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Effect of drip irrigation and NPK fertigation on soil-plant water, productivity, fertilizer expense efficiency and nutrient uptake of capsicum (*Capsicum annuum* L.) in an acid Alfisol

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ABSTRACT

The study was carried out at experimental farm of CSK HPKV, Palampur, during 2011 and 2012 with the objectives of evaluating the effects of drip irrigation levels and NPK fertigation on soil-plant water, productivity, fertilizer expense efficiency and nutrient uptake of capsicum. The treatments comprised of (a) three drip irrigation levels *viz.,* 1.2 CPE-Drip at 120% CPE, 1.0 CPE-Drip at 100% CPE and 0.8 CPE-Drip at 80% CPE, (b) three fertigation levels *viz.,* 100% NPK, 66.6% NPK and 33.3 % NPK of recommended dose of fertilizer and (c) recommended practice (RP)-flood Irrigation of 4 cm at 8-10 days interval and 100% recommended dose of fertilizer. The capsicum cv. California wonder was transplanted during third week of April during 2011 and 2012. The results indicated that 1.2 CPE treatments had higher soil and relative leaf water content, lower aeration porosity, higher marketable yield, B.C ratio and fertilizer expense efficiency in comparison to 1.0 and 0.8 CPE. Increase in fertigation level from 33.3 to 100% RDF significantly increased number of leaves, relative leaf water content, marketable yield and B:C ratio but decrease in fertilizer expense efficiency. Drip based irrigation along with fertigation in general had higher fruit yield but lower B:C ratio in comparison to flood and conventional fertilizer application.

1. INTRODUCTION

In Himachal Pradesh, 81.6% net cultivated area is rainfed and mostly, subsistence type of agriculture is being practiced. Creating assured irrigation facilities for diversification to vegetables and other high value cash crops are either very costly or practically not feasible and also not economical. Harvesting rain-water and run-off water in small/ big ponds is being practiced since past. For seepage control, use of UV resistant blue coloured plastic sheet (200-250 GSM thickness) has been recommended. The stored rain- water is being utilized effectively for drinking, domestic and for agricultural purposes. Therefore, the efforts have been made to utilize the harvested rain-water very efficiently especially through micro-irrigation system for agricultural purposes.

Diversification to vegetable crop production for sustaining livelihood of small farmers is being encouraged especially in hills. However, non-availability of assured irrigation is one of the limiting factors for diversification. Judicious use of scarce water resources through hi-tech pressurized irrigation such as drip irrigation including fertigation is very popular in most parts of India, but needs to be popularized in Himachal Pradesh, not only for obtaining higher nutrient and water use efficiency but also to increase the area under high value cash crops.

Drip irrigation is an irrigation method which saves water and fertilizer by allowing water to drip slowly to the roots of plants either to the soil surface or directly to the root zone. It is adopted extensively in areas of acute water scarcity and especially for widely spaced crops. It is eco-friendly irrigation system saving maximum upto 60% water and results an increase in the yield to the extent of 30-40% over existing methods (Magar and Nandgude, 2005). Also, drip irrigation is an option wherever water availability limits conventional irrigation and further it reduces the risk of yield reduction due to terminal dry spell (Ramamurthy *et al.,* 2009; Kumar *et al.,* 2012). Moreover, this system recharges the root-zone and maintains the uniformity of seed-zone moisture throughout the planting area for a longer period as compared to conventional method of irrigation. Drip irrigation added with fertilizers through fertigation reduces the wastage of water and fertilizers especially nitrogenous and subsequently optimizes the nutrient use by applying them at critical stages and proper place and time, which finally increase water and nutrients use efficiency. The availability of N, P and K nutrient was found to be higher in root zone area of drip fertigated plots (Sathya *et al.,* 2008).

Capsicum (*Capsicum annuum L.)* is an important crop grown in almost all parts of Himachal Pradesh. The fruit of capsicum is a rich source of vitamin C ranging from 150-180 mg 100 g^{-1} and vitamin A, constituting up to 12% of total pigment content. It has become a very important crop due to its demand in the pharmaceutical industries on account of its medicinal values. It also contains appreciable amount of protein, calcium, thiamine, riboflavin and niacin. It has some medicinal properties and is used in treatment of dropsy, colic, toothache and cholera. The plant requires good and precise amount of water for higher yield and quality (Mahajan *et al.,* 2007) hence, provides a scope of drip based irrigation scheduling for precise application of water and nutrients to the crop. The present investigation was carried out with the objectives of evaluating the effects of drip irrigation levels and NPK fertigation on soil and plant water retention, productivity, fertilizer expense efficiency and nutrient uptake.

2. MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during 2011 and 2012. The area lies in Palam Valley (32.6^0 N latitude and 76.3^0 E longitude) at an elevation of 1290 m above msl of Kangra district of Himachal Pradesh and represents the mid hills sub humid agro climatic zone of Himachal Pradesh in North Western Himalayas. The soil of the experiment field is silty clay loam and rich in clay content with accumulation of sesquioxides. Taxonomically, the soils are classified as Alfisols-Typic Hapludalf (Verma, 1979). The soil was low in available N (220.2 kg ha^{-1}), high in available P (48.1 kg ha^{-1}) and medium in available K (270.2 kg ha^{-1}) with soil pH 5.8. At 33 and 1500 kPa tensions, the soil retained around 0.31 and 0.16 $m^3 m^{-3}$ moisture.

The experiment was laid out in factorial randomized block design with ten treatments replicated thrice. The treatments comprised of (a) Three drip irrigation levels *viz.,* 1.2 CPE-Drip at 120% of cumulative pan evaporation (CPE), 1.0 CPE-Drip at 100 % of CPE and 0.8 CPE-Drip at 80% CPE, (b) Three fertigation levels *viz.,* 100% NPK, 66.6% NPK and 33.3% NPK of recommended dose of fertilizer and (c) Recommended practices (RP) - flood irrigation of 4 cm at 8-10 days interval and 100% recommended dose of fertilizer. The capsicum cv. California wonder was transplanted during third week of April 2011 and 2012, at 60 x 45 cm spacing in 5 x 2 m (10 m^2) plots. Raised plots were laid out as per the plan before transplanting.

The fertilizer doses were calculated by decreasing/ increasing the recommended dose of fertilizer (100:75:55) based on soil test values. Since, available N was in low range, the dose was increased by 25%, K dose remain unchanged; whereas available P was in high range, hence P dose was decreased by 25% (125:56:55). In fertigation treatments, the NPK fertilizer doses calculated as per treatment were applied in ten equal splits at 8-10 days interval through fertigation. The water soluble fertilizers *viz.,* urea, 19:19:19 and 0:0:50 were used. In control half of N and whole of P and K were given basal and the remaining N was given in two equal splits, at 30 and 75 Day After Transplanting (DAT).

The drip irrigation system was installed in all experimental plots except (recommended package) control plots where flood irrigation was given. The drip lines at spacing of 45 cm (laterals) x 30 cm (drippers) were laid with valves provided on each lateral. A total of 64 drippers were available for irrigation in 10 m^2 plot. The water source for drip irrigation was from a poly-lined farm pond located near the experimental site and water was lifted using 2 hp electric pumps. The average discharge rate from each dripper was 2.30 L h^{-1}. A venturi system was provided near the electric pumping unit for fertigation with average discharge rate of about 1 L min^{-1}.

In drip irrigation treatments, drip system was operated daily for 30 minutes for initial 20 days. The scheduling of irrigation was done according to treatments, commencing from 20 days after transplanting. The averaged pan evaporation data (2006 to 2011) were used to determine the amount of water to be given at the rate of 0.8, 1.0 and 1.2 Cumulative Pan Evaporation (CPE). The drip irrigation was given at 2 days interval. The irrigations of 40 mm depth were given to 'RP' treatment at 2-3 days interval in the beginning and thereafter at 8-10 days intervals after 20 days of transplanting as per treatment throughout crop growth period.

The soil water content at 0-0.075, 0.075-0.15 and 0.15-0.30 m depths were determined by thermo gravimetric method at 50 DAT one day after irrigation. Volumetric water content (θ) for different depths was calculated by multiplying the gravimetric water content (w/w basis) with pre determined bulk density for that depth (Hillel, 1982). The aeration porosity was calculated by determining relation of air to water content on a particular day by the following equation (Rattan, 2009).

$$fa\ (\%) = (f - \theta)$$

Where, 'f_a' is the aeration porosity (%) and 'θ' is volumetric wetness (%). The number of leaves plant^{-1} was counted in randomly selected five plants at 50 DAT.

The Relative Leaf Water Content (RLWC) was determined at 50 DAT during 0700 h and 1400 h and was calculated by the method given by Weatherly (1950) as:

$$RLWC = \frac{\text{Fresh weight - Oven dry weight}}{\text{Fully turgid - Oven dry weight}} \times 100$$

The fresh marketable yield of capsicum was recorded at harvest expressed in Mg ha^{-1}. The fertilizer expense efficiency was computed as described by Veeranna *et al.* (2001).

$$FEE\ (kg\ ha^{-1}) = \frac{\text{Oven dried fruit yield (kg ha}^{-1}\text{)}}{\text{Toal quantity of nutrient applied (kg ha}^{-1}\text{)}}$$

The uptake of nitrogen, phosphorus and potassium in fruit and stover were calculated using the following formula (Pomares and Pratt, 1987).

Nutrient uptake (kg ha^{-1}) = Nutrient concentration x oven dried biomass (kg ha^{-1}).

3. RESULTS AND DISCUSSION

Rainfall and Evaporation

The rainfall distribution and evaporation during growth period of capsicum for the year 2011 and 2012 are given in Table 1. The data indicated that less amount of rainfall was received during the month of April and May under both the study years and increased from June onwards with the onset of monsoon and highest amount of rainfall was received in the month of August during both the years (872.2 and 843.5 mm). The highest evaporation rate was recorded in the month of May during both the years and daily evaporation rate ranged from 5.8-1.8 and 8.3-1.4 mm day^{-1} from May to August during both the study years.

Soil Water Content and Aeration Porosity

The soil water content (θ) and aeration porosity determined at 24 and 50 DAT (before onset of monsoon) is given in Table 2. The data indicated that the soil water content increased from 0.8 CPE to 1.2 CPE irrigation levels and also with increasing depth from 0-0.075 to 0.15-0.30 m. There was uniform distribution of soil water among different soil layers in $I_{0.8,}$ $I_{1.0}$ and $I_{1.2}$ whereas, $I_{rec,}$ had lowest

Table: 1
Weekly rainfall and monthly evaporation (mm) during capsicum period growth

Week	2011					2012				
	April	May	June	July	Aug	April	May	June	July	Aug
Week I (1-7 Days)	2 (1)	11.4 (4)	40.6 (3)	97.0 (5)	141.2 (7)	3.6 (1)	0 (0)	0.5 (2)	152.6 (4)	272.0 (6)
Week II (8-14 Days)	8.6 (4)	1.2 (1)	96 (5)	83.6 (5)	397.8 (7)	17.6 (4)	34.0 (1)	1.8 (1)	103.8 (7)	127.0 (5)
Week III (15-21 Days)	80.0 (4)	2.8 (2)	57 (4)	86.4 (7)	178.4 (7)	8.8 (3)	0.6 (1)	0 (0)	71.8 (4)	243.7 (6)
Week IV (22-28 Days)	0 (0)	97.2 (4)	140.6 (6)	190.2 (6)	133.2 (7)	27.2 (4)	0.6 (1)	42.2 (3)	301.8 (6)	182.0 (6)
Week V (29-30/31 Days)	0 (0)	5.8 (3)	55.4 (2)	25.8 (2)	21.6 (2)	0 (0)	0 (0)	14.8 (1)	120.6 (3)	18.8 (2)
Total monthly rainfall (mm)	90.7 (9)	120.4 (14)	389.6 (20)	483.0 (25)	872.2 (30)	57.2 (12)	35.2 (3)	59.3 (7)	750.6 (24)	843.5 (25)
Monthly evaporation (mm)	134.3	179.9	99.4	80.5	57.3	137.2	249.4	243.4	85.0	44.6
Daily evaporation rate (mm d^{-1})	4.5	5.8	3.3	2.6	1.8	4.6	8.3	8.1	2.7	1.4

Values in parentheses indicate number of rainy days

Table: 2
Effect of drip based irrigation scheduling on soil water content and aeration porosity at 24 & 50 DAT

Drip based irrigation	Soil depth (m)	Soil water content (%)				Aeration porosity (%)			
		2011		2012		2011		2012	
		24 DAT	50 DAT	24 DAT	50 DAT	24 DAT	50 DAT	24 DAT	50 DAT
0.8 CPE	0-0.075	24.0	25.1	24.0	26.3	28.0	26.8	28.0	25.6
	0.075-0.15	26.0	26.2	29.0	28.1	25.6	25.6	23.2	24.4
	0.15-0.30	32.0	31.2	32.0	30.2	17.3	17.8	17.2	19.1
1.0 CPE	0-0.075	27.0	26.4	25.0	28.1	25.0	25.6	26.8	24.4
	0.075-0.15	29.0	28.2	30.0	30.2	23.2	24.4	22.0	22.0
	0.15-0.30	35.0	33.2	35.0	36.3	13.9	16.5	13.9	12.6
1.2 CPE	0-0.075	28.0	28.1	29.0	30.2	24.4	24.4	23.2	22.0
	0.075-0.15	31.0	30.4	32.0	35.1	20.8	22.0	19.6	17.2
	0.15-0.30	38.0	39.1	38.0	39.1	11.3	10.0	11.3	10.0
RP	0-0.075	19.0	17.5	20.0	20.5	32.8	35.2	31.6	31.6
	0.075-0.15	22.0	18.2	23.0	20.4	30.4	34.0	29.2	31.6
	0.15-0.30	25.0	27.3	29.0	27.1	24.3	21.7	20.4	21.7

soil moisture content in comparison to other drip treatments. The aeration porosity decreased correspondingly with irrigation levels and with soil depths. In treatment 1.2 CPE, where 20% water higher than the cumulative evaporation was applied, the aeration porosity in the sub surface layer reached to 10% *i.e.* the critical limit. In general, the higher soil water content was recorded under drip irrigation treatments in comparison to recommended practice (irrigation at weekly interval) due to periodical application of irrigation in drip treatments at 2 days interval. Ponnuswamy and Santhi (1998) reported that more water penetrated into the deeper layers in drip system of irrigation and the crop utilized the water very effectively.

Number of Leaves Plant^{-1}

The data pertaining to the effect of drip irrigation and fertigation on number of leaves and relative leaf water content at 50 DAT is given in Table 3. The numbers of leaves per plant recorded with 1.2 CPE was significantly higher over 1.0 and 0.8 CPE during both the study years. The number of leaves per plant was higher under 1.2 CPE due to application of more quantity of water indicating higher soil moisture availability in comparison to 0.8 CPE. Similar findings were also reported by Antony and Singandhupe (2004). They found that the plants grown under drip irrigation had more number of leaves and plant heights compared to that of surface irrigated plants.

Under both the study years among fertigtion treatments, the number of leaves recorded in 100% NPK was significantly superior over 66.6% NPK and 33.3% NPK. The higher number of leaves plant^{-1} in 100% NPK treatment was due to the application of recommended doses of fertilizer with fertigation technique in comparison to treatments where 66.6 and 33.3% fertilizer doses were applied. The number of leaves per plant under 'RP' vs 'others' was not significant during both the study years.

Relative Leaf Water Content (RLWC)

A significant increase in relative leaf water content (RLWC) was recorded with increasing quantity of irrigation (Table 3). During both the study years, the RLWC was significantly higher under 1.2 CPE compared to 1.0 and 0.8 CPE at 0700 h and 1400 h, respectively. The RLWC decreased with decrease in irrigation amount from $I_{1.2}$ to $I_{0.8}$ leading to proportional decrease in quantity of available water in soil. The RLWC however, in all the fertigation treatments were statistically at par with each other during both the years. The RLWC under 'others' treatment was significantly higher over 'RP' during 0700 h and 1400 h during both the years. The higher RLWC in 'others' treatments may be due to regulated and frequent application of irrigation water at 2 days interval which might have maintained higher root zone moisture in comparison to 'RP' where irrigations were applied at 8-10 days interval.

Marketable Yield

The effect of drip irrigation and fertigation levels on marketable yield of capsicum is given in Table 4. The data indicated that the highest fruit yield was recorded with 1.2 CPE which was significantly superior over 1.0 and 0.8 CPE during the year 2011 only. During the year 2012, however, it was not significant under irrigation treatment due to occurrence of monsoon rains after 52 DAT. Among fertigation treatments, the marketable yield recorded in 100% NPK was significantly superior over 66.6% NPK and 33.3% NPK fertigation. The higher yield in 100% NPK treatment was due to the application of recommended doses of fertilizer with fertigation in comparison to treatments where 66.6 and 33.3% fertilizer doses were applied. Similar findings were also

Table: 3
Effect of drip based irrigation and fertigation on shoot growth and relative leaf water content at 50 DAT

Treatment	No of leaves		Relative Leaf Water Content (%)			
	2011	2012	2011		2012	
			0700 h	1400 h	0700 h	1400 h
Drip irrigation levels						
0.8 CPE	59	43	58.63	53.17	61.06	55.46
1.0 CPE	72	58	63.96	56.51	65.24	61.09
1.2 CPE	85	79	73.38	65.47	73.59	69.63
CD (P<0.05)	6.2	7.8	1.04	1.52	2.22	1.22
Fertigation levels						
33.3% NPK	62	41	64.38	56.89	65.05	61.03
66.6% NPK	72	56	65.57	58.25	66.44	62.13
100% NPK	82	77	66.01	60.01	68.39	63.02
CD (P<0.05)	6.2	7.8	1.04	1.52	2.22	1.22
'RP' vs 'Others'						
RP	76	67	75.08	66.14	63.97	58.08
Others	72	64	79.06	58.38	66.63	62.06
CD (P<0.05)	NS	NS	1.34	1.97	2.87	1.58

Table: 4
Effect of NPK fertigation and irrigation depth on productivity and fertilizer expense efficiency of capsicum

Treatment	2011			2012		
	Marketable Yield ($Mg\ ha^{-1}$)	Fertilizer expense efficiency ($kg\ kg^{-1}$)	B:C Ratio	Marketable Yield ($Mg\ ha^{-1}$)	Fertilizer expense efficiency ($kg\ kg^{-1}$)	B:C Ratio
Irrigation levels						
0.8 CPE	25.74	46.80	5.29	18.98	34.43	3.40
1.0 CPE	27.93	50.78	5.74	19.57	35.63	3.53
1.2 CPE	29.44	53.52	6.04	19.13	36.67	3.41
CD (P <0.05)	1.47	2.72		NS	2.14	
Fertigation levels						
33.3 % NPK	23.89	74.66	6.54	18.36	56.51	4.28
66.6 % NPK	28.00	43.08	5.64	19.26	29.82	3.34
100 % NPK	31.21	31.85	4.94	20.06	20.40	2.72
CD (P <0.05)	1.47	2.72		1.10	2.14	
'RP' vs 'Others'						
RP	26.16	26.69	10.70	18.40	18.79	5.44
Others	27.70	51.30	5.70	19.23	35.57	3.44
CD (P <0.05)	NS	3.41		NS	2.77	

reported by Mahajan *et al.* (2007); Singandhupe *et al.* (2007); Tanaskovik *et al.* (2011) and Pandey *et al.* (2013). The fruit yield obtained under 'RP' vs 'others' was not significant during both the study year. Gupta *et al.* (2010) reported that there was significant improvement in yield, quality, water and fertilizer use efficiencies of capsicum under drip irrigation and fertigation.

Fertilizer Expense Efficiency (FEE)

The highest FEE was recorded under 1.2 CPE because of higher fruit yield in comparison to 1.0 and 0.8 CPE during both the study years. Among fertigation, highest FEE was recorded under 33.3% RDF in comparison to other treatments with 66.6 and 100% RDF because of less amount of fertilizers application. The FEE was almost double in 'others' (drip-fertigation treatments) in comparison to 'RP' during both the study years. This was due to variation in fertilizer doses from 33.3 to 100% NPK under 'others' as compared to 'RP' where 100% NPK was applied. Veerana *et al.* (2001) reported that the FEE was higher with lower fertilizer dose and hence the performance of capsicum was not considerably affected due to small variation in dose of fertilizer with respect to water soluble fertilizer.

Benefit Cost Ratio

The B:C ratio was recorded highest under 1.2 CPE and 1.0 CPE as compared to 0.8 CPE in 2011 and 2012 primarily due to higher fruit yield. Among fertigation, highest B:C ratio was recorded under 33.3% RDF in comparison to other treatments with 66.6 and 100% RDF because of less amount of fertilizers application. Beyaert *et al.* (2007) reported that drip irrigation coupled with fertigation showed significant advantages in terms of yield and economic returns compared with conventional fertilization practices. In general, the B:C ratio was highest in RP in comparison to drip-fertigation treatments during both the study years. The higher B:C ratio in RP was due to less cost of cultivation primarily due to less cost of conventional fertilizers in comparison to drip irrigation treatments where cost of soluble fertilizers was much higher (by 15 times). Also, the interest and depreciation values of drip system were included which resulted in higher cost of cultivation. The data also revealed that the labour requirement was higher under 'RP' in comparison to drip irrigated treatments. Similar results were also reported by Woltering *et al.* (2011) they that total labour requirement for the drip irrigated African Market Garden was on average 1.1 man hours per day against 4.7 man hours per day for the farmers practice on a 500 m^2 garden.

Plant Nutrient Uptake

The nutrient uptake in fruit and stover was determined at harvest and is given in Table 5.

Nitrogen Uptake

There was an increase of N uptake by 18.09 and 11.11% in fruit and total uptake under 1.2 CPE in comparison to 0.8 CPE. The higher uptake in $I_{1.2}$ may be due to higher soil water content, better root and shoot growth and yield, among irrigation level. Among fertigation treatments, significantly higher N uptake was recorded in fruit and stover (38.90 and 54.85 $kg\ ha^{-1}$) in 100% NPK application in comparison to 66.6 and 33.3% NPK leading to better root and shoot growth. Similar results were also reported by Badr *et al.* (2011) they found that total N uptake was appreciably higher with increasing N rate and with more frequent than with less frequent fertigation. The N uptake was significantly highest under 'others' over 'RP'.

Table: 5
Effect of drip based irrigation and fertigation on nutrient uptake during 2012

Treatments	Nitrogen uptake (kg ha^{-1})			Phosphorous uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
	Fruit	Stover	Total	Fruit	Stover	Total	Fruit	Stover	Total
Drip irrigation levels									
0.8 CPE	30.88	47.37	78.26	40.35	27.46	67.81	16.52	14.98	31.50
1.0 CPE	33.34	50.13	83.48	43.22	30.33	73.55	17.76	16.53	34.29
1.2 CPE	36.46	50.49	86.96	45.23	31.89	77.12	18.34	17.65	35.99
CD (P<0.05)	5.63	NS	6.59	3.20	4.20	6.81	1.31	1.70	2.24
Fertigation levels									
33.3 % NPK	30.54	43.89	74.43	40.29	24.84	65.13	15.89	14.81	30.70
66.6 % NPK	31.24	49.27	80.51	42.33	30.22	72.54	17.38	16.26	33.65
100 % NPK	38.90	54.85	93.75	46.18	34.63	80.81	19.35	18.08	37.43
CD (P<0.05)	5.63	3.62	6.59	3.20	4.20	6.81	1.31	1.70	2.24
'RP' vs 'Others'									
RP	26.67	45.35	72.02	40.20	33.53	73.73	15.46	14.04	29.50
Others	33.56	49.33	82.90	42.93	29.90	72.83	17.54	16.39	33.93
CD (P<0.05)	7.27	4.67	8.51	NS	NS	NS	1.69	2.19	2.89

Phosphorus Uptake

Phosphorus uptake in fruit and stover was significantly higher under 1.2 CPE in comparison to 1.0 CPE and 0.8 CPE. A significant increase of P uptake by 16.02% in stover was recorded with 1.2 CPE over 0.8 CPE. Among fertigation treatments, significantly higher P uptake was recorded in fruit and stover in 100% NPK in comparison to 66.6% NPK and 33.3% NPK. The P uptake in fruit and stover was not significant under 'RP' over 'others'.

Potassium Uptake

A significant increase of K uptake (11.01%) in fruit was recorded with 1.2 CPE over 1.0 and 0.8 CP. This may be due to better vegetative growth as a result of more volume of water applied in comparison to 0.8 CPE. In case of fertigation, the highest K uptake in fruit and stover was recorded with 100% NPK in comparison to 66.6 and 33.3% NPK. There was an increase of K uptake by 21.77 and 21.92% in fruit and total uptake with the application of 100% recommended dose of fertilizer in comparison to 66.6 and 33.3% NPK. Similar results were also reported by Hebbar *et al.* (2004) that NPK uptake was increased by WSF fertigation. The K uptake was significantly highest under 'others' over 'RP'.

4. CONCLUSIONS

The study concluded that the soil moisture content increased and aeration porosity decreased from 0.8 to 1.2 CPE up to 50 DAT. The drip based irrigation along with fertigation in general had higher fruit yield but lower B:C ratio in comparison to flood and conventional fertilizer application. This was due to less cost of cultivation primarily due to less cost of conventional fertilizers in comparison to drip irrigation treatments where cost of soluble fertilizers was much higher. The drip based irrigation & fertigation led to increase in fertilizer expense efficiency over conventional flood irrigation and conventional fertilizers.

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