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Implications of mulch and drip fertigation on chemical composition of litchi (*Litchi chinensis*) cv. Rose Scented

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Abstract
The present study was carried to assess the impact of mulch and drip fertigation on the chemical composition of litchi cv. Rose Scented. The experimental trial was conducted for two successive year viz. 2015-16 and 2016-17 at HRC, Pattharchatta, GBPUA&T, Pantnagar. The trial was laid in randomised block design with three replications. Twelve treatment combinations including one control (viz. surface irrigation in conjunction with soil fertilization) were examined. The treatment combinations incorporated three drip irrigation levels (i.e. 50, 75 and 100 per cent based on estimated irrigation water requirement) and two fertigation doses (1:0.5 and 1:1 N/K of recommended fertilizer dose), with and without mulch. The results revealed that the treatment combination viz. mulch application with drip irrigation at 100 per cent level and fertigation at 1:1 N/K of recommended fertilizer dose was most superior with maximum ascorbic acid, total sugar, reducing sugar and non-reducing sugar during the first as well as second year of study.

Keywords: mulch, drip irrigation, fertigation, litchi

Introduction
The fruit crop *Litchi chinensis* is widely popular for its bright red fruits containing transluscent juicy aril as edible part. The ripe fruits are enriched with sugars, vitamin C, protein, fat, minerals (like calcium, phosphorus and iron) and organic acids. India ranks second across the world in the area and production of litchi (Anonymous, 2014) [2]. But due to its exacting climatic requirements litchi production is mainly limited to northern part of India including Bihar, West Bengal, Uttarakhand and Uttar Pradesh. Litchi prefers hot humid summers and cool dry winters. Even slight fluctuations in the climatic conditions may drastically affect the quality production. Although, the climatic anomalies can't be overcomed but litchi production can yet be improved by adopting proper crop management techniques.

Drip fertigation is one such technique which allows direct and steady application of water along with fertilizers to the root zone. Water is as one of the limiting factor in litchi production. Nutrients also play an important role in improving the productivity and fruit quality of litchi. The plant status is closely rated with the N-K balance in plants. Potassium application accentuates the fruit quality by augmenting the sugar content and shelf life in litchi fruits. Thus, the adoption of drip technology besides, reducing the water and nutrient losses, also promotes quality production by enhancing the uptake and utilization of water and nutrients in the plants. Also, when combined with mulch, the technology may further boost the production by reducing evaporation losses, soil erosion and crop competition due to weeds. Keeping these points in views, the present study was conducted to analyse the effect of mulch in combination with varying drip irrigation levels and fertigation doses on fruit quality attributes of Litchi.

Materials and Method
The present study was conducted at Horticulture Research Centre, Pattharchatta, GBPUA&T, Pantnagar during the year 2015-16 and 2016-17. The soil of the research site was sandy loam in texture with a pH of 7.26 and an electrical conductivity of 0.201 dSm^{-1}. The experimental litchi trees (cv. Rose Scented) aged 15-year old, were planted at a spacing of 5m × 5m. The experiment was laid out in randomized block design. There were twelve treatment combinations with one control (i.e. surface irrigation with soil application of fertilizers at recommended dose). The different treatment combinations included three drip irrigation

regimes viz. at 50 per cent (I_1), 75 per cent (I_2) and 100 per cent (I_3) of estimated irrigation water requirement and two fertigation doses i.e. 1:0.5 N/K of recommended fertilizer dose (F_1) and 1:1 N/K of recommended fertilizer dose (F_2), with (M) and without (M_0) black plastic mulch application. The recommended dose of fertilizer was 600g N, 300g P and 600g K. Each treatment combination was replicated thrice with two trees per replication. Further, every plant row was provided with one lateral drip line having eight emitters (of 4l/hr discharge rate) per tree. The operating pressure of the drip irrigation system was maintained at 1.2 kg/cm^2.The drip irrigation was applied at three distinct regimes viz. 50 per cent, 75 per cent and 100 per cent based on estimated irrigation water requirement. The estimated irrigation water requirement was calculated on daily basis by using the formula suggested by (Allen, 1998) [1].

In the present study, the chemical quality attributes viz., titrable acidity, TSS/acidity ratio, ascorbic acid, total sugar, reducing sugar and non-reducing sugar were adjudged. The titratable acidity (per cent) and ascorbic acid were determined through the titration method as mentioned by (Ranganna, 1986) [12]. Total soluble solids/acidity ratio was calculated by dividing the total soluble solids with titratable acidity while; the total, reducing and non-reducing sugar per cent were determined by following the Lane and Eynon method as prescribed by (A.O.A.C, 1984)[3].

Table 1: Effect of different levels of mulch and drip fertigation on titrable acidity, TSS/acidity ratio and ascorbic acid in Litchi

Treatments	Titrable acidity (%)		TSS/Acidity ratio		Ascorbic acid (mg/100g)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Treatments	Titrable acidity		TSS/Acidity		Ascorbic acid	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Mulch						
M	0.46	0.46	38.96	42.61	24.6	24.88
M_0	0.55	0.51	32.99	35.83	23.52	23.66
$CD_{0.05}$	0.056	0.058	4.4	4.44	0.6	0.61
Irrigation						
I_1	0.57	0.58	30.61	30.2	21.07	21.31
I_2	0.5	0.45	36.73	42.57	24.38	24.53
I_3	0.44	0.44	40.58	44.89	26.73	26.98
$CD_{0.05}$	0.068	0.071	5.39	5.44	0.74	0.75
Fertigation						
F_1	0.52	0.46	34.24	40.69	23.66	23.69
F_2	0.49	0.51	37.71	37.75	24.46	24.85
$CD_{0.05}$	0.056	0.058	NS	NS	0.6	0.61
Mulch × Irrigation						
MI_1	0.56	0.6	30.37	29.15	21.4	21.55
MI_2	0.42	0.37	42.06	50.29	25.25	25.66
MI_3	0.41	0.41	44.45	48.39	27.15	27.45
M_0I_1	0.59	0.56	30.85	31.24	20.75	21.07
M_0I_2	0.57	0.52	31.4	34.85	23.52	23.4
M_0I_3	0.48	0.46	36.72	41.3 9	26.31	26.51
$CD_{0.05}$	0.097	0.1	7.62	7.7	1.05	1.06
Irrigation × Fertigation						
I_1F_1	0.59	0.56	28.03	29.83	20.9	20.9
I_1F_2	0.56	0.6	33.18	30.57	21.25	21.72
I_2F_1	0.53	0.44	34.4	43.16	23.76	24.06
I_2F_2	0.46	0.46	39.06	41.98	25	25
I_3F_1	0.44	0.39	40.27	49.07	26.32	26.11
I_3F_2	0.45	0.48	40.9	40.71	27.15	27.85
$CD_{0.05}$	0.097	0.1	7.62	7.7	1.05	1.06
Mulch × Fertigation						
MF_1	0.45	0.43	38.95	45.23	24.16	24.44
MF_2	0.47	0.49	38.96	39.99	25.04	25.33
M_0F_1	0.59	0.5	29.52	36.15	23.16	22.94
M_0F_2	0.51	0.53	36.46	35.51	23.89	24.38
$CD_{0.05}$	NS	NS	6.22	6.28	0.85	0.86
Mulch × Irrigation × Fertigation						
MI_1F_1	0.53	0.58	31.71	29.63	21.3	21.5
MI_1F_2	0.58	0.61	29.02	28.68	21.5	21.6
MI_2F_1	0.41	0.35	42.39	52.32	24.06	24.83
MI_2F_2	0.43	0.4	41.73	48.26	26.44	26.5
MI_3F_1	0.41	0.36	42.76	53.73	27.11	27
MI_3F_2	0.4	0.46	46.14	43.05	27.2	27.9
$M_0I_1F_1$	0.65	0.53	24.36	30.03	20.5	20.3
$M_0I_1F_2$	0.53	0.58	37.34	32.46	21	21.85

$M_0I_2F_1$	0.65	0.53	26.41	34	23.46	23.3
$M_0I_2F_2$	0.5	0.51	36.38	35.71	23.57	23.5
$M_0I_3F_1$	0.46	0.43	37.78	44.41	25.53	25.23
$M_0I_3F_2$	0.5	0.5	35.65	38.37	27.1	27.8
Control	0.53	0.53	32.91	34.57	23	23.23
$CD_{0.05}$	0.13	0.13	10.32	10.42	1.51	1.59

Table 2: Effect of different levels of mulch and drip fertigation on total, reducing and non-reducing sugar in litchi

Treatments	**Total Sugar (%)**		**Reducing Sugar (%)**		**Non reducing sugar (%)**	
	2015-16	**2016-17**	**2015-16**	**2016-17**	**2015-16**	**2016-17**
Treatments	**Total Sugar**		**Reducing Sugar**		**Non-Reducing Sugar**	
	2015-16	**2016-17**	**2015-16**	**2016-17**	**2015-16**	**2016-17**
Mulch						
M	11.5	11.8	8.67	8.25	2.83	3.54
M_0	11	10.87	8.23	8.05	2.77	2.82
$CD_{0.05}$	0.43	0.47	0.17	NS	NS	0.43
Irrigation						
I_1	9.46	9.08	7.16	7.59	2.29	1.49
I_2	11.7	11.99	8.91	8.25	2.78	3.73
I_3	12.61	12.94	9.28	8.62	3.32	4.31
$CD_{0.05}$	0.53	0.57	0.21	0.25	0.57	0.53
Fertigation						
F_1	10.90	10.95	8.3	8.24	2.59	2.71
F_2	11.61	11.72	8.6	8.15	3	3.65
$CD_{0.05}$	0.43	0.47	0.17	NS	NS	0.43
Mulch × Irrigation						
MI_1	9.61	9.61	7.5	7.69	2.1	1.92
MI_2	11.94	12.30	9.03	7.99	2.9	4.3
MI_3	12.97	13.50	9.48	9.09	3.48	4.4
M_0I_1	9.31	8.55	6.82	7.49	2.48	1.06
M_0I_2	11.46	11.68	8.79	8.51	2.66	3.17
M_0I_3	12.24	12.38	9.08	8.15	3.15	4.23
$CD_{0.05}$	0.75	0.81	0.29	0.36	0.81	0.75
Irrigation × Fertigation						
I_1F_1	9.4	8.7	6.93	7.37	2.46	1.33
I_1F_2	9.52	9.46	7.4	7.81	2.12	1.65
I_2F_1	10.94	11.41	8.74	8.51	2.19	2.9
I_2F_2	12.46	12.57	9.08	7.99	3.38	4.57
I_3F_1	12.37	12.75	9.23	8.84	3.13	3.91
I_3F_2	12.84	13.13	9.33	8.41	3.50	4.72
$CD_{0.05}$	0.75	0.81	0.29	0.36	0.81	0.75
Mulch × Fertigation						
MF_1	11	11.2	8.44	8.26	2.55	2.94
MF_2	12.01	12.4	8.9	8.25	3.1	4.14
M_0F_1	10.80	10.7	8.16	8.21	2.64	2.49
M_0F_2	11.20	11.04	8.3	7.88	2.9	3.15
$CD_{0.05}$	0.61	0.66	0.24	0.29	NS	0.61
Mulch × Irrigation × Fertigation						
MI_1F_1	9.5	9.11	7.1	7.11	2.4	2
MI_1F_2	9.72	10.12	7.91	8.27	1.81	1.85
MI_2F_1	11.11	11.77	8.99	8.87	2.11	2.9
MI_2F_2	12.77	12.83	9.07	7.12	3.69	5.71
MI_3F_1	12.40	12.74	9.24	8.81	3.15	3.92
MI_3F_2	13.55	14.26	9.73	9.37	3.82	4.88
$M_0I_1F_1$	9.3	8.30	6.76	7.63	2.53	0.66
$M_0I_1F_2$	9.33	8.81	6.89	7.35	2.44	1.45
$M_0I_2F_1$	10.77	11.05	8.50	8.15	2.27	2.9
$M_0I_2F_2$	12.15	12.31	9.08	8.87	3.06	3.44
$M_0I_3F_1$	12.35	12.77	9.23	8.86	3.11	3.9
$M_0I_3F_2$	12.14	12	8.94	7.44	3.19	4.55
Control	10.14	12.40	9.02	7.22	1.11	5.17
$CD_{0.05}$	1.05	1.23	0.48	0.49	1.14	1.14

Results and Discussion

Among the different treatment combinations, the maximum titrable acidity (0.65 per cent) was found under $M_0I_1F_1$ as well as $M_0I_2F_1$, in first year (Table 1). In the following year (2017), the treatment combination MI_1F_2 exhibited maximum titrable acidity (0.61 per cent). Besides, the lowest (0.40 per cent and 0.35 per cent) titrable acidity were obtained under MI_3F_2 and MI_2F_1, in 2016 and 2017 respectively. Further, the integrated effect of mulch × drip irrigation, drip irrigation × fertigation and fertigation × mulch illustrated that the lowest titrable acidity was recorded under mulch with drip irrigation at 100 per cent level in the first year (0.41 per cent) and mulch with drip irrigation at 75 per cent level (0.37 per cent) in the following year. The interaction effect of drip irrigation and fertigation was also found significant during both the years. But, the interaction of mulch with fertigation gave non-significant results in the entire course of study. These variations could be attributed to the differences in the availability and distribution of soil moisture and nutrients in the root zone under drip irrigation as compared to control. The favourable moisture and nutrient supply throughout the entire fruit development stage due to the combined influence of all the three factors might have promoted the enzymatic activity and further favoured the hydrolysis of metabolites (such as organic acids) resulting into reduced acidity level, under drip fertigation in association with mulch. Further, the main effect of mulch also had a significant influence on the on titrable acidity of fruits during the first year of study but was found non-significant for the following year (Table 1). The main effect of drip irrigation and fertigation also showed significant differences wherein I_3 (drip irrigation at 100 per cent level) possessed least titrable acidity i.e. 0.44 per cent during both the years. But, in terms of the fertilizer, F_2 revealed lowest titrable acidity in 2016 (0.46 per cent) while F_1 in 2017 (0.49 per cent). (Bhanukar *et al*, 2015)[4], (Kumar *et al*, 2015) [9] and (Khan *et al*, 2013) [8] also reported similar findings. In line with these results, decline in titrable acidity was also found in guava cv. Shweta when irrigated at 100 per cent level under drip irrigation (Ramnivas *et al*, 2013) [11].

A higher TSS/acidity ratio is desirable in litchi for improved flavour. In the present study, the treatment combinations MI_3F_2 (46.14) and MI_3F_1 (53.73) were adjudged with highest TSS/acidity ratio, in respective years (Table 1). In terms of the integrated effect of mulch with drip irrigation, mulch application with drip irrigation at 100 per cent level resulted in significantly higher TSS/acidity ratio (44.45) during first year while the second year found mulch application with drip irrigation at 75 per cent level as superior (50.29). The application of drip irrigation in association with mulch might have promoted constant moisture supply to the root zone which could have led to active absorption by roots resulting into higher TSS/acidity ratio. The interaction of drip irrigation × fertigation witnessed highest TSS/acidity ratio under I_3F_2 (40.58) and I_3F_1 (44.89) in first and second year, respectively. However, the integrated effect of mulch with fertigation indicated no significant results. Also, a significant variation was found due to the main effect of mulch, which revealed higher TSS/acidity ratio (38.96 in 2016 and 42.61 in 2017) under mulch over no mulch. The main effect of drip irrigation indicated that the TSS/acidity ratio augmented with increase in irrigation level. But, influence of fertigation was found statistically at par for both the years.

The ascorbic acid also showed significant variations among the treatment combinations including control (Table 1). The maximum amount was obtained under MI_3F_2 (27.20 mg/100g and 27.9 mg/100g, respectively). This could be due to the combined influence of mulch, drip irrigation and fertigation which provided a favourable environment in the rhizosphere resulting in better moisture and nutrient uptake. Also, the interactions among mulch × drip irrigation, drip irrigation × fertigation and mulch × fertigation were found statistically superior during both the years. The combination of mulch with drip irrigation at 100 per cent level produced maximum ascorbic acid content viz. 27.15 mg/100 g and 27.45 mg/100 g, in both the years, respectively. Further during the two year of study, the interactive effect of drip irrigation at 100 per cent level with fertigation at 1:1 N/K of recommended fertilizer dose i.e. I_3F_2 (27.15 mg/100g and 27.85 mg/100g) and mulch with fertigation at 1:1 N/K of recommended fertilizer dose i.e. MF_2 (25.04 mg/100g and 25.33 mg/100g) produced significantly superior results in 2016 and 2017, respectively. The main effect of mulch (Table 1) led to significantly higher ascorbic acid (24.60 mg/100 g and 24.88 mg/100 g). Likewise, augmentation of drip irrigation level and fertilizer dose significantly improved the ascorbic acid in first as well as second year of study. These findings were in accordance with (Ramniwas *et al*., 2013) [11] who found maximum ascorbic acid under drip irrigation at 100 per cent level along with fertigation. (Singh *et al*, 2015) [13] and (Ghosh and Pal, 2010)[6] also reported similar results.

In terms of total sugars, the maximum amount (13.55 per cent) was recorded in treatment combination MI_3F_2 which was statistically at par with the treatment MI_2F_2 exhibiting 12.77 per cent total sugar (Table 2). Again, in the following fruiting season (2017) the treatment MI_3F_2 recorded maximum total sugar (14.26 per cent). Furthermore, the interaction of mulch × drip irrigation at 100 per cent level (12.97 per cent and 13.50 per cent), drip irrigation at 100 per cent level × fertigation at 1:1 N/K of recommended fertilizer dose (12.84 per cent and 13.13 per cent) and mulch × fertigation at 1:1 N/K of recommended fertilizer dose (12.01 per cent and 12.40 per cent) produced superior results in both the years, respectively. The application of higher potassium dose over nitrogen (i.e. 1:1 N/K of RDF) might have improved the total sugar per cent in fruits. Being considered as a quality element, potassium promotes the carbohydrate accumulation in developing fruits and their subsequent hydrolysis into sugars through enzyme activation thus, resulting in improved sugar content (Ganeshamurthy *et al*., 2011) [5]. Significant differences were also indicated for individual effect of mulch, drip irrigation and fertigation during the entire course of study. Further, the reducing sugar showed significant variations ranging from 6.76 per cent to 9.73 per cent in first year and 7.11 per cent to 9.37 per cent in second year of study, respectively (Table 2). In both the years, the highest reducing sugar per cent was estimated under treatment combination MI_3F_2 i.e. 9.73 per cent and 9.37 per cent, respectively. The interactive effect of mulch × drip irrigation level and drip irrigation level × fertigation were also found significant during the two year of study. The interaction of mulch with fertigation too indicated superior results by recording the highest reducing sugar i.e. 8.90 per cent (MF_2) and 8.26 per cent (MF_1) during the year 2016 and 2017, respectively. Such findings were also confirmed by (Iqbal *et al*, 2015) [7] and (Pande *et al*, 2005) [10]. In terms of non-reducing sugar, the treatment combination MI_3F_2 was found significantly superior (3.82 per cent) while, the treatment combination MI_2F_2 (5.71 per cent) in the following year. The interactive effect of mulch × drip irrigation level and drip irrigation level × fertigation was found significant throughout

the two years of study. But, insignificant result was obtained with the combined effect of mulching and fertigation, in the first year, while in the second year, mulching with fertigation at 1:1 N/K of recommended fertilizer dose was found significantly superior (4.14 per cent). The non-reducing sugar was also statistically at par due to the main effect of mulch and fertigation in the year 2016 but, the year observed significant variations with respect to irrigation level wherein the application of drip irrigation at 100per cent level produced highest per cent of non-reducing sugar (3.32) in fruits. In the following year i.e. 2017, significant differences were obtained for individual effect of mulch, drip irrigation and fertigation.

Conclusion

The present study thus, concluded that the interaction between mulch and drip fertigation significantly affected the chemical composition in litchi. The treatment combination MI_3F_2, mulch application with drip irrigation at 100 per cent level and fertigation at 1:1 N/K of recommended fertilizer dose was found most superior. It was followed by treatment combination MI_2F_2, mulch application with drip irrigation at 75 per cent level and fertigation at 1:1 N/K of recommended fertilizer dose

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