertilizer. Similar findings reported by Maan *et al*. (2018) [11].
Dry haulm weight increases with increase in fertigation doses as it provides more nutrients in root zone and better root development help in more nutrients uptake under fertigation than farmers practice. Hence, more dry matter accumulation occurs under higher fertigation treatment. Above findings was in agreement with El-Abedin *et al.* (2017) [6].

Effect of fertigation system, fertigation scheduling and fertigation treatment on fresh root weight
The data pertaining to fresh root weight (g) have been presented in table 6. It is evident from the table that the fresh root weight was affected significantly by different fertigation treatments at 30 DAP. The effect of fertigation system (Table 6) on fresh root weight (g) was found significant in 2016-17 and 2017-18 in which the maximum fresh root weight (12.45) and (14.21) found in sub-surface fertigation (S_2) whereas, lowest weight observed in surface fertigation (S_1) with (9.33) and (10.01), respectively.
The effect of fertigation scheduling (Table 6) on fresh root weight (g) was observed significant in 2016-17 and 2017-18. In 2016-17 and 2017-18, schedule 2 (L_2) was found to have maximum fresh root weight (11.83) and (13.20) which was found statistically at par with schedule 3 (L_3) (11.46) and (12.34) whereas, minimum fresh root weight (9.40) and (10.80) was found in schedule 1 (L_1), respectively.
The effect of different fertigation treatment on fresh root weight (Table 6) was observed significant in 2016-17 and 2017-18. In 2016-17 and 2017-18, the maximum fresh root weight observed in treatment T_1 (120% of RDF) (13.03) and (14.43), respectively which was found statistically at par with treatment T_2 (100% of RDF) (11.83) and (12.84), respectively. Whereas, treatment T_6 (without fertilizer) found to have minimum fresh root weight with (9.01) and (9.64) in 2016-17 and 2017-18, respectively which was statistically at par with T_5 (40 % of RDF) (9.91) and (11.30), respectively.
Farmers practice v/s fertigation treatment data was found (Table 6) significant in 2016-17 and 2017-18, in which maximum fresh root weight (14.67 and 15.49) found in farmers practice whereas, minimum weight found in fertigation treatment (10.89 and 12.11), respectively.
The interaction effect of A×B *viz*., fertigation system × fertigation scheduling, B×C *viz*., fertigation scheduling × fertigation treatment and A×B×C *viz* fertigation system × fertigation scheduling × fertigation treatment (Table 6) on fresh root weight was found non-significant in both the years as well as in pooled analysis over the years.
The interaction effect of A×C *viz*., fertigation system × fertigation treatment was found significant (Table 6) only in 2017-18 whereas, it was found non-significant in 2016-17. In 2017-18, the maximum fresh root weight was found in S_2T_1

(16.54) and lowest weight in S_1T_3 (8.99) which was found statistically at par with S_1T_4 (9.55), S_1T_5 (9.33) S_1T_6 (9.46) and S_2T_6 (9.83).

Fresh root weight was observed to be higher in sub-surface fertigation method over the surface fertigation. It might be due to nutrient application directly in the active root zone of plant. Similar results reported by Raj *et al*. (2013) [14].

Under fertigation treatment an increase in the fresh root weight was found with increase in the fertilizer doses, it could be due to the frequent application of water and nutrient to plant root zone which results in better root development. The above results are in agreement with findings of Jeelani *et al.* (2017) [7].

Effect of fertigation system, fertigation scheduling and fertigation treatment on dry root weight

The data pertaining to dry root weight (g) have been presented in table 6. It is evident from the table that the dry root weight (g) was affected significantly by different fertigation treatments at 30 DAP. The effect of fertigation system and fertigation scheduling on dry root weight (Table 6) was observed non-significant in both the years.

The effect of different fertigation treatment on dry root weight (g) (Table 6) was observed significant in 2016-17 and 2017-18. In 2016-17 and 2017-18, the maximum dry root weight observed in treatment T_1 (120% of RDF) (1.38) and (1.38), respectively and it was found statistically at par with T_2 (100% of RDF) (1.27) and (1.28) and T_3 (80% of RDF) (1.21) and (1.23), respectively. The minimum dry root weight (0.98) and (1.05) was recorded in treatment T_6 (without fertilizer) and it was found statistically at par with T_4 (60% of RDF) (1.14) and (1.15) and T_5 (40% of RDF) (1.07) and (1.15) in 2016-17 and 2017-18, respectively.

Farmers practice v/s fertigation treatment data was found (Table 4.126) non-significant in 2016-17 and 2017-18.

The interaction effect of A×B *viz*., fertigation system × fertigation scheduling, B×C *viz*., fertigation scheduling × fertigation treatment, A×C *viz*., fertigation system × fertigation treatment and A×B×C *viz* fertigation system × fertigation scheduling × fertigation treatment (Table 6) on dry root weight was found non-significant in both the years.

Higher dry root weight was observed under sub-surface fertigation over the surface fertigation method. It could be due to higher nutrient uptake in plant roots under sub-surface fertigation, as the frequent optimum water and nutrients supplied through in the root zone. Above findings was in agreement with Kahlel (2015) [8].

Dry root weight observed to be higher under higher fertigation treatment which might be due to the active higher nutrient in active root zone of crop hence higher uptake takes place which results into higher root dry weight. Above findings was supported by Kahlel (2015) [8].

Table 6: Effect of fertigation system, fertigation scheduling, fertigation treatment and interaction effect on fresh root weight and dry root weight (g) at 30 DAP

Factors	Fresh plant weight (g)		Dry plant weight (g)	
A : Fertigation system	**2016-17**	**2017-18**	**2016-17**	**2017-18**
Surface fertigation (S_1)	9.33	10.01	1.12	1.18
Sub-surface fertigation (S_2)	12.45	14.21	1.23	1.23
S.Em.±	0.39	0.37	0.04	0.04
C.D. at 5%	1.10	1.05	NS	NS
B : Fertigation scheduling				
Schedule 1 (L_1)	9.40	10.80	1.12	1.19
Schedule 2 (L_2)	11.83	13.20	1.17	1.22
Schedule 3 (L_3)	11.46	12.34	1.25	1.22
S.Em.±	0.48	0.46	0.05	0.05
C.D. at 5%	1.34	1.29	NS	NS
C : Fertigation treatment				
120 per cent of RDF (T_1)	13.03	14.43	1.38	1.38
100 per cent of RDF (T_2)	11.83	12.84	1.27	1.28
80 per cent of RDF (T_3)	10.93	11.96	1.21	1.23
60 per cent of RDF (T_4)	10.65	12.49	1.14	1.15
40 per cent of RDF (T_5)	9.91	11.30	1.07	1.15
Without fertilizer (T_6)	9.01	9.64	0.98	1.05
S.Em.±	0.67	0.65	0.07	0.07
C.D. at 5%	1.90	1.82	0.19	0.19
Farmer's practice vs Fertigation treatment				
Farmer's practice (T_7)	14.67	15.49	1.32	1.40
Fertigation treatment	10.89	12.11	1.18	1.21
S.Em.±	1.18	1.13	0.12	0.12
C.D. at 5%	3.33	3.19	NS	NS
Interaction effect				
A×B	0.67	0.65	0.07	0.07
C.D. at 5%	NS	NS	NS	NS
B×C	1.17	1.12	0.11	0.12
C.D. at 5%	NS	NS	NS	NS
A×C	0.95	0.91	0.09	0.09
C.D. at 5%	NS	2.57	NS	NS
A×B×C	1.65	1.58	0.16	0.16
C.D. at 5%	NS	NS	NS	NS

Conclusion

Fertigation had significant impact on germination of potato. In early stage of crop growth, plant height, fresh haulm weight, dry haulm weight, fresh root weight and dry root weight were found to increased under drip fertigation practices as compared to farmers practice with band placement of fertilizers and furrow irrigation. Fertigation with 120 percent of RDF registered maximum plant height, fresh haulm weight, dry haulm weight, fresh root weight and dry root weight. Fertigation promotes the vegetative growth of plant and its related parameters. On the other hand, conventional method of irrigation and fertilizer application has exhibited limited growth in the early stage of crop growth.

References

1. Anonymous. Food and agriculture data base, 2008, 1-347.
2. Anonymous. Ground water scenario in India, Central Ground Water Board, Ministry of Water Resources, 2016a, 52.
3. Anonymous. Statical data base of the national horticulture board and ministry of agriculture, Government of India, 2018a.
4. Badr MA, Hussein SDA, El-Tohamy WA, Gruda N. Efficiency of subsurface drip irrigation for potato production under different dry stress conditions. Gesunde Pflanzen. 2010; 62:63-70.
5. Darwish T, Atallah T, Khatib N, Karam F. Fertigation and conventional potassium application to field grown potato in Lebanon: Perspective to enhance efficiency. IPI regional workshop on Potassium and Fertigation development in West Asia and North Africa; Rabat, Morocco, 2004.
6. El-Abedin TKZ, Mattar MA, Alazba AA, Al-Ghobari HM. Comparative effects of two water-saving irrigation techniques on soil water status, yield, and water use efficiency in potato. Scientia horticulturae. 2017; 225:525-532.
7. Jeelani J, Katoch KK, Sandal SK. Effect of drip fertigation levels on soil water dynamics, water use efficiency, yield and quality parameters of broccoli (*Brassica oleracea* L. var. *italica*) in wet temperate zone of Himachal Pradesh, Indian Journal of Soil Conservation. 2017; 45(1):96-104.
8. Kahlel AMS. Effects of different irrigation and fertilization treatments on growth and yield of potato (*Solanum tuberosum* L.) in Iraq. International Journal of Horticulture and Ornamental Plants. 2015; 1(1):002-010.
9. Karam F, Amacha N, Fahed S, Asmar TE, Domínguez A. Response of potato to full and deficit irrigation under semiarid climate: Agronomic and economic implications. Agricultural water management. 2014; 142:144-151.
10. Kumar R, Sharma R, Bhatia SK. Effect of irrigation and Fertigation levels on growth and yield of potato. International Journal of Chemical Studies. 2018; 6(4):1458-1462.
11. Maan DS, Bhatia AK, Vikram, Anshul. Impact of irrigation methods and nitrogen levels on growth and yield of potato in Haryana. Journal of Pharmacognosy and Phytochemistry. 2018; 7(6):2267-2271.
12. Malik RS, Kumar K, Bhandari AR. Effect of urea application through drip irrigation system on nitrate distribution in loamy sand soils and pea yield. J. Indian Soc. Soil Sci. 1994; 42(1):6-10.
13. Pooja P. Effect of Nitrogen scheduling on growth, yield and quality of potato (*Solanum tuberosum* L.). Ph. D. Horticulture (Vegetable Science). Thesis submitted to G.B.P.U.A. & T., Pantnagar. 2017; 43-98.
14. Raj AFS, Muthukrishnan P, Ayyadurai P. Root characters of maize as influenced by drip fertigation levels. American Journal of Plant Sciences. 2013; 4:340-348.
15. Rangaswamy R. A Text Book Agric. Stat. New Age Int. Ltd., New Delhi, 2006, 358.
16. Sanchita B, Phookan DB, Pankaj B, Luchon S. Effect of drip-fertigation on performance of tomato under Assam conditions. Ind. J. Hort. 2010; 67(1):56-60.