Effects of chemical thinning agents on the growth, fruit set, yield, and quality of the nectarine cultivar 'Silver King.'

Abstract

The study was carried out in the Research Farm of the Division of Fruit Science at SKUAST-Kashmir, Shalimar campus during the year 2016 and 2017, to assess the Effects of Chemical Thinning Agents on the Growth, Fruit set, Yield, and Quality of the Nectarine cultivar 'Silver King.' The chemicals tested, were Naphthalene Acetic Acid (NAA), Urea, and Ethephon and were applied after petal fall. The results indicated that NAA (30 ppm) significantly promoted vegetative growth, like plant height, shoot extension, and leaf area. NAA and Ethephon effectively reduced fruit set and overall yield, while enhancing fruit quality attributes like size, weight, and color. Ethephon (150 ppm) advanced fruit maturity by 7 – 8 days. These findings suggest that chemical thinning, particularly with NAA and ethephon, can optimize fruit quality and marketability in Nectarines, making them promising agents for managing the 'Silver King' cultivar.

Key words - Nectarine 'Silver King', thinning agents, chemical thinning, Naphthalene Acetic Acid (NAA), Urea, Ethephon

Introduction

Nectarines (*Prunus persica* L. Batsch var. *nucipersica*) are recent introduction to the Kashmir valley and have quickly gained popularity due to their attractive appearance, smooth skin, and high market value. However, like peaches, nectarine trees tend to produce an excessive number of flowers, which can lead to overcrowded branches and smaller fruit size if not managed properly. Traditionally, thinning has been done manually, involving the removal of excess blossoms or fruitlets by hand. Although effective, manual thinning is labor-intensive, time-consuming, and costly (Jackson & Looney, 1999). This has led to a shift towards chemical thinning as a more efficient alternative. Chemical thinning agents, including plant growth regulators like Naphthalene Acetic Acid (NAA), Ethrel, and other chemicals such as Urea, thiourea, and ammonium thiosulphate, have become widely used in modern horticulture. These chemicals are applied at various stages of fruit development to control the number of fruits per tree and optimize fruit size, color, and sugar content. Research has demonstrated that applying chemical thinners at critical stages—such as the closed pink stage, full bloom, and early fruitlet stage—can effectively reduce fruit set, leading to an increase in individual fruit weight and overall fruit quality (Zilkah *et al*., 1988; Meitei *et al*., 2013). For instance, studies have shown that urea, when applied at these stages, helps to reduce the excessive number of fruits and promotes the growth of larger, higher-quality fruits. NAA and Ethrel, in particular, have shown excellent results in Nectarine production. When applied after the bloom stage, these plant growth regulators not only help in reducing fruit set but also enhance other key attributes such as fruit size, color, and sugar concentration. Ethrel, for example, can advance fruit maturity, allowing growers to bring their produce to the market earlier, thus gaining a competitive advantage (Rajiv *et al*., 2017; Rimpika *et al*., 2017). NAA has been found to promote vegetative growth, which in turn supports better fruit development by ensuring more balanced distribution of nutrients to the developing fruits. The use of chemical thinners is also advantageous in reducing the physiological strain on trees, preventing issues like limb breakage due to excessive fruit load. By controlling the number of fruits early in the development process, trees can allocate more resources to fewer fruits, resulting in better-quality harvests. This practice not only improves marketability by producing fruits that are more appealing in size and appearance but also enhances the tree's health and productivity over time.

Material and methods

The study was carried out in the Research Farm of the Division of Fruit Science at SKUAST-Kashmir, Shalimar campus during the year 2016 and 2017. The experimental orchard is situated at an elevation of 1611 m above mean sea level and lies at 34º 09' N latitude and 74º 52' E longitude. Kashmir has a temperate climate with severe winters from December to March, often dropping below freezing and covered in snow. The valley's altitude ranges from 1500 to 2500 meters above sea level. It experiences a mean maximum temperature of 24.5°C and a minimum of 1.2°C, with a relative humidity of 43.9%. Precipitation averages 650 mm, primarily falling between March and May. The study used four-year-old Nectarine plants of the cultivars Snow Queen, Silver King, and Red Gold, grafted onto peach seedling rootstocks. Planted at a distance of 3 x 3 meter and trained in an open centre system. The plants were chosen for their uniform vigour and maintained under consistent cultural practices throughout the research.

Experimental plants were pruned each year during December by thinning out all the weak, thin, very vigorous and diseased shoots. Among the remaining healthy shoots, only one year old shoots, well distributed throughout the tree canopy, was retained and headed back to 10-12 nodes. These plants were subjected to growth regulators / chemical treatments and hand thinning as per details given in Table 1.

To assess the impact of chemicals on thinning 'Silver King' nectarines, solutions of Naphthalene acetic acid (NAA), Urea, and Ethephon were prepared by dissolving specified amounts in 100 ml of water, with a few drops of Teepol added to lower surface tension. Each solution was made in 5-liter quantities and applied using a knapsack sprayer to fully cover the developing fruits without causing runoff. The spraying commenced with lower concentrations to avoid dilution, and the sprayer was rinsed before using higher concentrations. The treatments were carried out on clear, calm mornings. Once the fruits reached full maturity, two kilograms were randomly collected from various parts of the tree for physico-chemical analysis, while any deformed or damaged fruits were discarded to ensure consistency.

Table 1: Treatment details

S.NO.	Treatment	Concentration	Time of application
T_1	Control	No thinning	The sprays were performed one week after petal fall
T_2	Naphthalene acetic acid	10 ppm	
T_3	Naphthalene acetic acid	20 ppm	
T_4	Naphthalene acetic acid	30 ppm	
T_5	Ethephon	50 ppm	
T_6	Ethephon	100 ppm	
T_7	Ethephon	150 ppm	
T_8	Urea	0.2 %	
T_9	Urea	0.4 %	
T_{10}	Urea	0.6 %	

Observations recorded during the study was Plant Girth (cm), Trunk Cross Section Area (cm^2), Plant Height (cm), Leaf Area (cm^2), Annual Shoot Extension Growth (cm), Date of Initial Bloom (about 10 % flowering), Date of Full Bloom (above 80 % flowering), Percent Fruit Set (%), Date of Fruit Maturity, Fruit Length (cm), Fruit Breadth (cm), Fruit Weight (g), Fruit Firmness (kg/cm2), Fruit Colour (hunter colour lab), Soluble Solids Concentration, SSC (%), Titratable Acidity (%), SSC/Acidity Ratio, Total Sugars (%), Yield (kg/tree), Yield Efficiency (kg/TCSA) Fruit Nutrient Status and Statistical Analysis.

Results and Discussion

The current study explored the effects of chemical treatments on the Growth, Fruit set, Yield, and Fruit quality of nectarine. It was found that the application of NAA at 30 ppm significantly increased the annual shoot growth (52.21 and 52.72 cm), plant height (273.78 and 283.61 cm), plant girth (23.76 and 26.51 cm), trunk cross-sectional area (44.95 and 55.97 cm^2), and leaf area (36.54 and 37.36 cm^2), compared to other treatments. Urea, applied at various concentrations, also increased annual shoot growth (50.67 and 50.82 cm) and leaf area (35.76 and 35.62 cm^2) during 2016 and 2017. The enhanced vegetative growth with NAA might be attributed to increased availability of photosynthates and nutrients, promoting cell division and wall plasticity. Additionally, fruit thinning reduced the crop load, leading to more vigorous growth of the remaining shoots. These results are consistent with previous findings by Zilkha *et al*. (1989), Devnath and Kundo (2001), Taghipour *et al*. (2012), and Rimpika *et al*. (2017), who observed increased vegetative growth in nectarine with the application of NAA and urea. On the contrary, ethephon showed the lowest vegetative growth due to its inhibitory effects on leaf expansion and cell enlargement. Similar outcomes were reported by Hamad and Mohammad (1990), who found that ethrel retarded vegetative growth in apples.

The study also found that different chemical thinners (ethephon, NAA, and urea), when applied one week after petal fall, significantly impacted fruit set. Ethephon at 150 ppm and NAA at 30 ppm resulted in a lower fruit set (53.38, 52.43%, and 54.21, 53.15%) compared to the control (75.54, 72.42%). This may be due to NAA's stimulation of ethylene production, leading to the abscission of young fruits. Ethephon's fruit thinning effect is attributed to the activation of specific genes that stimulate cell wall-degrading enzymes like EG (endo-β-1,4-glucanase) in the separation zone. Urea also caused fruit thinning, resulting in lower fruit set than the control, aligning with earlier findings by Zilkha *et al*. (1988). These results agree with the studies of Basak (2006), Taghipour *et al*. (2012), and Meitei *et al*. (2013), who observed that NAA, ethephon, and urea reduced fruit set in peaches and nectarines.

The study also found that the different thinning treatments significantly reduced the average fruit yield (12.43 and 12.12 kg/plant) compared to the control (18.14 and 19.16 kg/plant). While the maximum yield efficiency (0.72 and 0.55 kg cm^{-2}) was observed under treatment T_1 (control) followed by treatment T_8 (urea @ 2%). However, the minimum yield efficiency (0.29 and 0.22 kg cm^{-2}) was registered in treatment T_4 (NAA @ 30 ppm) during both the years of study. This decrease in total yield aligns with the findings of Sharma *et al*. (2003), Rimpika *et al*. (2017), and Rajput *et al*. (2017), who observed that fruit thinning with ethephon and NAA led to a reduction in yield but improved the production of higher-quality fruits.

The study showed that fruit size, weight, and firmness were significantly affected by the thinning treatments. Ethephon at 150 ppm and NAA at 30 ppm increased fruit length, diameter, and weight. This improvement can be attributed to an increased source-to-sink ratio, higher leaf area, and canopy surface area, promoting better nutrient translocation to the remaining fruits after thinning. These findings align with previous research by Vego *et al*. (2010), Taheri *et al*. (2012), and Rimpika *et al*. (2015), who reported that NAA and ethephon applications increased fruit size and weight in peaches and nectarines. However, the firmness of fruits was reduced in plants treated with ethephon, as ethylene production stimulated the activity of cell wall-degrading enzymes, reducing firmness. This is consistent with findings from Sharma *et al*. (2003) and Devlal *et al*. (2017).

Additionally, the study revealed that thinning treatments improved the skin color of the fruits. Ethephon-treated fruits showed better color development, measured by a lower hue angle, possibly due to enhanced ripening and ethylene-induced anthocyanin pigmentation. These results align with the observations of Whale *et al*. (2012) and Chandel and Singh (2015), who reported improved fruit color in nectarine and peach.

The chemical thinning treatments also reduced the time from fruit set to maturity, with ethephon (100 ppm and 150 ppm) advancing fruit maturity by 7 to 8 days compared to the control. This earlier maturity could be due to increased ethylene production during the final growth phase. These results are in line with those of Sandhu and Singh (2001), who found that ethephon application advanced peach fruit maturity.

Soluble solid concentration, titratable acidity, and sugar content were influenced by the chemical thinning treatments. Ethephon and NAA significantly increased the soluble solids and sugar content while reducing acidity. This may be due to the enhanced translocation of organic metabolites from leaves to fruits, promoting ripening and sugar accumulation. These findings are consistent with previous research by Sharma *et al*. (2001), Taheri *et al*. (2012), and Chandel and Singh (2015). The increase in soluble solids and sugar content can also be attributed to a reduced fruit load, resulting in more carbohydrates being available for the remaining fruits.

The study revealed that different chemical treatments had varying effects on the macronutrient content of nectarine fruits over two years. The highest nitrogen content (0.70%

and 0.72%) was observed in fruits from plants treated with NAA @ 30 ppm, followed closely by urea @ 0.6%, while the lowest nitrogen content (0.61% and 0.60%) was recorded in the control group. Phosphorus content showed no significant differences between treatments, though NAA @ 30 ppm resulted in the highest P content (0.051% and 0.054%). Potassium levels were significantly affected, with the highest content (0.83% and 0.85%) found in fruits from plants treated with NAA @ 30 ppm, and the lowest in untreated plants. Calcium content was not significantly influenced by treatments, with control plants showing the highest Ca content (0.068% and 0.069%). Similarly, magnesium content was also non-significant, though maximum levels (0.029% and 0.030%) were observed in plants treated with NAA @ 30 ppm, while the control group had the lowest Mg content (0.022% and 0.021%).

Conclusion

In conclusion, the application of NAA, followed by urea, proved to be effective in enhancing growth parameters and improving the nutrient status of the fruits. Additionally, the use of NAA and ethephon significantly boosted yield and resulted in high-quality, marketable fruits due to their greater efficiency in chemical thinning for the cultivar Silver King across both years of the study.

Table 2: Effect of chemical thinning on growth characteristics of nectarine cv. Silver King during 2016 and 2017

Treatments		Annual shoot extension growth (cm)		Plant height (cm)		Plant girth (cm)		Trunk Cross sectional area (cm^2)		Leaf area (cm^2)	
		2016	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
T_1	Control	44.21	43.74	260.26	268.12	18.36	20.41	26.84	33.16	32.12	31.68
T_2	Naphthalene acetic acid @ 10ppm	45.44	44.62	262.72	270.79	19.15	21.38	29.20	36.41	32.76	32.24
T_3	Naphthalene acetic acid @ 20ppm	50.14	50.27	271.87	281.68	21.81	24.05	37.87	46.05	35.15	34.51
T_4	Naphthalene acetic acid @ 30ppm	52.21	52.72	273.78	283.61	23.76	26.51	44.95	55.97	36.54	37.36
T_5	Ethephon @ 50ppm	46.79	45.81	265.24	272.60	19.77	21.82	31.11	37.91	33.54	33.34
T_6	Ethephon @ 100ppm	47.61	46.33	266.64	274.45	20.12	22.46	32.23	40.20	33.71	33.66
T_7	Ethephon @ 150ppm	48.17	47.05	267.21	276.67	20.44	22.83	33.30	41.53	33.83	33.78
T_8	Urea @ 0.2%	45.27	44.23	262.37	270.42	18.81	20.84	28.18	34.58	32.44	32.14
T_9	Urea @ 0.4%	49.15	49.26	268.15	278.13	20.77	23.18	34.37	42.78	34.39	34.28
T_{10}	Urea @ 0.6%	50.67	50.82	270.84	280.63	21.46	24.32	36.67	47.09	35.76	35.62
$CD_{(p\leq0.05)}$		**1.29**	**1.15**	**1.72**	**1.61**	**0.54**	**0.61**	**1.76**	**2.18**	**0.66**	**0.61**

Table 3: Effect of chemical thinning on days to flowering characteristics of nectarine cv. Silver King during 2016 and 2017

Treatments		*Date of initial bloom (About 10%)		*Date of full bloom (Above 80%)	
		2016	2017	2016	2017
T_1	Control	17.00	24.33	23.33	33.00
T_2	Naphthalene acetic acid @ 10ppm	16.00	23.33	22.00	33.33
T_3	Naphthalene acetic acid @ 20ppm	16.67	23.67	22.67	33.33
T_4	Naphthalene acetic acid @ 30ppm	16.00	24.67	24.00	34.00
T_5	Ethephon @ 50ppm	15.00	24.00	21.67	33.33
T_6	Ethephon @ 100ppm	15.33	22.67	22.67	33.67
T_7	Ethephon @ 150ppm	15.33	23.67	23.00	33.33
T_8	Urea @ 0.2%	15.67	23.67	22.33	34.00
T_9	Urea @ 0.4%	15.00	23.00	23.33	33.67
T_{10}	Urea @ 0.6%	15.33	23.67	22.33	33.33
$CD_{(p \leq 0.05)}$		**NS**	**NS**	**NS**	**NS**

***Reference Date: 1st Week of March**

Table 4: Effect of chemical thinning on fruit set (%), fruit maturity and yield characteristics of nectarine cv. Silver King during 2016 and 2017

Treatments		Initial fruit set (%)		Fruit maturity (DAFB to Harvesting)		Fruit yield (kg tree^{-1})		Yield efficiency (Kg cm^{-2})	
		2016	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
T_1	Control	75.54	72.42	85.33	87.33	19.16	18.14	0.72	0.55
T_2	Naphthalene acetic acid @ 10ppm	72.23	69.37	84.00	86.33	17.48	16.72	0.60	0.46
T_3	Naphthalene acetic acid @ 20ppm	62.75	60.06	82.00	83.67	15.03	14.25	0.40	0.31
T_4	Naphthalene acetic acid @ 30ppm	54.21	53.15	79.33	81.00	13.02	12.34	0.29	0.22
T_5	Ethephon @ 50ppm	63.06	60.67	80.33	82.67	14.76	14.36	0.46	0.36
T_6	Ethephon @ 100ppm	58.26	56.44	78.33	79.67	13.24	13.04	0.40	0.31
T_7	Ethephon @ 150ppm	53.38	52.43	77.33	78.33	12.43	12.12	0.36	0.28
T_8	Urea @ 0.2%	73.12	70.61	84.33	86.67	18.76	17.04	0.67	0.49
T_9	Urea @ 0.4%	69.41	66.29	83.00	85.00	17.17	16.55	0.55	0.44
T_{10}	Urea @ 0.6%	66.73	63.21	82.33	84.33	16.28	15.58	0.45	0.33
$CD_{(p\leq0.05)}$		**1.79**	**1.71**	**1.14**	**1.01**	**1.52**	**1.60**	**0.05**	**0.03**

Table 5: **Effect of chemical thinning on physical fruit characteristics of nectarine cv. Silver King during 2016 and 2017**

Treatments		Fruit length (cm)		Fruit diameter (cm)		Fruit weight (g)		Fruit firmness (kg cm^{-2})	
		2016	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
T_1	Control	4.12	4.07	3.91	3.83	44.59	45.01	9.17	9.06
T_2	Naphthalene acetic acid @ 10ppm	4.31	4.26	4.12	4.03	49.63	50.04	9.02	8.91
T_3	Naphthalene acetic acid @ 20ppm	4.92	5.01	4.74	4.78	61.15	62.12	8.63	8.55
T_4	Naphthalene acetic acid @ 30ppm	5.23	5.22	5.00	5.01	72.62	71.45	8.22	8.12
T_5	Ethephon @ 50ppm	4.94	4.82	4.68	4.59	62.65	63.26	8.53	8.42
T_6	Ethephon @ 100ppm	5.06	5.01	4.90	4.83	67.44	68.37	8.41	8.33
T_7	Ethephon @ 150ppm	5.25	5.24	5.05	5.03	73.62	72.61	8.16	8.04
T_8	Urea @ 0.2%	4.27	4.23	4.08	4.01	48.24	47.63	9.08	8.96
T_9	Urea @ 0.4%	4.48	4.45	4.25	4.24	51.02	50.42	8.91	8.84
T_{10}	Urea @ 0.6%	4.68	4.66	4.44	4.38	53.40	52.56	8.77	8.66
$CD_{(p\leq0.05)}$		**0.21**	**0.24**	**0.15**	**0.16**	**4.94**	**5.31**	**0.17**	**0.15**

Table 6: Effect of chemical thinning on fruit colour of nectarine cv. Silver King during 2016 and 2017

Treatments	Fruit colour (L*a H)					
	2016			2017		
	L*	A	ºH	L*	A	ºH
T_1 Control	34.25	23.72	32.06	33.54	23.68	32.19
T_2 Naphthalene acetic acid @ 10ppm	32.27	25.07	30.06	31.36	24.65	30.51
T_3 Naphthalene acetic acid @ 20ppm	28.27	29.58	24.82	27.38	29.43	25.17
T_4 Naphthalene acetic acid @ 30ppm	25.66	32.12	22.52	24.58	31.39	23.51
T_5 Ethephon @ 50ppm	27.34	30.53	24.27	25.29	30.33	24.56
T_6 Ethephon @ 100ppm	26.65	31.64	23.30	25.67	32.33	23.07
T_7 Ethephon @ 150ppm	24.35	32.50	22.01	23.37	33.16	22.14
T_8 Urea @ 0.2%	33.35	24.44	30.77	32.42	24.23	31.21
T_9 Urea @ 0.4%	31.26	26.35	28.15	30.29	25.29	29.35
T_{10} Urea @ 0.6%	30.21	27.58	26.54	29.34	27.33	27.25
CD$_{(p\leq0.05)}$	**1.15**	**2.15**	**2.16**	**2.32**	**1.86**	**1.79**

Table 7: Effect of chemical thinning on fruit chemical characteristics of nectarine cv. Silver King during 2016 and 2017

- Treatments	SSC (%)		Titratable acidity (%)		SSC/Acidity ratio		Total sugars (%)	
	2016	2017	2016	2017	2016	2017	2016	2017
T_1 Control	11.15	11.07	0.60	0.61	18.48	18.25	8.33	8.30
T_2 Naphthalene acetic acid @ 10ppm	11.32	11.23	0.58	0.59	19.41	19.14	8.48	8.42
T_3 Naphthalene acetic acid @ 20ppm	11.88	11.83	0.53	0.53	22.46	22.47	9.03	9.05
T_4 Naphthalene acetic acid @ 30ppm	12.71	12.81	0.50	0.50	25.76	25.80	9.37	9.49
T_5 Ethephon @ 50ppm	12.06	12.03	0.54	0.54	22.51	22.42	9.08	9.12
T_6 Ethephon @ 100ppm	12.27	12.26	0.51	0.52	24.07	23.73	9.17	9.21
T_7 Ethephon @ 150ppm	12.77	13.11	0.50	0.49	26.04	25.72	9.45	9.53
T_8 Urea @ 0.2%	11.26	11.17	0.59	0.60	19.21	18.63	8.42	8.38
T_9 Urea @ 0.4%	11.47	11.38	0.57	0.58	20.02	19.74	8.62	8.56
T_{10} Urea @ 0.6%	11.76	11.69	0.55	0.54	21.28	21.70	8.77	8.68
$CD_{(p \leq 0.05)}$	**0.40**	**0.41**	**0.021**	**0.022**	**1.11**	**1.09**	**0.19**	**0.24**

Table 8: Effect of chemical thinning on fruit nutrient status of nectarine cv. Silver King during 2016 and 2017

Treatments		N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
		2016	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
T_1	Control	0.61	0.60	0.042	0.041	0.71	0.70	0.068	0.069	0.022	0.021
T_2	Naphthalene acetic acid @ 10ppm	0.62	0.61	0.043	0.042	0.73	0.72	0.067	0.066	0.022	0.022
T_3	Naphthalene acetic acid @ 20ppm	0.66	0.67	0.047	0.049	0.78	0.79	0.063	0.064	0.027	0.028
T_4	Naphthalene acetic acid @ 30ppm	0.70	0.72	0.051	0.054	0.83	0.85	0.061	0.060	0.029	0.030
T_5	Ethephon @ 50ppm	0.63	0.64	0.046	0.047	0.76	0.77	0.063	0.062	0.026	0.025
T_6	Ethephon @ 100ppm	0.66	0.67	0.048	0.049	0.77	0.78	0.062	0.061	0.027	0.028
T_7	Ethephon @ 150ppm	0.68	0.69	0.049	0.051	0.82	0.84	0.060	0.059	0.028	0.029
T_8	Urea @ 0.2%	0.62	0.62	0.042	0.042	0.72	0.71	0.067	0.068	0.023	0.023
T_9	Urea @ 0.4%	0.65	0.64	0.044	0.045	0.74	0.73	0.066	0.067	0.024	0.025
T_{10}	Urea @ 0.6%	0.69	0.71	0.050	0.053	0.79	0.80	0.065	0.064	0.025	0.026
CD$_{(p\leq0.05)}$		**0.017**	**0.013**	**NS**	**NS**	**0.027**	**0.034**	**NS**	**NS**	**NS**	**NS**

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