Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2019; SP1: 192-194

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(Special Issue- 1)
2nd International Conference
"Food Security, Nutrition and Sustainable Agriculture - Emerging Technologies"
(February 14-16, 2019)

Effect of fertigation levels on nutrient uptake, leaf area index and fertilizer expense efficiency of strawberry (*Fragaria ananasa*) under protected cultivation

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Abstract
Fertigation is an attractive technology in modern irrigated agriculture which not only increases yield and fertilizer use efficiency but also maintains optimal nutrient levels and water supply according to the specific needs of each crop and type of soil. A study was conducted at experimental farm of CSK HPKV, Palampur, during the year 2015-16 with the objectives of evaluating the effect of fertigation levels on nutrient uptake, leaf area index and fertilizer expense efficiency of strawberry under protected cultivation. The treatments comprised of, (a) three drip irrigation levels, $DI_{0.6}$ (Daily drip irrigation at 60 per cent of open pan evaporation), $DI_{0.8}$ (Daily drip irrigation at 80 per cent of open pan evaporation) and $DI_{1.0}$ (Daily drip irrigation at 100 per cent of open pan evaporation) and (b) three NK fertigation levels *viz*., NK_{50} (50% of RDF of which 25% applied as basal and rest 75 % through fertigation at weekly interval), NK_{75} (75% of RDF of which 25% applied as basal and rest 75 % through fertigation at weekly interval) and NK_{100} (100% of RDF of which 25% applied as basal and rest 75 % through fertigation at weekly interval). In addition, one control (C)- 100% RDF applied through conventional method (1/2 N and full PK as basal and remaining 1/2 N in equal split at monthly intervals) with drip irrigation at 1.0 PE was also kept. The results revealed that with increasing irrigation level from $DI_{0.6}$ to $DI_{1.0}$ there was no significant improvement in plant nutrient uptake, leaf area index and fertilizer expense efficiency. However, increasing fertigation level from NK_{50} to NK_{100} improved plant nutrient uptake, leaf area index and fertilizer expense efficiency. The N and K uptake in fruit in treatment NK_{75} was statistically at par with NK_{100}. The P uptake in fruit in NK_{50} was statistically at par with NK_{100}. The fertilizer expense efficiency (FEE) under various drip irrigation levels was non-significant. However, among different NK fertigation levels, the FEE in NK_{75} was statistically at par with NK_{50}. A saving of 40-60 % irrigation water and 25% NK was observed from the study.

Keywords: Strawberry, fertigation, nutrient uptake, leaf area index, fertilizer expense efficiency

Introduction
Greenhouse farming, also known as protected cultivation, is one of the farming systems widely used to provide and maintain a controlled environment suitable for optimum crop production leading to maximum profits. This includes creating an environment suitable for working efficiency as well as for better crop growth (Aldrich and Bartok, 1989) [3]. Low cost naturally-ventilated polyhouses provide a great scope to raise the off-season crops for round the year supply. Irrigation system is one of the most important components affecting the yield and quality of agricultural produce for greenhouse farming system. The use of drip irrigation considerably decreases the amount of water used and maintains adequate moisture content in the soil (Rolbiecki and Rzekanowski, 1997) [8]. The drip irrigation results in 51% saving of irrigation water and 19% higher fruit yield as compared to surface irrigation (Kumar *et al*., 2005) [5]. To obtain the higher crop and water productivity under protected environment, there is a need to regulate drip irrigation frequency based on climatic demand and fertigation frequency with commonly available water soluble fertilizers such as 19:19:19, 12:61:0, 0:0:50.The fertigation with recommended dose of NPK gives significantly higher plant height, leaf area and fruit yield of strawberry (Kachwaya and Chandel, 2015) [4]. Keeping in view the

quality and high marketable price of strawberry in Himachal Pradesh, the present study was conducted to evaluate the effect of fertigation levels on nutrient uptake, leaf area index and fertilizer expense efficiency of strawberry under protected cultivation.

Material and Method

An experiment was conducted during 2015-16 with strawberry as a test crop in naturally ventilated polyhouse to study the effect of fertigation levels on nutrient uptake, leaf area index and fertilizer expense efficiency of strawberry under protected cultivation at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experimental site lies in Palam Valley ($32^0.6'$ N latitude and $76^0.3'$ E longitude) at an elevation of 1290 m above mean sea level of Kangra district of Himachal Pradesh and represents the mid hills sub humid agro climatic zone of Himachal Pradesh in North-western Himalayas. The research farm lies in Wet Temperature Zone according to Thornwaite's classification (Aggarwal *et al*., 1978). The mean air temperature varies from 2^0C in January to around 36^0C during the months of May-June. Soil temperature drops as low as 2^0C and frost incidences are common. The relative humidity in the region varies from 46 to 84 per cent. The average annual rainfall of the place is about 2500 mm. The soil of the naturally ventilated polyhouse was loam and rich in silt content. The average values of physic-chemical, OC and chemical properties of pH of the surface soil (0-0.15 m) were pH 5.67 and organic carbon 12.20 g kg^{-1}. The soil was low in available N (212.0 kg ha^{-1}), high in available P (41.65 kg ha^{-1}) and medium in available K (180.9 kg ha^{-1}).

The strawberry cv. Chandler was transplanted on October 03, 2015 on raised strips with dimensions of 3.00 m length and 0.60 m width providing 1.8 sq m cultivated area per strip. In each strip, 7 runners per strip were transplanted near to drippers as per plan. The nine treatment combinations were imposed in a completely randomized design replicated three times. An additional treatment of control was also kept as an independent module for general comparison of results. The treatments comprised of, (a) three drip irrigation levels, $DI_{0.6}$ (Daily drip irrigation at 60 per cent of open pan evaporation), $DI_{0.8}$ (Daily drip irrigation at 80 per cent of open pan evaporation) and $DI_{1.0}$ (Daily drip irrigation at 100 per cent of open pan evaporation) and (b) three NK fertigation levels *viz*., NK_{50} (50% of RDF of which 25% applied as basal and rest 75 % through fertigation at weekly interval), NK_{75} (75% of RDF of which 25% applied as basal and rest 75 % through fertigation at weekly interval) and NK_{100} (100% of RDF of which 25% applied as basal and rest 75 % through fertigation at weekly interval). In addition, one control (C) - 100% RDF applied through conventional method (1/2 N and full PK as basal and remaining 1/2 N in equal split at monthly intervals) with drip irrigation at 1.0 PE was also kept.

The FYM @ 2.5 kg m^{-2} was applied to all the treatments. In conventional method, urea, single super phosphate and mureate of potash were used whereas, in fertigation treatments, water soluble fertilizers such as 0:0:50 and urea were applied through drip irrigation system. In nutrient schedules, NK fertilizer doses calculated as per treatment were applied as basal and through fertigation in varying intervals starting from 3rd week of transplanting to 30 days before the final harvest. The 100% RDF of P was applied as basal in all the treatments. Leaf area index was calculated after Radford 1967. The uptake of nitrogen, phosphorus and potassium in fruit were calculated after Pomares and Pratt (1987) [6]. The fertilizer expense efficiency was computed as described by Veeranna *et al*. (2001) [9].

Results and Discussion

Leaf area index

This includes leaf area index per plant was calculated at 124 DAT of strawberry. The leaf area index was non-significant under different irrigation levels. The leaf area index values under different NK fertigation levels were 25.4, 36 and 51.1 in NK_{50}, NK_{75} and NK_{100}, respectively. The data showed that leaf area index was significantly higher in NK_{100} followed by NK_{75} and NK_{50}. This may be due to higher application of fertilizers leading to better shoot growth. Similar results were reported by Abdrabbo *et al*. (2005) [1] and Kachwaya and Chandel (2015) [4] where fertigation with RDF of NPK gave significantly higher leaf area. The leaf area index was significantly higher in 'others' (37.5) as compared to 'control' (26.0).

Table 1: Effect of NK fertigation on fertilizer expense efficiency (FEE) and leaf area index (LAI)

Treatments	FEE (g g^{-1})	LAI
Drip irrigation		
$DI_{0.6}$	2.81	35.7
$DI_{0.8}$	2.75	39.3
$DI_{1.0}$	2.78	37.6
LSD(P=0.05)	NS	NS
Fertigation treatments		
NK_{50}	3.07	25.4
NK_{75}	2.88	36.0
NK_{100}	2.39	51.1
LSD (P=0.05)	0.12	2.9
Control vs. others		
Control	2.33	26.0
Others	2.78	37.5
LSD(P=0.05)	0.18	4.3

Fertilizer expense efficiency

The fertilizer expense efficiency was determined at harvest of strawberry. The data showed that fertilizer expense efficiency under various drip irrigation levels was non-significant. Among different NK fertigation levels, FEE was 3.07 g g^{-1} in NK_{50}, 2.88 g g^{-1}in NK_{75} and 2.39 g g^{-1} in NK_{100}. The data further showed that NK_{75} was statistically at par with NK_{50}. In 'control' vs. 'Others', 'Others' (2.78 g g^{-1}) had significantly higher fertilizer expense efficiency as compared to 'control' (2.33 g g^{-1}).

Plant uptake

The nutrient uptake in plant was determined at harvest.

Nitrogen (N) uptake

The N uptake in fruit was non-significant under all irrigation treatments. Among different NK fertigation levels, N uptake in fruit under NK_{100} was 58.8 g m^{-2}, 56.3 g m^{-2} in NK_{75} and 37.4 g m^{-2} in NK_{50}. The data showed that NK_{75} was statistically at par with NK_{100}. The higher N uptake may be due to the better utilization of applied nitrogen through combined fertigation treatment and conventional application as a basal dose leading to better root and shoot growth. Similar results were reported by Kachwaya and Chandel (2015) [4] where fertigation with ¾ of RDF resulted in higher leaf nutrient content. The N content was significantly higher in 'others' (50.8 g m^{-2} in fruits) as compared to 'control' (38.5 g m^{-2} in fruits).

Phosphorus (P) uptake

Among different irrigation levels, P uptake in fruit was non-significant for all irrigation levels. Among different NK fertigation levels, P uptake in fruit was 9.1 kg ha^{-1} in NK_{50}, 8.3 g m^{-2} in NK_{75} and 9.3 g m^{-2} in NK_{100}. The data showed that NK_{50} was statistically at par with NK_{100}.The P uptake in 'control' vs. 'others' was non-significant.

Table 2: Effect of NK fertigation on nutrient uptake of strawberry (g m^{-2})

Treatments	N uptake	P uptake	K uptake
Drip irrigation			
$DI_{0.6}$	51.7	8.9	10.2
$DI_{0.8}$	49.1	8.9	10.6
$DI_{1.0}$	51.7	8.9	11.1
LSD(P=0.05)	NS	NS	NS
Fertigation treatments			
NK_{50}	37.4	9.1	8.0
NK_{75}	56.3	8.3	11.3
NK_{100}	58.8	9.3	12.7
LSD (P=0.05)	5.2	0.4	1.7
Control vs. others			
Control	38.5	9.5	14.9
Others	50.8	8.9	10.6
LSD(P=0.05)	7.7	NS	2.5

Potassium (K) uptake

The potassium uptake in fruit was non-significant but significantly higher under 'control' (14.9 g $m^{-2)}$ than 'others' (10.6 g m^{-2}). Among different NK fertigation levels, K uptake in fruit was 8.0 g m^{-2} in NK_{50}, 11.3 g m^{-2} in NK_{75} and 12.7 g m^{-2} in NK_{100}. The data showed that $NK_{75}$was statistically at par with NK_{100}. Similar results were reported by Kachwaya and Chandel (2015) [4] where fertigation with ¾ of RDF resulted in higher leaf nutrient content.

Conclusion

From the study conducted, it was observed that with increasing irrigation level from $DI_{0.6}$ to $DI_{1.0}$ there was no significant improvement in plant nutrient uptake, leaf area index and fertilizer expense efficiency. With increased fertigation level from NK_{50} to NK_{100}, there was improvement in plant shoot growth and nutrient uptake. The FEE increased with the increase in NK fertigation level from 2.39 to 3.07 g g^{-1}.

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