



Effect of drip irrigation, fertigation and mulching on fruit quality of strawberry (*Fragaria × ananassa*)

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Received: 09 January 2019; Accepted: 09 August 2019

ABSTRACT

The present study was conducted at the Department of Fruit Science and Soil Water & Engineering, Punjab Agricultural University, Ludhiana for two consecutive years (2016, 2017) to explore the effect of drip irrigation, fertigation and mulching on fruit quality of strawberry (*Fragaria × ananassa* Duch.) cultivar Chandler. The experiment was laid out in Factorial Split Plot Design with 12 combinations, comprising four levels of irrigation (I) at 120, 100, 80, 60 % ETc, three doses of fertigation (F) at 100, 80, 60 % of SDF (55 N: 40 P₂O₅: 50 K₂O kg/acre) and four type of mulches (M) (Straw, Black-black, Silver-black and Red-black); the experiment was replicated thrice. Fruit production and quality related attributes, viz. fruit yield/ha, juice acid (%), TSS (Brix°), TSS/acid ratio, total sugars (%), reducing sugars (%), ascorbic acid (mg/100g), fruit juice (%) and sensory score improved significantly with irrigation at 80% level, fertigation at 80% of SDF and plant mulched with Silver-black mulch as compared to other treatments. Interaction effect of I×F, I×M, F×M and I×F×M significantly enhanced TSS/acid ratio and reducing sugars attributes, however, the results were statistically non significant for TSS, total sugars, non reducing sugars and juice content (%). The sustainable fruit yield and fruit quality of strawberry cv. Chandler was achieved in the plants irrigated at 80% ETc level, fertigation at 44 kg N: 32 kg P₂O₅: 40 kg K₂O/acre and soil covered with silver-black mulch as alone or in various combination treatments.

Key words: Fertigation, Fruit quality, Irrigation, Mulching, Strawberry

Strawberry (*Fragaria × ananassa* Duch.), belonging to family Rosaceae, is one of the most attractive, delicious, refreshing fruits of Asia, Europe and North America, which contribute nearly 85.5% to the total world production. It is a good natural source of carotenoids, vitamins, phenols, flavonoids, and has high level of antioxidants. In addition, it is consumed as fresh fruit and used in food processing industry for preparation of jam, ice-cream, syrups, RTS, confectioneries etc. In north India, being a highly remunerative and short duration crop, growers are showing keen interest in its cultivation. During production process, irrigation, fertigation and mulching practices plays a significant role in the production of quality strawberry fruits (Singh *et al.* 2007). If soil moisture is not maintained properly during fruit growth and development then soil temperature increases which in turn decreases biological activity and rate of soil mineralization (Asrey and Singh 2004). Application of fertilizers along with mulching and irrigation, produced fruits of good quality and gave higher fruit yield related attributes (Narayanankutty *et al.* 2017).

In recent years, optimization of irrigation and nutrients scheduling in horticultural crops is primarily concerned with the improvement of fruit production and quality (Shrigure

and Srivastava 2014, 2015). Fertigation substantially enhances plant growth, fruit yield, quality and uniform distribution of applied water as well as available nutrients within active root zone than band placement method (Shrigure *et al.* 2016, Bhatt *et al.* 2011). Mulching also protects the fruit from direct contact with the soil, reduces the number of infected fruits, prevents the occurrence of soil borne diseases, reduces weed population and also improves soil physico-chemical properties. Both organic and inorganic mulches are used for strawberry cultivation (Tripathi *et al.* 2017). However, the effect of different levels of irrigation, fertigation and type of mulches on fruit quality attributes has not been studied thoroughly under plains of north India. The aim of this study was to evaluate the effect of these variables on fruit chemical and yield attributes.

MATERIALS AND METHODS

The study was carried out during 2016 and 2017 at Department of Fruit Science and Precision Farming Development Centre (PFDC), Soil & Water Engineering, Punjab Agricultural University, Ludhiana situated at 30°4' N longitude, 75°5' E latitude at 256 m amsl. Annual mean temperature under Ludhiana conditions (N-W region of India) is about 29.8°C and 16.5°C during summer and winter. Physical and chemical properties of soils were sandy-loam texture, basic in reaction (pH 7.5), low in organic

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carbon (0.33 %), available soil N (121.8 kg/ha), available soil P_2O_5 (13.3 kg/ha) and available soil K_2O (171.8 kg/ha) at 0-15 cm soil depth. The experiment was laid out in Factorial Split-plot Design with 12 combinations in main plots, comprising four irrigation levels (I_1 : 120, I_2 :100, I_3 : 80 and I_4 :60% ETc), fertigation (F_1 :100, F_2 : 80 and F_3 : 60% of SDF (55 kg N: 40 kg P_2O_5 : 50 kg K_2O) along with four different types of mulches (M_1 : Straw @6 Mt/ha, M_2 : Black-black, M_3 : Silver-black and M_4 : Red-black) in sub plots whereas, thickness of polythene mulch was 30 μ . Healthy runners of Chandler strawberry were planted in the 2nd fortnight of October at the spacing of 30 × 30 cm on raised beds. Irrigation was applied through drip system twice a week during earlier plant growth stages, later, on the basis of crop coefficient (Kc), i.e. 0.40 (0 to 30 DAP) and 0.85 (from 30 DAP to final fruit harvest) for calculation of crop evapotranspiration (ETc) as per FAO Penman-Monteith equation ($ET_c = ET_o \times K_c$). Fertigation was done after one week from date of transplanting of seedlings and then regularly at 4 days intervals. Soluble fertilizers @55 N: 40 P_2O_5 : 50 K_2O Kg/acre were applied in split doses as per requirement in the different treatments. Fruits were harvested from five randomly selected strawberry plants/replication. Fruit yield/ha was worked out by multiplying the yield/plant with number of plants/ha. Quality parameters were tested

as per standard procedure (AOAC 2005). Data for various fruit characters was analysed using SAS software version 9.3 (SAS Institute Inc., Cary, NC, USA) and significance was identified at $P \leq 0.05$ whereas, non-significant results were denoted as 'NS'.

RESULTS AND DISCUSSION

Fruit quality attributes: Water and nutrient use efficiency were focussed on improvement in fruit quality parameters (Table 1 & 2). All fruit parameters except juice acid content were considerably influenced by varied levels of drip irrigation, fertigation and mulching and their interactions. When quantity of irrigation water was reduced through drip irrigation at I_3 (80 % ETc level), various chemical attributes significantly increased, viz. TSS (8.15°B), TSS/acid ratio (9.95), total sugar (7.72 %), reducing sugar (5.57%), ascorbic acid content (49.19 mg/100g), fruit juice (89.9 %) and sensory score (7.73). Whereas, juice acid content (0.90%) and non reducing sugars (2.18 %) noted maximum at 120% ETc level but the results were statistically non significant with other treatments. These results are in conformity with the findings of Shirgure *et al.* (2016), Kachwaya *et al.* (2016) in Nagpur mandarin and Chandler strawberries, respectively. Fruit quality attributes notably improved when the plants were

Table 1 Effect of drip irrigation, fertigation and mulching on fruit quality parameters in strawberry cv. Chandler (two years pooled data)

Treatment	TSS (Brix°)	Acidity (%)	TSS/acid ratio	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Ascorbic acid (mg/100g)	Juice (%)	Sensory Score	Fruit yield (Mt/ha)
<i>Irrigation level (ETc)</i>										
I_1 (120 %)	7.85 ^b	0.90 ^a	8.76 ^{bc}	7.43 ^{bc}	5.25 ^c	2.18 ^a	44.15 ^c	85.17 ^c	7.48 ^c	11.12 ^c
I_2 (100 %)	7.91 ^b	0.88 ^a	8.92 ^{bc}	7.49 ^b	5.39 ^b	2.11 ^a	48.50 ^b	89.30 ^b	7.68 ^b	11.88 ^b
I_3 (80 %)	8.15 ^a	0.83 ^a	9.95 ^a	7.72 ^a	5.57 ^a	2.15 ^a	49.19 ^a	89.90 ^a	7.73 ^a	12.50 ^a
I_4 (60 %)	7.90 ^b	0.88 ^a	9.00 ^b	7.37 ^c	5.26 ^c	2.12 ^a	41.73 ^d	85.07 ^c	7.20 ^d	10.04 ^d
LSD (P=0.05)	0.10	NS	0.24	0.11	0.03	NS	0.56	0.46	0.04	0.49
<i>Fertigation level (SDF)</i>										
F_1 (100%)	7.95 ^a	0.88 ^a	9.09 ^b	7.52 ^a	5.32 ^b	2.20 ^a	44.37 ^c	87.73 ^b	7.53 ^b	11.03 ^b
F_2 (80%)	8.07 ^a	0.85 ^a	9.47 ^a	7.61 ^a	5.44 ^a	2.16 ^a	48.04 ^a	89.53 ^a	7.66 ^a	12.45 ^a
F_3 (60%)	7.85 ^a	0.88 ^a	8.91 ^b	7.39 ^b	5.33 ^b	2.06 ^a	45.28 ^b	84.82 ^c	7.37 ^c	10.68 ^c
LSD (P=0.05)	0.09	0.02	0.21	0.10	0.03	NS	0.49	0.40	0.04	0.43
<i>Mulching</i>										
M_1 (Straw mulch)	7.74 ^c	0.96 ^a	7.93 ^c	7.27 ^c	5.09 ^d	2.21 ^a	42.03 ^c	86.79 ^c	7.43 ^d	9.41 ^d
M_2 (Black-black)	8.01 ^{ab}	0.89 ^c	8.99 ^b	7.56 ^{ab}	5.41 ^b	2.14 ^a	46.65 ^b	87.21 ^b	7.52 ^b	11.07 ^c
M_3 (Silver-black)	8.10 ^a	0.73 ^d	11.02 ^a	7.69 ^a	5.60 ^a	2.07 ^a	48.50 ^a	88.32 ^a	7.67 ^a	13.80 ^a
M_4 (Red-black)	7.96 ^b	0.91 ^b	8.69 ^b	7.49 ^b	5.36 ^c	2.14 ^a	46.39 ^b	87.13 ^b	7.48 ^c	11.26 ^b
LSD (P=0.05)	0.10	0.02	0.28	0.16	0.03	NS	0.67	0.67	0.04	0.66
<i>Interaction</i>										
$I \times F$	NS	0.03	0.42	NS	0.04	NS	0.98	NS	0.08	0.85
$I \times M$	NS	0.04	0.56	NS	0.06	NS	1.33	NS	0.08	1.32
$F \times M$	NS	NS	0.49	NS	0.05	NS	NS	NS	0.07	NS
$I \times F \times M$	NS	0.07	0.98	NS	0.11	NS	NS	NS	NS	NS

Means with same letter are not significantly different at $P \leq 0.05$

Table 2 Interaction between drip irrigation, fertigation and mulching on fruit chemical characteristics and yield in strawberry cv. Chandler

Treatment	Acidity (%)	TSS/acid ratio	Reducing sugar (%)	Ascorbic acid (mg/100g)	Sensory Score	Fruit yield/ha
I ₁ F ₁	0.91 ^a	8.85 ^{fghi}	5.26 ^{ef}	43.32 ^{fg}	7.47 ^{fg}	12.07 ^b
I ₁ F ₂	0.90 ^{ab}	8.71 ^{ghik}	5.30 ^e	43.81 ^f	7.57 ^{cde}	9.94 ^{fghi}
I ₁ F ₃	0.89 ^{abc}	8.72 ^{ghij}	5.18 ^g	45.31 ^e	7.40 ^{gh}	11.34 ^{bcde}
I ₂ F ₁	0.87 ^{abcd}	8.89 ^{fgh}	5.23 ^f	49.11 ^b	7.65 ^{bc}	9.93 ^{fghij}
I ₂ F ₂	0.86 ^{de}	9.45 ^{bcdj}	5.49 ^b	47.57 ^{cd}	7.89 ^a	14.83 ^a
I ₂ F ₃	0.91 ^a	8.42 ^{ijkl}	5.44 ^c	48.83 ^c	7.52 ^{def}	10.89 ^c
I ₃ F ₁	0.87 ^{bc}	9.37 ^{bde}	5.58 ^a	43.00 ^{fgh}	7.76 ^b	11.39 ^{bc}
I ₃ F ₂	0.77 ^f	10.67 ^a	5.58 ^a	57.73 ^a	7.86 ^a	14.71 ^a
I ₃ F ₃	0.84 ^{de}	9.80 ^{bc}	5.55 ^a	46.86 ^d	7.58 ^{cd}	11.39 ^{bcd}
I ₄ F ₁	0.86 ^{de}	9.23 ^{def}	5.22 ^f	42.04 ^h	7.25 ⁱ	10.71 ^{cdef}
I ₄ F ₂	0.88 ^{abc}	9.07 ^{defg}	5.39 ^d	43.03 ^f	7.35 ^{gh}	10.32 ^{fg}
I ₄ F ₃	0.89 ^{abc}	8.71 ^{ghik}	5.15 ^g	40.12 ⁱ	7.00 ⁱ	9.08 ^f
LSD (P=0.05)	0.03	0.42	0.04	0.98	0.08	0.83
I ₁ M ₁	0.97 ^a	7.72 ^{ghijkl}	4.93 ^l	39.91 ^m	7.39 ⁱ	8.94 ^{lm}
I ₁ M ₂	0.96 ^{ab}	8.05 ^{fghijk}	5.36 ^{fg}	45.02 ⁱ	7.50 ^{hi}	10.43 ^{hijk}
I ₁ M ₃	0.72 ^{hi}	11.13 ^{abc}	5.50 ^{cd}	47.22 ^f	7.57 ^{gh}	13.20 ^{bc}
I ₁ M ₄	0.96 ^{ab}	8.15 ^{fghi}	5.19 ^{hij}	44.44 ^j	7.47 ⁱ	12.07 ^{cdefg}
I ₂ M ₁	0.95 ^{abc}	8.12 ^{fghij}	5.18 ^{ij}	46.13 ^h	7.71 ^{bc}	10.44 ^{hij}
I ₂ M ₂	0.93 ^{abcd}	8.27 ^{fg}	5.39 ^f	48.37 ^e	7.65 ^{ce}	12.29 ^{cde}
I ₂ M ₃	0.79 ^g	10.11 ^d	5.56 ^c	50.10 ^b	7.72 ^{bc}	13.67 ^b
I ₂ M ₄	0.85 ^f	9.18 ^e	5.42 ^{ef}	49.42 ^{cd}	7.66 ^{def}	11.33 ^{defghi}
I ₃ M ₁	0.97 ^a	8.00 ^{fh}	5.24 ^h	46.60 ^g	7.64 ^{dfg}	9.68 ^{lm}
I ₃ M ₂	0.71 ^{hij}	11.39 ^{ab}	5.66 ^b	49.61 ^c	7.77 ^b	12.51 ^{bcd}
I ₃ M ₃	0.73 ^h	11.46 ^a	5.87 ^a	51.45 ^a	7.82 ^a	16.31 ^a
I ₃ M ₄	0.90 ^{de}	8.94 ^e	5.51 ^{cd}	49.11 ^d	7.70 ^{bcd}	11.69 ^{defgh}
I ₄ M ₁	0.96 ^{ab}	7.90 ^{ghijkl}	5.01 ^k	35.46 ⁿ	6.97 ^l	8.72 ^m
I ₄ M ₂	0.95 ^{abc}	8.25 ^{fgh}	5.22 ^{hi}	43.61 ^k	7.15 ^k	9.21 ^{ijkl}
I ₄ M ₃	0.69 ^{hij}	11.37 ^{abc}	5.46 ^e	45.25 ⁱ	7.57 ^g	12.26 ^{cdef}
I ₄ M ₄	0.92 ^{bcde}	8.49 ^f	5.32 ^g	42.60 ^l	7.10 ^k	10.12 ^{ijkl}
LSD (P=0.05)	0.04	0.56	0.06	0.33	0.07	1.32

Means with same letter are not significantly different at P≤0.05

applied with higher but split doses of fertilizer in F₁ and F₂ treatments through drip irrigation in comparison to F₃. However, plants fertigated with 80% SDF level (F₂) substantially improved fruit quality and categorically TSS (8.07°B), TSS/acid ratio (9.47), total sugars (7.61 %), reducing sugars (5.44 %), ascorbic acid (48.04 mg/100g), fruit juice (89.54 %) and sensory score (7.66), during entire course of investigations. Fruit quality parameters increased from 7.85 to 8.15°B, 8.76 to 9.95, 7.43 to 7.72%, 5.25 to 5.57 %, 44.15 to 49.19 mg/100g, 85.17 to 89.90 %, 7.48 to 7.73 for TSS, TSS/acid ratio, total sugars, reducing sugars, ascorbic acid, fruit juice and sensory score, respectively, with the decrease in irrigation levels from 120% ETc to 80% ETc. The use of both optimum level of fertilizers and irrigation schedule considerably improved the production of quality fruits as these practices maintained constant

soil moisture and nutrients availability during growth and development period of plants and fruits. Singh *et al.* (2009) explained the effect of moderation in hydrothermal regime substantially facilitated to increase the uptake of water and nutrients and appreciably improved fruit quality. It was also observed that growing of strawberries by covering the soil of raised beds with Silver-black mulch (M₃) significantly increased fruit quality parameters, viz. TSS (8.10°B), TSS/acid ratio (11.02), total sugars (7.69 %), reducing sugars (5.60 %), ascorbic acid (48.50 mg/100g), fruit juice content (88.32 %) and sensory score (7.67) respectively followed by Black-black mulch (M₂) (Table 1). Singh *et al.* (2019) revealed that strawberry plant growth parameters were influenced by microclimate altering techniques with plastic mulches, fertigation and irrigation which resulted in the improvement of fruit quality attributes.

Significant effect of $I \times F$ and $I \times M$ interactions on fruit quality characteristics is shown in Table 2. Strawberries grown under combination of I_3F_2 produced fruits of superior TSS/acid ratio blend, reducing sugars, ascorbic acid and sensory score. Maximum (10.67 %) TSS/acid ratio was observed in I_3F_2 followed by I_3F_3 (9.80%), I_2F_2 (9.45 %) and minimum in I_2F_3 (8.42%), whereas, I_3F_3 , I_3F_1 and I_2F_2 were statistically at par with each other. These observations are in the agreement with the studies conducted by Kachwaya *et al.* (2016). Reducing sugars were significantly higher to the tune of 5.58% both in I_3F_1 and I_3F_2 combinations and these were statistically at par with I_3F_3 (5.55%). However, interaction of $I_4 \times F_3$ substantially produced fruits of inferior quality and had lower reducing sugars in comparison to other combinations. Higher (57.73 mg/100g) ascorbic acid content was attained in the plants treated with combination of I_3F_2 followed by I_2F_1 treatment. Sensory score of strawberry fruits is the assessment on the basis of quality, taste and appearance, and this parameter was evaluated by a panel of experts. The interactive of I_2F_2 showed maximum score to the tune of 7.89 followed by I_3F_2 and these were statistically at par with each other. Beneficial effect of $I \times F$ interactions on fruit quality has been also reported by Imamsaheb *et al.* (2014).

Significant pooled data for two years for interactive effect of $I \times M$ treatments was higher in I_3M_3 for the quality attributes, viz. TSS/acid ratio, reducing sugars, ascorbic acid and sensory score except fruit juice acid (%). Furthermore, TSS/acid ratio was significantly improved with I_3M_3 (11.46) followed by I_3M_2 , I_4M_3 I_1M_3 as compared to other combinations (Table 2). Similar findings were also observed by Kumar *et al.* (2012), Bhamini *et al.* (2017). Plant irrigated and mulched with I_3M_3 had better juice reducing sugars (5.87 %) and lowest values of 4.93% were obtained in I_1M_1 . Maximum (51.45 mg/100g) ascorbic acid was observed in I_3M_3 followed by I_2M_3 and minimum (35.46 mg/100g) in I_4M_1 . Similar results were also observed by Ali and Gaur

(2007) while studying the effect of mulching on fruit yield and quality. Organoleptic score was higher (7.82) in I_3M_3 , however, I_3M_2 (7.77), I_2M_3 (7.72), I_2M_1 (7.71) and I_3M_4 (7.70) were statistically at par with each other.

Interactive effect between $F \times M$ treatments significantly enhanced TSS/acid ratio, reducing sugars and sensory score (Fig 1). Higher (11.57) TSS/acid ratio blend was attained in the plants treated with F_2M_3 combination and lower (7.56) in F_3M_1 . Narayanankutty *et al.* (2017) examined the effect of $M \times F$ combinations and concluded that higher doses significantly produced fruits of superior quality. Strawberries harvested in F_2M_3 treatment had higher reducing sugars (5.75%) followed by F_1M_3 and the lowest in F_3M_1 . However, sensory score was highest (7.77) in F_2M_3 and minimum (7.20) in F_3M_1 . In general, interactive results on fruit quality might be due to cumulative and synergistic effects which resulted in the improvement of quality traits.

The effect of $I \times F \times M$ interactions was explored for juice acid content, being maximum (0.99%) in $I_1F_2M_4$ and minimum (0.65%) in $I_4F_3M_3$ (Fig 2). Strawberry fruits harvested at physiological maturity possessed higher TSS/acid blend of 12.71 in $I_3F_3M_3$ followed by $I_2F_1M_3$ (12.23) and lower (7.62) in $I_1F_3M_1$. Plants irrigated and treated with $I_3F_1M_3$ combination showed maximum (5.96 %) reducing sugars content in Chandler strawberries and minimum (4.88 %) in $I_1F_1M_1$.

Fruit yield: The response of three different irrigation, fertigation and mulching levels; and their interaction ($I \times F$, $I \times M$) showed a significant effect on fruit yield/ha (Table 1 and 2). The production of fruits was maximum in plants irrigated with I_3 , applied with fertilizers- F_2 through fertigation and soil mulched with M_3 to the tune of 12.50, 12.45 and 13.80 Mt/ha, respectively. Further, the interactive effect of $I \times F$ combinations showed that fruit productivity was highest in I_2F_2 (14.83 MT/ha) which was statistically at par with I_3F_2 (14.71 Mt/ha) as compared to other combination, where it ranged from 9.08 Mt/ha to 12.07 Mt/

ha. In $I \times M$ interaction, significantly higher fruit yield/ha was noted in I_3M_3 (16.31 Mt/ha) than other combinations (Table 2). Singh *et al.* (2019) noted that strawberry plants mulched with Silver-black considerably improved fruit yield/plant than Black-black, Red-black and Straw type of mulching materials. The results are attributed to the mutual effect of irrigation, fertigation and mulches on strawberry plants which significantly enhanced water and nutrient use efficiency as well as kept the plots free from weeds. These results are conformity with the results of Kumar *et al.* (2012). Improvement in fruit yield under drip irrigation system might have resulted due to significantly utilization of water, higher uptake of nutrients and excellent

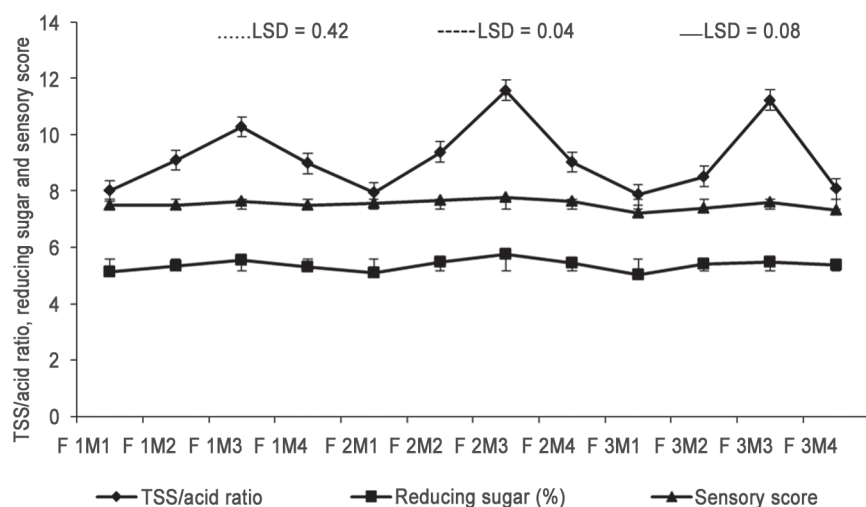


Fig 1 Interaction between fertigation and mulching ($F \times M$) on TSS/acid ratio, reducing sugar and sensory score in strawberry. Vertical bars represent standard error means of three replications.

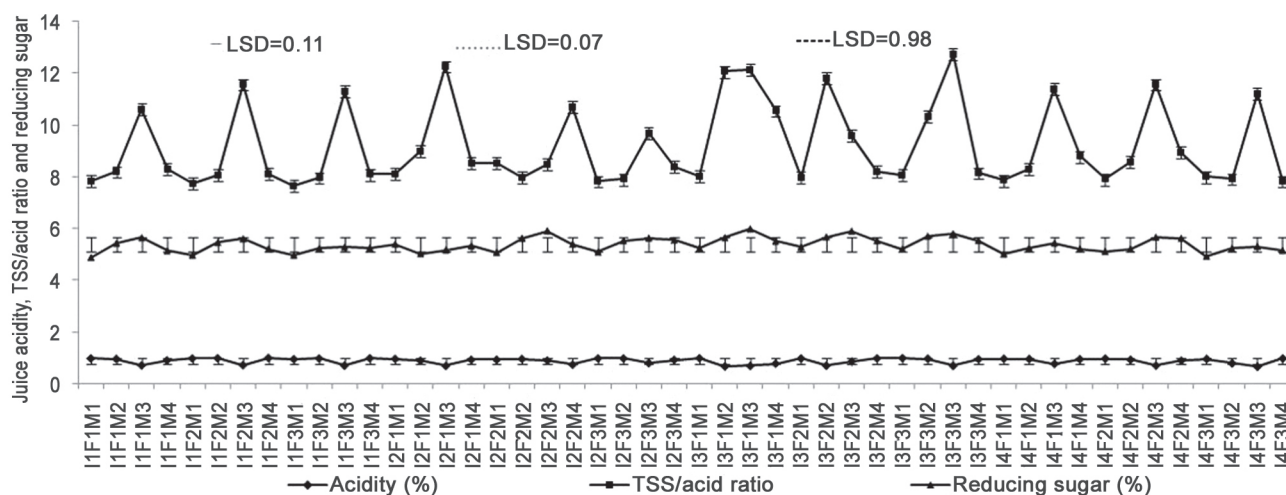


Fig 2 Interaction between drip irrigation, fertigation and mulching ($I \times F \times M$) on juice acidity, TSS/acid ratio and reducing sugar content in strawberry. Vertical bars represent standard error means of three replications.

water–soil–air relationships with more oxygen concentration in the root zone (Gornat *et al.* 1973).

The present investigation clearly suggests that Chandler strawberries grown under open field conditions, irrigated at 80% E_{Tc} level, fertigated with 44 N: 32 P_2O_5 : 40 K_2O Kg/acre (80% SDF) through drip system and mulched with Silver-black had higher fruit yield and produced fruits of good quality, wherein, inputs were applied as alone and in combinations as $I_3 \times F_2$, $I_3 \times M_3$, $F_2 \times M_3$ and $I_3 \times F_2 \times M_3$. It is suggested that precise application of inputs (irrigation, fertigation and mulching) substantially improves fruit quality and production and also checks over exploitation of natural resources.

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