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Effect of fertigation on growth, yield, fruit quality and leaf nutrients content of strawberry (*Fragaria* × *ananassa*) cv Chandler

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ABSTRACT

A field experiment was conducted during 2011-12 to study the performance of different levels of fertigation and soil fertilization on growth, yield, fruit quality and leaf nutrients content of strawberry *(Fragaria × ananassa* Duch.*)*. The experiment was laid out in randomized block design with five fertigation treatments, viz. (T_1) recommended dose of NPK through soil, (T_2) recommended dose of NPK through drip, (T_3) ¾ of recommended dose of NPK through drip, (T_4) ½ of recommended dose of NPK through drip and (T_5) 1/3 of recommended dose of NPK through drip and each treatment was replicated five times. The healthy runners of cv. Chandler were planted at a spacing of 25 cm × 50 cm in well prepared beds of 2 m × 2 m size in the last week of September 2011 and 2012 as the crop was taken as annual crop. The results revealed that fertigation with recommended dose of NPK gave significantly higher plant height (24.23 cm), leaf area (129.20 cm^2), fruit yield (35.64 tonnes/ha) as compared to fertigation with ½ and 1/3 of recommended dose of NPK and soil fertilization, but was found at par with ¾ recommended dose of NPK fertigation treatment. The maximum fruit length (42.49 mm), fruit breadth (31.74 mm) and fruit weight (19.87 g) was also recorded in fertigation with full recommended dose of NPK. The values of TSS (9.88°B), total sugar (9.44%), anthocyanin (0.249 OD) and ascorbic acid (53.39 mg/100g) was significantly higher in fertigation with recommended dose of NPK treatment as compared to lower levels of fertigation and soil fertilization. The plants fertigated with full and ¾ recommended dose of NPK also had higher leaf nutrients content. Fertigation with ¾ of recommended dose of NPK registered 60 per cent higher fertilizer use efficiency over soil fertilization with full recommended dose of NPK and also resulted in 25 per cent saving of fertilizers without any adverse effect on growth, yield and fruit quality.

Key words: Chandler, Fertigation, Quality, Strawberry, Yield

Strawberry (*Fragaria* × *ananassa* Duch.) is one of the most important soft fruit and is commercially cultivated in the states of Maharashtra, Haryana, Punjab, Uttar Pradesh, Himachal Pradesh, Uttarakhand, Jammu and Kashmir, Meghalaya and West Bengal (Singh *et al.* 2006). Among the fruits, it gives quickest return in shortest possible time. It is a shallow rooted plant, thus requires nutrients more frequent for normal plant growth and fruit production.

Applying fertilizers through an efficient drip irrigation system offers a vast potential for more accurate and timely crop nutrition. Fertilizers applied through broadcasting are not efficiently utilized by the plant, whereas, fertigation allows an accurate and uniform application of nutrients to the wetted area, where the active roots are concentrated (Jat *et al.* 2011). Fertigation also increases the efficiency in the application of the fertilizers, thus reduces the production cost as well as lessens the potential of ground water pollution caused by the fertilizers leaching. Fertigation allows adopting the amount and concentration of the applied nutrients in order to meet the actual nutritional requirement of the crop throughout the growing season (Raina *et al*. 2011). Keeping these points in view, the present investigation was carried out to study the effect of different levels of fertigation on growth, yield and fruit quality of strawberry and to work out its fertilizer use efficiency over soil fertilization.

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MATERIALS AND METHODS

A field experiment was conducted on strawberry cultivar Chandler at Dr Y S Parmar University of Horticulture and Forestry, Solan (Himachal Pradesh) located at 30° 51' latitude and 76° 11' E longitude and at an elevation of 1250 meter above mean sea level during 2011 and 2012. The soil was clay loam with pH 6.3, organic carbon 1.92% and available N, P, K was 368.70, 24.21 and 161 kg/ha, respectively. The experiment was laid out in Randomized Block Design with five fertigation treatments, (T_1) recommended dose of NPK through soil (150, 100, 120 kg/ha), (T_2) recommended dose of NPK through drip (150, 100, 120 kg/ha), (T_3) 3/4 of recommended dose of NPK through drip (112, 75, 90 kg/ha), (T_4) 1/2 of recommended dose of NPK through drip (75, 50, 60 kg/ha) and (T_5) 1/3 of

recommended dose of NPK through drip (50, 33, 40 kg/ha). Each treatment was replicated five times. Well rotten FYM at the rate of 60 MT/ha was applied at the time of land preparation. Healthy runners of Chandler variety were planted at a spacing of 25 cm × 50 cm in well prepared beds of 2 m × 2 m size accommodating 32 plants/bed in the last week of September 2011 and again in 2012 as the crop were taken as annual crop. Five beds having 32 plants in each bed were kept under each treatment. Under conventional soil fertilization, full doses each of P_2O_5 and K_2O was applied at the time of preparation of beds for planting. Nitrogen was applied in two split doses, half of the amount was applied before planting and remaining half dose was applied in February (before flowering). These fertilizers were applied in the beds and mixed in the soil. In fertigation, the total quantities of water soluble NPK fertilizer were divided in 10 equal parts depending upon the fertigation treatments and were applied through drip irrigation in 10 equal split doses at 10 days intervals after two months of planting. During the course of study, the irrigation was applied at 100% ETc in all the experimental beds.

The height of 10 randomly selected plants from each plot was measured with the help of measuring scale from the crown level to the apex of the primary leaf and the number of leaves was counted in these plants in May. Fifty fully expanded leaves were collected at random from each plot and leaf area was recorded with LI-COR 3100 leaf area meter. The length and diameter of 20 randomly selected fruits from each plot was measured with the help of digital Vernier Calipers on each harvesting. The weight of 20 randomly selected fruits used for recording fruit size was taken on a top pan balance. The yield of fruits under different treatments were determined on the basis of total weight of fruits harvested from 10 randomly selected plants from each treatment and average yield per plant and per hectare was calculated. The total soluble solid of the juice was determined with an Erma-hand refractometer. Chemical analysis of fruits was done with the standard procedure of AOAC (1980). Anthocyanin pigment of berry was determined by the method given by Harborne (1973).

Leaf samples (without petioles) were collected from each treatment in mid June for nutrient estimation. After digestion of leaf samples, total nitrogen was determined by Kjeldhal's method. Total phosphorus was determined by vanado-molybdate phosphoric yellow colour method (Koeing and Johnson 1942) and K was determined with the help of flame photometer. Total Mg were determined on atomic absorption spectrophotometer. Fertilizer-use efficiency was calculated by dividing the yield of fruits by total fertilizers used during the crop growth. The data obtained were statistically analyzed in accordance with the method described by Gomez and Gomez (1986).

RESULTS AND DISCUSSION

Vegetative growth

Pooled data over two years indicates that vegetative growth parameters were significantly influenced by different fertigation treatments (Table 1). The maximum plant height (24.23 cm), leaf area (129.20 cm^2) and number of leaves (26.40/plant) was recorded in recommended dose of NPK through drip, which was statistically at par with 3/4 of recommended dose of NPK through drip irrigation, which registered a plant height of 23.63 cm and 25.40 leaves/plant having leaf area of 128 cm^2. These treatments were significantly superior to soil fertilization with recommended dose of NPK and fertigation with 1/2 and 1/3 of recommended dose of NPK with respect to growth parameters. The higher growth parameters recorded under these fertigation treatments may be due to increased nutrient use efficiency by minimizing the leaching losses coupled with the split application of NPK fertilizers through drip over one time application of fertilizers as soil application. There was a continuous supply of nutrients in fertigation treatments as the fertilizers were applied in 10 split doses during the entire growth period of the plants, which might have helped in meeting the requirements of nutrients during the critical period of growth. These results are in accordance with the findings of Martinsson *et al*. (2006) who obtained maximum plant height and number of

Table 1 Effect of fertigation and soil fertilization on vegetative growth, yield, fruit size and weight of strawberry cv Chandler (two years pooled data)

Treatment	Plant height (cm)	Number of leaves/plant	Leaf area (cm^2)	Yield (tonnes/ha)	Fruit length (mm)	Fruit breadth (mm)	Fruit weight (g)
T_1 (Recommended dose of NPK through soil)	22.05	23.5	122.5	26.07	40.9	30.03	17.35
T_2 (Recommended dose of NPK through drip)	24.23	26.4	129.2	35.64	42.49	31.74	19.87
T_3 ($3/4^{th}$ of recommended dose of NPK through drip)	23.63	25.4	128.2	31.03	42.03	31.01	18.86
T_4 (½ of recommended dose of NPK through drip)	21.83	23	120.5	26.14	40.86	29.11	17.3
T_5 ($1/3^{rd}$ of recommended dose of NPK through drip)	20.79	22.1	117.9	23.04	38.86	27.76	16.27
CD (P=0.05)	0.62	1.65	1.23	1.1	0.87	0.85	1.01

leaves in plants fertigated with full nutrient package as compared to soil fertilization in strawberry. Santos and Chandler (2009) also observed increase in canopy diameter in strawberry with increasing nitrogen level under fertigation.

Fruit yield

A comparison of different levels of fertigation and soil fertilization indicated highest yield (35.64 tonnes/ha) with recommended dose of NPK through drip, followed by fertigation with 3/4 of recommended dose of NPK through drip (31.03 tonnes/ha), which was significantly higher than soil fertilization with recommended dose of NPK and fertigation with 1/2 and 1/3 of recommended dose of NPK. The plants fertigated with recommended dose of NPK through drip showed 26.85 per cent increase in yield over soil fertilization with recommended dose of NPK. Similarly, there was appreciable increase in yield with fertigation of ¾ recommended dose of NPK fertilizers over soil fertilization and lower levels of fertigation, but was at par with fertigation with full recommended dose of NPK. These results are in line with those of Reddy *et al*. (2002) and Martinsson *et al*. (2006), who observed significant increase in yield of strawberry with fertigation of full nutrient package as compared to low levels of fertigation and soil fertilization. Significantly higher yields under fertigation with full and 3/4 recommended dose of NPK may be attributed to the improved vegetative growth and better nutrient utilization in comparison to soil fertilization. Furthermore, under fertigation, fertilizers were applied in 10 equal split applications and such fractionated supplies might have met the nutrients requirement of strawberry at different growth stages thus leading to higher fruit yield. The better fruit size and weight of fruits under these fertigation treatments in present study might have accounted for higher yield. Gutal *et al*. (2005) also recorded significantly higher yield of strawberry with fertigation as compared to soil application. Fertigation with 100 and 75 per cent recommended dose of NPK fertilizer on an average increased the fruit yield of apricot by 16.4 and 13.7 per cent over soil fertilization (Raina *et al*. 2011).

Physico-chemical characteristics of fruits

The recommended dose of NPK through drip significantly increased fruit size and weight as compared to soil fertilization with recommended dose of NPK during both the years. Pooled data reveals that the maximum fruit length (42.49 mm), breadth (31.74 mm) and fruit weight (19.87 g) was observed in recommended dose of NPK through drip, followed in 3/4 of recommended dose of NPK through drip. These treatments were statistically at par with each other but significantly superior to 1/2 and 1/3 recommended dose of NPK through drip and soil fertilization with NPK. This may be ascribed to the increased synthesis of metabolites and more uptake of nutrients, and their translocation to the fruits. These results are in accordance with the findings of Thakur and Singh (2004) and Mahalakshmi *et al.* (2001) who observed significant increase in fruit size and weight with increasing level of NPK fertilizers through. Similarly, Raina *et al*. (2011) also recorded higher fruit size and weight of apricot fruits with 100 per cent of recommended dose of conventional fertilizers applied through fertigation. The results of plants receiving recommended dose of NPK through soil application was comparable to that of plants receiving 60 per cent of the recommended dose of NPK through drip. It seems that uniform distribution of nutrients, coupled with its confinement in the root zone under fertigation, might have leads to the increased nutrient uptake. Similarly, Peterson (1998) observed better fruit size and overall quality in fertigated plot than the non-fertigated plants.

Recommended dose of NPK through drip significantly increased total soluble solids, total and reducing sugars as compared to soil fertilization during both the years. The maximum TSS (9.88°B), total sugar (9.44%) and reducing sugar (6.52%) was recorded in fruits harvested from plots subjected under fertigation with recommended dose of NPK. These results are in conformity with those of Thakur and Singh (2004), who recorded highest TSS and reducing sugar with 100% of recommended dose of NPK applied through drip irrigation. This increase in sugar content of fruits harvested from 100% recommended dose of NPK through drip might be due to more absorption of nitrogen which may have further exerted the regulatory role in affecting the fruit quality. Jeyakumar *et al*. (2010) also found that total sugar were comparatively higher in papaya fruits harvested from 100% recommended dose of N and K_2O through drip irrigation. The data also indicates that full and ¾ of recommended dose of NPK through drip significantly increased anthocyanin and ascorbic acid as compared to recommended dose of NPK through soil during both the years of study. The maximum anthocyanin (0.248 OD) and ascorbic acid (53.39 mg/100g) was observed in recommended dose of NPK through drip irrigation. These results are in accordance with the findings of Moor *et al*. (2005) and Wold and Opstad (2007), who reported that fertigation increased vitamin C and anthocyanin content as compared to control. Higher ascorbic acid content with the higher levels of nitrogen might be attributed to increase in synthesis and catalytic activity of several enzymes and co-enzymes which are instrumental in ascorbic acid synthesis by Boora and Singh (2000). Similarly the involvement of nitrogen at metabolic level in regulating the physiological and biochemical process especially in the phenylalanine ammonia lyase (PAL) activity, which seems to be the primary cause in increasing the red pigment (Peonidin-3-glucocide) responsible for red colour in strawberry (Martinez *et al*. 1996).

Leaf nutrient content

The plants fertigated with full and 3/4 of recommended dose of NPK fertilizers had significantly higher leaf nutrient contents during both the years of study (Table 2). The highest leaf nitrogen (3.13%), phosphorous (0.40%),

Table 2 Effect of fertigation and soil fertilization on chemical attributes of fruits, leaf nutrients content and fertilizer use efficiency of strawberry cv Chandler (two years pooled data)

Treatment	TSS°B	Total sugar (%)	Reducing sugar (%)	Antho-cyanin (OD 530 nm)	Ascorbic acid (mg/100g)	Leaf N (%)	Leaf P (%)	Leaf K (%)	Leaf Mg (%)	Fertilizer use efficiency (t/ha/t)
T_1 (Recommended dose of NPK through soil)	9.04	9.05	6.24	0.231	47.16	2.92	0.31	1.78	0.41	22.64
T_2 (Recommended dose of NPK through drip)	9.88	9.44	6.52	0.248	53.39	3.13	0.4	2.25	0.42	52.79
T_3 (3/4th of recommended dose of NPK through drip)	9.74	9.42	6.51	0.244	52.32	3.12	0.37	2.19	0.39	57.46
T_4 (½ of recommended dose of NPK through drip)	9.3	9.13	6.26	0.236	48.75	2.98	0.29	1.86	0.35	64.54
T_5 (1/3rd of recommended dose of NPK through drip)	8.66	8.89	6.09	0.224	44.92	2.83	0.25	1.54	0.32	85.64
CD (P=0.05)		0.28	0.05	0.02	NS	1.55	0.06	0.03	0.06	0.02

potassium (2.25%) and magnesium (0.42%) content was observed in drip fertigated plants with recommended dose of NPK. Similarly, increase in leaf N, P and K of strawberry plants with the application of higher dose of fertilizer under fertigated treatments have also been reported by Wold and Opstad (2007). Jeyakumar *et al*. (2010) also observed that leaf nutrient contents were significantly higher in 100% recommended dose of N and K_2O through drip irrigation in papaya. The low N, P and K content in the leaves of strawberry which received full dose of N, P and K through conventional method may be attributed to the leaching losses and fixation of nutrients in the soil, which might have reduced their availability to plants.

Fertilizer-use efficiency

The result revealed that all the treatments of fertigation was found to enhance the fertilizer use efficiency over soil fertilization (Table 2). Highest fertilizer use efficiency (85.64 t/ha/t) was observed in plants fertigated with 1/3 of recommended dose of NPK fertilizer. The increased fertilizer use efficiency may be attributed to the reduction in the quantity of fertilizers added in this treatment. Although the fertilizer use efficiency was higher in this treatment but yield, fruit size and quality was significantly reduced in comparison to higher levels of fertigation. Fertigation with ¾ of recommended dose of NPK resulted in optimum fertilizer use efficiency without any adverse effect on yield and fruit quality. This may be the result of a higher nutrient availability thereby causing higher uptake, lower losses through leaching and mineralization. Similarly, Martinsson *et al*. (2006) and Gutal *et al*. (2005) also reported higher fertilizer use efficiency in strawberry through fertigation over soil fertilization. Similarly, Raina *et al*. (2011) observed higher fertilizer use efficiency in drip fertigation and recorded saving of about 30 per cent fertilizers through fertigation in apricot.

Thus, it may be concluded that in fertigation, application of 3/4 of recommended dose of NPK fertilizers (112, 75 and 90 kg/ha) in ten split doses during December to March at ten days intervals resulted in better plant growth and gave 22 per cent higher yield of better quality fruits as compared to recommended dose of fertilizer through conventional method. This treatment also resulted in saving of 25 per cent of fertilizers and better fertilizer use efficiency than full recommended dose of NPK through drip irrigation and soil fertilization.

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