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PRUNING AND NITROGEN FERTILIZATION INTERACTIONS ON GROWTH AND PRODUCTIVITY OF NEW CASTLE APRICOT (*Prunus armeniaca* L.) TREES

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ABSTRACT

This study was motivated by the challenge of declining productivity and vitality in older apricot trees, especially the "New Castle" variety (*Prunus armeniaca* L.). As these trees age, they often grow more slowly, produce less fruit, and generally become less vigorous, which can threaten both orchard sustainability and economic returns for growers. Traditional approaches, such as fertilization and pruning, are commonly applied to manage tree health, yet the precise combination and intensity of these treatments that best support rejuvenation has not been extensively explored, especially in aging apricot orchards. This research explores the synergistic effects of nitrogen fertilization and pruning interactions. Using a factorial randomized block design, the study examined ten interaction treatments involving three levels of pruning (20%, 40%, and 60%) and three nitrogen fertilization doses (500g, 625g, and 750g N/tree). The findings demonstrate that strategic pruning in combination with appropriate nitrogen doses significantly accelerates tree vigour and fruiting. Notably, the interaction treatment involving light pruning (20%) and the highest nitrogen dose (750g per tree) yielded the most promising results, enhancing tree trunk girth, height, volume, fruit set, and productivity. Substantial pruning (60%) combined with the maximum nitrogen dose (750g per tree), resulted in enhanced canopy spread, increased annual shoot extension, greater pruning wood weight, expanded leaf area, and elevated chlorophyll contents. Crucially, the examined parameters exhibited a reliable and continuous growth trend, progressively increasing from the commencement of the study to its culmination as a result of the various rejuvenation treatments employed. This research sheds light on effective strategies for rejuvenating aging fruit trees and ensuring sustained productivity.

Keywords: *aging trees, rejuvenation, synergy, canopy, vigour, fruiting.*

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INTRODUCTION

Apricot (*Prunus armeniaca* L.) cultivation is prominent in the dry temperate regions of mid-hill areas, particularly in the sub-mountainous Himalayan regions (Raj *et al*., 2012). However, the production of apricots has been declining in Himachal Pradesh and other similar regions due to aging orchards.

Orchard decline is a multifaceted issue influenced by various factors including climatic conditions, nutritional management, and overall orchard management practices. Understanding these factors is crucial for developing effective strategies to mitigate orchard decline and ensure sustainable fruit production. Climate change affects the annual biological cycle of trees, leading to shorter vegetative rest periods, earlier spring vegetation, and advanced blooming periods. These changes can negatively affect the quantity of fruit production (Gitea *et al*., 2019). Extreme weather conditions such as severe cold winters and droughts have been linked to rapid apple decline (RAD) and other orchard declines, weakening trees and making them more susceptible to other stresses (Singh *et al*., 2019; Stokstad, 2019). High temperatures and soil moisture levels are significant factors in the early decline of kiwifruit, indicating that climatic conditions play a crucial role in orchard health (Bardi *et al*., 2020). Additionally, overcrowding and encroachment of trees in older orchards lead to competition for nutrient absorption, poor light penetration, and increased susceptibility to pests and diseases. This results in less productive orchards (Jotava, 2020; Suklabaidya and Mehta, 2019). High-density planting in apple orchards, which leads to competition for nutrients and moisture, is associated with rapid apple decline. This suggests that modern farming practices may contribute to orchard vulnerability (Stokstad, 2019; Serrano *et al*., 2023). Furthermost, non-compatible varieties, poor management practices, and pest and disease incidence contribute to the declining productivity of old and senile orchards. Effective management of existing plantations is essential for sustainable fruit production (Suklabaidya and Mehta, 2019).

The “New Castle” apricot variety, known for early ripening, is widely cultivated but faces issues of senility. As orchards surpass the 20-year mark, they often experience increased density, forming a dense canopy that obstructs sunlight and restricts cultural practices (Thind and Mahal, 2021). Furthermore, Singh *et al.* (2012) and Usha *et al.* (2015) proposed that reduced photosynthetic efficiency within these crowded canopies, combined with a higher incidence of pests and diseases, contribute to a significant decline in fruit production over time.

The conventional method of uprooting and replanting is time-consuming, expensive, and involves substantial financial losses during the long juvenile phase before new trees bear fruit **(**Usha *et al.*, 2015)**.** Rejuvenation treatments, involving pruning and nitrogen fertilization, offer a sustainable alternative to revitalizing aging fruit trees (Sharma, 2006)**.** Pruning or trimming in the dormant season or right after harvesting triggers dormant buds in the older sections of the tree, encouraging the growth of new vegetation (Radha and Mathew, 2007)**.** Additionally, Togun *et al.* (2003) emphasized the importance of nitrogen as a fundamental element in the growth and development of plants, giving its substantial role in the composition of cellular protoplasm. Earlier studies have underscored the synergistic impact of careful pruning back and nitrogen-based fertilization in rejuvenating the growth and productivity of mature fruit trees (Suklabaidya, 2012).

Considering the significance of meticulous pruning and applying nitrogenous fertilizer in plant resurgence metabolism, the focus of this study is to examine how their interaction influences the rejuvenation of aging “New Castle” apricot trees.

MATERIALS AND METHODS

The research spanned five years and took place in the experimental orchard located at the Department of Fruit Science, College of Horticulture, Dr. Yaswant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India. The experimental site featured an undulated hilly topography in the dry temperate and mid-hill regions of the Himalayan Mountains, situated at 30°51'44.5"N and 77°09'17.7"E, and positioned at an elevation of 1300 meters above the mean sea level.

Soil analysis: At the commencement of the experiment, the physico-chemical attributes of the orchard soil were evaluated. The soil displayed a bulk density of 1.26 mg/m^3 and a field capacity of 28.08%. The pH of the soil was gauged at 6.6 through a digital pH meter, and its electrical conductivity was measured at 0.44 dSm^{-1} using a digital conductivity meter. Additionally, the soil contained 1.62% organic carbon, with available nutrient levels of 319.67 Kg/ha for nitrogen, 16.76 Kg/ha for phosphorus, and 180 Kg/ha for potassium.

Experimental and treatment details: The research centered on mature “New Castle” apricot trees aged 25 years, grafted onto wild apricot rootstocks and planted with a spacing of 5 × 5m (plant to plant and row to row). The revitalization procedure began in the dormant period of February 2011 (18^{th} February, 2011) where winters are cold and spring arrives relatively late, with the initial step involving the pruning of the primary trunk, trimming it back by 2 meters from the surface level. This timing allows the pruning wounds to heal as the tree moves into its active growth period in spring, reducing the risk of frost damage and promoting strong, new growth. Subsequent years (on 18^{th} of February 2012, 2013 and 2014 respectively) involved routine pruning of the primary scaffold branches at 20%, 40%, and 60%. After rejuvenation pruning in late winter or early spring, bud break ideally begins as temperatures start to warm consistently, occurring on March 24th, 20th, 22nd, and 28th in the years 2011, 2012, 2013, and 2014, respectively. Simultaneously, three nitrogen doses (500g, 625g, and 750g per tree) were administered in conjunction with pruning and consistently maintained throughout the entire study duration.

The experiment was conducted considering factorial randomize block design (RBD). The study contained two factors as (pruning level x nitrogen fertilization) at four levels each as shown in Table 1. Various factorial combinations of the treatments were implemented on the experimental trees.

Parameters studied: Standard procedures were followed for assessing tree morphological features such as trunk girth, tree height, canopy spread, and annual shoot growth. Pruning wood weight was measured individually for each tree.

The calculation of the overall above ground volume for each experimental tree was derived from height and spread measurements, following the formulae outlined by Westwood (2009). The volume, expressed in cubic meters, was determined based on the following formula for trees with a greater height than width:

$$\text{Volume} = 4/3\ \pi\ ab^2 \ (\text{if } a > b)$$

Where, r = 3.1416, a = half the length of the major axis, and b = half the length of the minor axis.

Leaf area measurement utilized the Automatic leaf area meter (Licor Model 3100), while the determination of total chlorophyll contents followed the procedures recommended by Jayaraman (2011) and was calculated employing the subsequent formula.

$$\text{Total chlorophyll (mg/g)} = \frac{20.2\,(A_{645}) + 8.02\,(A_{663}) \times V}{1000 \times W}$$

Where, A = Absorbance at specific wave length (nm); V = Volume of chlorophyll extract in 80% acetone and W = Fresh weight of tissue extracted (g).

To assess fruit set, five branches located on distinct aspects of the tree were marked for tallying both flowers and the number of fruit set in consecutive years. The recording of fruit set occurred three weeks post petal fall, and the percentage of fruit set was determined using the formula provided by Westwood (2009), as detailed below:

$$\text{Total fruit set (\%)} = \frac{\text{Total no. of fruit set}}{\text{Total no. of flower}} \times 100$$

Following this, fruits that exhibited uniform size and shape, devoid of any indications of damage, disease, or pest infestation, were manually harvested at the optimal stage of maturity. This stage was determined when the fruits maintained firmness, and their skin color transitioned gradually from green to yellow, typically occurring around 71-73 days from full bloom, aligning with the guidelines proposed by Singh *et al.* (2001b). The mean yield of harvested fruits for each treatment was calculated and presented in kilograms per tree (Kg/tree).

Weather data seasonal wise: Climatic variables during study period from start of pruning until recording last data are depicted in Table 2. The data on climatic variability were recorded in the Weather Forecast Centre, Department of Environmental Science, Dr. Yaswant Singh Parmar University of Horticulture and Forestry, Solan, Himachal Pradesh, India.

Data analysis: The analysis of the dataset involved an evaluation of data normality utilizing the Kolmogorov-Smirnov test method outlined by Sokal and Rohlf (2012). In instances where the normality assumptions were not satisfied, a logarithmic transformation with a base of 10 was implemented. Subsequently, an analysis of variance was performed employing a randomized complete block experimental design with a factorial arrangement. In cases where treatment effects were observed in the character variables, Tukey's mean comparison tests were employed, and significance was set at $P \leq 0.05$. Furthermore, the relationships between independent variables and the annual increment influenced by the applied interaction treatments were statistically scrutinized through linear regression analysis using Pearson correlation, and significance was considered at $p < 0.05$. All statistical analyses were carried out using SAS statistical software version 9.3 from SAS Institute Inc. (2011).

RESULTS

Evaluation of tree growth variables: The combination of pruning and nitrogen fertilization significantly affected trunk girth in senile "New Castle" apricot trees (Table 3). There is an increment in the trunk girth over the 4 years, and the best treatment is found to be P_1xN_3, which shows the highest increment of the most number of years and the highest mean growth of 3.09%. Similar result is being observed with the treatments P_2xN_2 and P_2xN_3, which are also at par with P_1xN_3. In particular, the treatment P_2xN_2 has a mean increment of 3.04%, and P_2xN_3 has a mean of 3.05. This feature makes them the two most potent treatment options since their growth rates are quite similar to the best treatment, thus being statistically comparable.

From the data on tree height increment over four years (Table 3), the treatment P_1xN_3 resulted in the best treatment across most years, which has been accompanied by the overall height increment of 5.35 meters. The treatment P_2xN_3 is at par with P_1xN_3 because of the fact that it has a height increment of 5.31 meters, the equivalent performance of P_1xN_3. This makes P_2xN_3 an effective alternative treatment with a statistically similar impact on tree height increment. This shows how targeted treatments can effectively stimulate vertical growth in mature orchards.

From the data on tree volume over four years (Table 5), the best treatment is found to be P_1xN_3, which consistently demonstrates the highest increment in tree volume each year and has the highest overall mean volume of 64.88 m^3. The treatment P_2xN_3 is at par with P_1xN_3, achieving a high mean tree volume of 60.41 m^3, closely following the performance of P_1xN_3. This makes P_2xN_3 an effective alternative, with tree volume increases statistically comparable to the best treatment.

The growth in trunk girth experienced a notable increase, progressing significantly from 2.51 cm in the first year to 2.66 cm in the fourth year. Similarly, tree height displayed substantial growth, with measurements rising significantly from 4.48 meters in the first year to 5.01 meters in the fourth year. Furthermore, tree volume expanded significantly from 33.77 m^3 in the first year to 61.71 m^3 in the fourth year (Table 5). Importantly, all of these parameters exhibited a steady annual increment, supported by high R^2 values ($R^2 = 0.996$ for trunk girth; $R^2 = 0.982$ for tree height; $R^2 = 0.987$ for tree volume) because of the implementation of various combinations of rejuvenation treatments (Figure 1A and 1C).

The mean annual shoot growth, canopy expansion, and pruning wood weight of apricot trees all increased progressively with the pruning severity (20% < 40% < 60%) and higher nitrogen doses (500g/tree < 625g/tree < 725g/tree) (Table 3, 4 and 5). Among the treatments, P_3xN_3 emerged as the most significant treatment. For annual shoot growth, P_3xN_3 had the highest average increase at 160.25 cm, at par with P_3xN_2 treatment at 159.41 cm, making it a comparable option. In terms of canopy spread between rows, P_3xN_3 achieved the widest mean spread of 4.20 m, at par with P_3xN_2 at 4.16 m. For canopy spread within rows, P_3xN_3 again led with a mean spread of 4.21 m, at par to P_2xN_3 at 4.16 m. Finally, for pruning wood weight, P_3xN_3 showed the highest average weight of 8.32 kg/tree, at par with P_3xN_2 also performing well at 7.97 kg/tree, making it a strong alternative.

The annual growth of shoots, the canopy's expansion between rows, and the canopy's expansion within rows (Figure 1B) all displayed linear associations with the various combinations of rejuvenation treatments (R^2 = 0.994, 0.952, 0.938, respectively) and exhibited a consistent annual increase from the first to the fourth year. This growth spanned from 137.48 cm to 157.82 cm (=1.37 to 1.57 m) for annual shoot growth, from 3.21 m to 4.64 m for canopy spread between rows, and from 3.19 m to 4.62 m for canopy spread within rows.

Assessment of leaf characteristics and overall chlorophyll contents: Across all the treatments, the leaf area and chlorophyll content of apricot trees increased significantly with more intensive pruning and higher nitrogen levels, as shown in Table 6. Among the treatments, P_3xN_3 have the highest mean values, with a leaf area of 35.79 cm² and chlorophyll content of 2.44 mg/100g. Notably the treatment, P_3xN_2 is at par with P_3xN_3, displaying a significant similarly strong mean leaf area of 35.48 cm² and chlorophyll content of 2.40 mg/100g, offering a viable comparable option.

The leaf area showed a remarkable increase, advancing significantly from 31.55 cm^2 in the first year to 34.05 cm^2 in the fourth year. In a similar manner, the chlorophyll content in the leaves demonstrated substantial growth, with measurements increasing significantly from 2.16 mg/100g (equivalent to 21.62 mg/50g) in the first year to 2.29 mg/100g (equivalent to 22.85 mg/50g) in the fourth year. Crucially, all of these parameters displayed a consistent annual increment, backed by robust R^2 values (R^2 = 0.927 for leaf area; R^2 = 0.972 for chlorophyll content) due to the application of various combinations of rejuvenation treatments (Figure 1D).

Evaluation of fruit set and yields of rejuvenated trees: In examining the effect of different treatments on apricot fruit set and yield, both parameters were significantly influenced by higher levels of nitrogen application and light pruning (Table 7). The P_1xN_3 treatment achieved the highest mean fruit set (47.52%) and fruit yield (14.36 kg per tree). This treatment is at par with P_1xN_2, which showed a comparable mean fruit set of 45.55% and fruit yield of 11.56 kg per tree, offering a strong alternative in terms of yield and yield attributes.

The percentage of fruit set exhibited a remarkable increase, advancing significantly from 38.08 % in the first year to 81.33 % in the fourth year. Similarly, the fruit yield per tree showed a linear growth pattern, with measurements significantly increasing from 3.59 kg/tree in the first year to 16.51 kg/tree in the fourth year. Importantly, all of these parameters displayed a consistent annual increment, supported by strong R^2 values (R^2 = 0.982 for fruit set percent; R^2 = 0.920 for fruit yield per tree) as a result of applying various combinations of rejuvenation treatments (Figure 1E).

Climatic variables during study period: The present study was conducted in Nauni, Solan, Himachal Pradesh, India with seasonal climatic data recorded from 2011 to 2014. There is variability in the seasonal distribution of mean temperature, relative humidity, and rainfall during this period (Table 2).

During the winter months (January-February), mean temperatures ranged from 11-16°C. Relative humidity was generally high, averaging between 70% and 86%. Rainfall varied significantly each year, with lower rainfall in January across most years (14.1-68.7 mm) and slightly higher levels in February, particularly in 2013 with 138 mm.

Spring season (March-May) saw an increase in temperatures, ranging from 20°C in early March to around 33°C in May. Humidity was moderate to high, between 42% and 75%. Rainfall was relatively consistent, with moderate amounts in March (37-184 mm), and May rainfall highest in 2014 at 114 mm.

Summer months (June-August) recorded the highest temperatures, peaking at 29-35°C. Relative humidity remained high (48-86%), and rainfall was substantial, especially in July and August. The highest rainfall was observed in July 2014 (335.2 mm) and August 2012 (360.1 mm), marking these months as the wettest of the study period.

Autumn (September-November) temperatures gradually declined, ranging from 28°C in September to around 18-20°C by November. Humidity remained relatively high (67-84%), while rainfall decreased, with notable precipitation in September (up to 292.8 mm in 2012) and minimal rainfall in October and November, particularly in 2011.

December marked the onset of cooler conditions (Early Winter), with temperatures around 13-14°C. Humidity remained high, from 78% to 84%, and rainfall was modest, with the highest recorded value being 47.5 mm in 2013.

This seasonal climate data underscores the varied conditions throughout the study period, influencing apricot tree growth, flowering, and yield.

Table 1: Factors' level and details.

Factor I (Pruning level)	Factor II (Nitrogen-based fertilization)
P_1: 20% pruning of main scaffolds branches	N_1: Soil application of 500 g nitrogen fertilizer per tree
P_2: 40% pruning of main scaffolds branches	N_2: Soil application of 625 g nitrogen fertilizer per tree
P_3: 60% pruning of main scaffolds branches	N_3: Soil application of 750 g nitrogen fertilizer per tree
P_0: No pruning	N_0: No fertilization

Table 2: Climatic variables in Nauni, Solan during the study period from the start of pruning to the final data collection.

Months	2011			2012			2013			2014		
	T	H	R	T	H	R	T	H	R	T	H	R
January	-	-	-	12	79	14.1	11	83	68.7	12	85	47.5
February	16	81	10	15	70	40.8	15	86	138	14	84	29.7
March	21	75	37.8	21	65	37.6	21	75	39.8	20	74	184
April	26	55	52.2	27	54	55.3	27	55	25.1	26	59	84.5
May	32	53	80.1	33	42	46.7	33	52	45.3	31	57	114
June	31	68	184.1	35	48	130.8	31	75	81.3	34	49	107.1
July	30	78	207.5	31	77	326.9	31	80	304.1	31	75	335.2
August	29	82	306.7	29	86	360.1	29	85	45.3	-	-	-
September	28	84	133.6	28	84	292.8	28	80	118	-	-	-
October	25	73	0	24	74	2.6	25	77	6	-	-	-
November	20	72	0.6	18	74	32.2	19	67	13.1	-	-	-
December	14	78	28.4	13	84	13.7	14	80	47.5	-	-	-

*T: Mean temperature (°C), H: Mean relative humidity (%), Mean rainfall (mm)

Table 3: Effect of pruning and nitrogen fertilization interactions on tree vigour of the old and declining "New Castle" apricot trees.

Application	P_1xN_1	P_1xN_2	P_1xN_3	P_2xN_1	P_2xN_2	P_2xN_3	P_3xN_1	P_3xN_2	P_3xN_3	P_0xN_0
Increased in trunk girth (%)										
1st Year	2.26^{bc}	2.47^{bc}	3.14^{a}	2.18^{c}	2.93^{a}	2.93^{a}	2.58^{b}	2.19^{c}	2.44^{bc}	2.00^{c}
2nd Year	2.30^{bc}	2.50^{bc}	2.95^{ab}	2.19^{c}	2.97^{a}	3.18^{a}	2.60^{b}	2.26^{bc}	2.48^{bc}	2.04^{c}
3rd Year	2.38^{bc}	2.58^{bc}	3.21^{a}	2.21^{c}	3.00^{ab}	3.01^{ab}	2.63^{b}	2.31^{bc}	2.53^{bc}	2.10^{c}
4th Year	$2.44b^{c}$	2.67^{b}	3.07^{ab}	2.29^{c}	3.27^{a}	3.09^{ab}	2.71^{b}	2.38^{bc}	2.57^{bc}	2.12^{c}
Mean	2.35	2.56	3.09	2.22	3.04	3.05	2.63	2.29	2.51	2.07
Tree height (m)										
1st Year	4.67^{bc}	4.76^{bc}	4.81^{b}	4.44^{c}	4.50^{c}	5.13^{a}	4.39^{c}	4.45^{c}	4.42^{c}	3.24^{d}
2nd Year	4.85^{b}	4.96^{ab}	5.04^{ab}	4.53^{bc}	4.66^{bc}	5.27^{a}	4.40^{c}	4.74^{bc}	4.64^{bc}	3.54^{d}
3rd Year	4.98^{bc}	5.13^{bc}	5.70^{a}	4.74^{c}	4.72^{c}	5.33^{b}	4.59^{c}	4.87^{c}	4.74^{c}	3.80^{d}
4th Year	5.14^{c}	5.26^{bc}	5.85^{a}	4.96^{cd}	4.98^{cd}	5.51^{b}	4.68^{d}	4.76^{d}	4.84^{d}	4.09^{e}
Mean	4.91	5.03	5.35	4.67	4.72	5.31	4.52	4.71	4.66	3.67
Annual shoot growth (cm)										
1st Year	124.70^{h}	126.83^{g}	133.27^{f}	137.83^{e}	145.67^{c}	147.43^{b}	140.57^{d}	148.90^{ab}	150.40^{a}	119.23^{i}
2nd Year	130.40^{i}	134.50^{h}	139.53^{g}	143.27^{f}	150.37^{d}	153.13^{c}	147.33^{e}	158.27^{a}	156.47^{b}	127.53^{j}
3rd Year	138.15^{g}	144.22^{f}	146.57^{e}	150.04^{d}	160.88^{b}	162.22^{b}	158.82^{c}	163.41^{ab}	165.12^{a}	134.05^{h}
4th Year	144.30^{h}	151.18^{g}	153.37^{f}	157.07^{d}	164.13^{c}	166.47^{b}	165.37^{bc}	167.06^{b}	169.00^{a}	140.27^{i}
Mean	134.39	139.18	143.19	147.05	155.26	157.31	153.02	159.41	160.25	130.27

*Different alphabetical letters in each cropping season (one row) indicate significant differences in the index at p=0.05.

Table 4: Effect of pruning and nitrogen fertilization interactions on canopy expansion of the old and declining "New Castle" apricot trees.

Application	P_1xN_1	P_1xN_2	P_1xN_3	P_2xN_1	P_2xN_2	P_2xN_3	P_3xN_1	P_3xN_2	P_3xN_3	P_0xN_0
Canopy spread between rows (m)										
1st Year	3.10^{d}	3.18^{d}	3.30^{c}	3.16^{d}	3.32^{c}	3.41^{b}	3.26^{cd}	3.40^{bc}	3.51^{a}	2.45^{e}
2nd Year	3.56^{d}	3.64^{c}	3.70^{bc}	3.60^{cd}	3.73^{b}	3.77^{b}	3.72^{b}	3.84^{ab}	3.90^{a}	3.19e
3rd Year	4.32^{c}	4.43^{bc}	4.51^{b}	4.38^{c}	4.46^{bc}	4.55^{ab}	4.48^{b}	4.57^{ab}	4.61^{a}	3.85^{d}
4th Year	4.58^{c}	4.68^{b}	4.73^{b}	4.59^{c}	4.68^{b}	4.85^{a}	4.76^{b}	4.81^{ab}	4.77^{ab}	3.97^{d}
Mean	3.89	3.98	4.06	3.93	4.05	4.15	4.06	4.16	4.20	3.37
Canopy spread within row (m)										
1st Year	3.18^{cd}	3.10^{c}	3.20^{cd}	3.07^{d}	3.22^{c}	3.53^{b}	3.15^{cd}	3.52^{b}	3.65^{a}	2.32^{e}
2nd Year	3.66^{cd}	3.56^{d}	3.83^{b}	3.53^{d}	3.64^{cd}	3.67^{c}	3.58^{d}	3.92^{a}	3.81^{b}	3.11^{e}
3rd Year	4.21^{e}	4.34^{d}	4.44^{c}	4.27^{de}	4.55^{b}	4.65^{a}	4.35^{d}	4.48^{bc}	4.49^{bc}	3.77^{f}
4th Year	4.66^{c}	4.79^{b}	4.63^{c}	4.46^{d}	4.76^{b}	4.78^{b}	4.64^{c}	4.73^{bc}	4.90^{a}	3.88^{e}
Mean	3.93	3.95	4.03	3.83	4.04	4.16	3.93	4.16	4.21	3.27

*Different alphabetical letters in each cropping season (one row) indicate significant differences in the index at p=0.05.

Table 5: Effect of pruning and nitrogen fertilization interactions on tree volume and pruning wood weight of the old and declining "New Castle" apricot trees.

Application	P_1xN_1	P_1xN_2	P_1xN_3	P_2xN_1	P_2xN_2	P_2xN_3	P_3xN_1	P_3xN_2	P_3xN_3	P_0xN_0
Tree volume (m^3)										
1st Year	35.86^{d}	37.25^{c}	44.78^{a}	32.15^{f}	34.67^{e}	42.04^{b}	32.34^{f}	35.88^{d}	29.61^{g}	13.11^{h}
2nd Year	44.46^{d}	46.37^{c}	54.75^{a}	38.30^{f}	41.90^{e}	54.28^{b}	37.00^{g}	45.64^{c}	43.46^{d}	20.67^{h}
3rd Year	55.38^{d}	60.42^{c}	76.13^{a}	50.88^{f}	52.55^{e}	68.42^{b}	48.70^{g}	56.19^{d}	53.53^{e}	28.81^{h}
4th Year	63.91^{d}	68.59^{c}	83.86^{a}	58.29^{f}	61.29^{e}	76.88^{b}	53.90^{h}	56.59^{g}	59.37^{f}	34.38^{i}
Mean	49.90	53.16	64.88	44.91	47.60	60.41	42.99	48.58	46.49	24.24
Pruning wood weight (kg/tree)										
1st Year	4.83^{d}	4.93^{d}	5.00^{d}	5.66^{c}	6.13^{c}	6.46^{bc}	6.77^{b}	8.25^{a}	7.93^{a}	1.66^{e}
2nd Year	4.25^{d}	5.24^{c}	5.54^{c}	5.73^{c}	5.94^{c}	6.49^{bc}	6.82^{b}	7.15^{b}	8.26^{a}	1.33^{e}
3rd Year	4.63^{c}	4.83^{c}	5.18^{c}	5.32^{c}	5.98^{bc}	6.29^{b}	6.53^{b}	8.21^{a}	8.00^{a}	3.41^{d}
4th Year	5.34^{e}	5.36^{e}	5.57^{e}	6.21^{de}	6.43^{d}	7.08^{cd}	7.16^{c}	8.25^{b}	9.07^{a}	3.83^{f}
Mean	4.76	5.09	5.32	5.73	6.12	6.58	6.82	7.97	8.32	2.56

*Different alphabetical letters in each cropping season (one row) indicate significant differences in the index at p=0.05.

Table 6: Effect of pruning and nitrogen fertilization interactions on leaf area and chlorophyll content of the old and declining New Castle apricot trees.

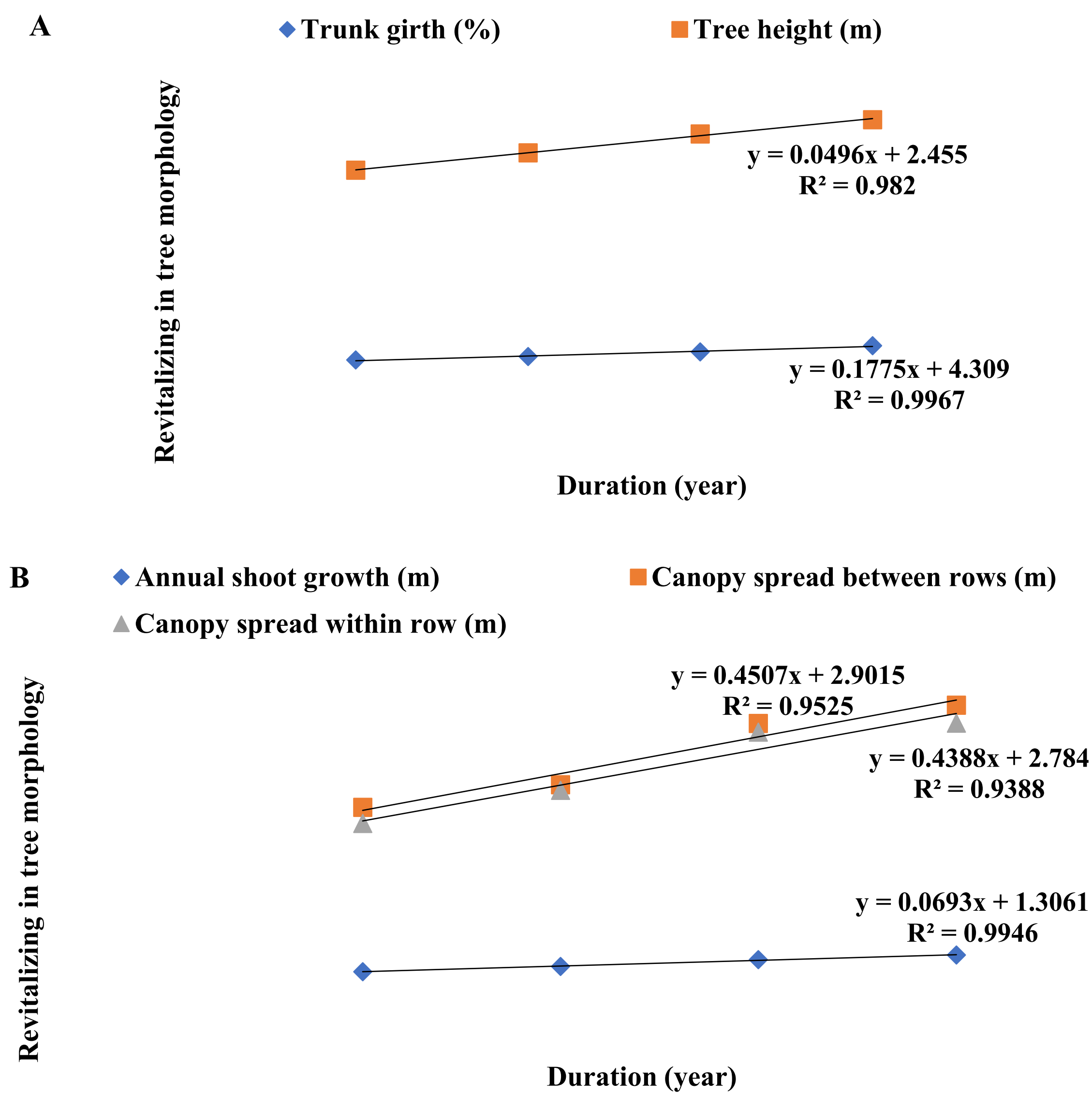
Application	P_1xN_1	P_1xN_2	P_1xN_3	P_2xN_1	P_2xN_2	P_2xN_3	P_3xN_1	P_3xN_2	P_3xN_3	P_0xN_0
Leaf area (cm^2)										
1st Year	29.78^{e}	30.13^{de}	31.83^{cd}	30.84^{d}	31.85^{cd}	33.76^{b}	32.48^{c}	34.88^{a}	35.52^{a}	24.42^{f}
2nd Year	30.48^{c}	30.27^{c}	32.22^{bc}	31.10^{c}	33.42^{b}	32.96^{b}	33.36^{b}	35.24^{a}	34.01^{ab}	30.15^{c}
3rd Year	31.61^{e}	32.04^{e}	32.87^{de}	33.29^{d}	34.98^{c}	38.25^{a}	35.52^{bc}	35.32^{c}	36.57^{b}	28.24^{f}
4th Year	32.76^{d}	32.31^{d}	33.15^{cd}	33.73^{cd}	35.35^{b}	34.14^{c}	35.31^{b}	36.49^{a}	37.05^{a}	30.19^{e}
Mean	31.16	31.19	32.52	32.24	33.9	34.78	34.17	35.48	35.79	28.25
Chlorophyll content (mg/100g)										
1st Year	2.08^{a}	2.09^{bc}	2.10^{bc}	2.12^{bc}	2.23^{ab}	2.26^{a}	2.27^{a}	2.17^{b}	2.28^{a}	2.02^{c}
2nd Year	2.10^{c}	2.11^{c}	2.12^{c}	2.13^{c}	2.25^{b}	2.27^{b}	2.31^{b}	2.47^{a}	2.38^{ab}	2.07^{c}
3rd Year	2.10^{c}	2.13^{c}	2.14^{c}	2.18^{c}	2.27^{bc}	2.28^{bc}	2.37^{b}	2.45^{ab}	2.52^{a}	2.10^{c}
4th Year	2.12^{d}	2.15^{d}	2.13^{d}	2.25^{cd}	2.24^{cd}	2.33^{c}	2.45^{b}	2.50^{ab}	2.59^{a}	2.09^{d}
Mean	2.10	2.12	2.12	2.17	2.25	2.29	2.35	2.40	2.44	2.07

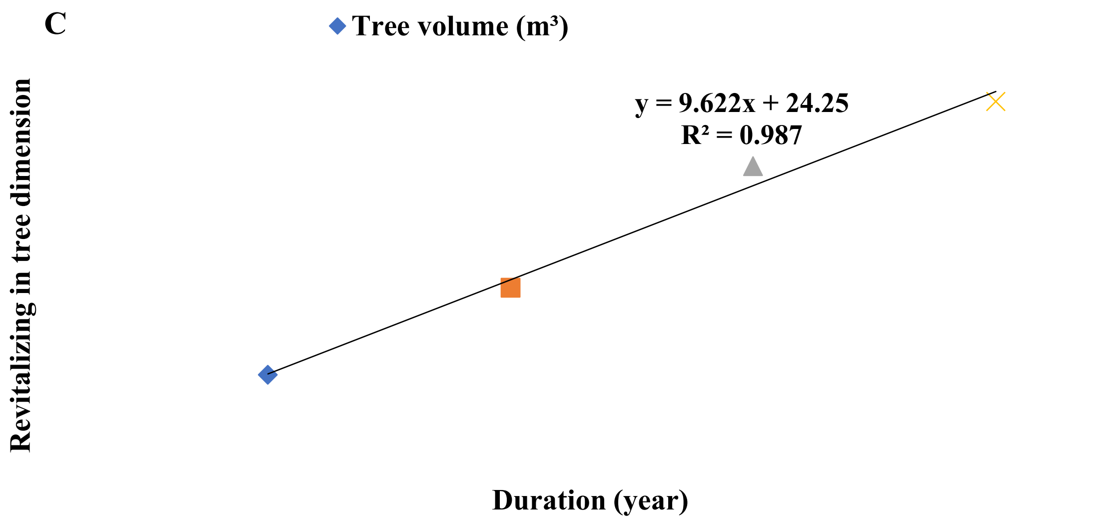
*Different alphabetical letters in each cropping season (one row) indicate significant differences in the index at p=0.05.

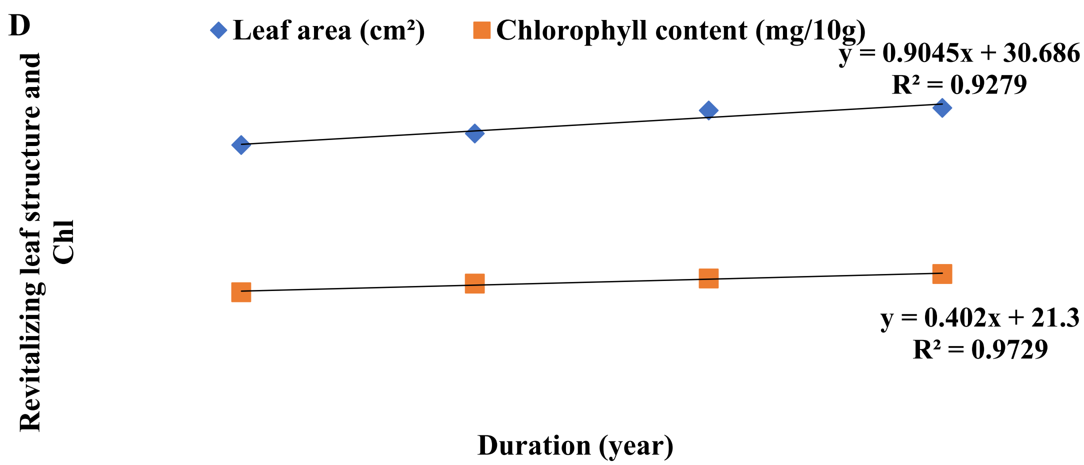
Table 7: Effect of pruning and nitrogen fertilization interactions on fruit set and yields of the old and declining "New Castle" apricot trees.

Application	P_1xN_1	P_1xN_2	P_1xN_3	P_2xN_1	P_2xN_2	P_2xN_3	P_3xN_1	P_3xN_2	P_3xN_3	P_0xN_0
Fruit set (%)										
1st Year	40.31^{b}	42.04^{a}	42.42^{a}	38.50^{c}	42.22^{a}	39.25^{bc}	37.97^{c}	25.66^{e}	38.82^{bc}	33.56^{d}
2nd Year	41.33^{cd}	42.69^{c}	44.62^{b}	33.54^{g}	40.06^{d}	48.04^{a}	40.17^{d}	39.89^{d}	38.02^{e}	35.83^{f}
3rd Year	40.05^{cd}	43.71^{b}	46.59^{a}	40.80^{cd}	41.32^{c}	39.94^{cd}	40.22^{cd}	40.23^{cd}	39.21^{d}	38.04^{d}
4th Year	49.96^{cd}	53.77^{b}	56.45^{a}	51.00^{cd}	51.23^{c}	50.17^{cd}	51.12^{c}	50.23^{cd}	49.25^{d}	50.16^{cd}
Mean	42.91	45.55	47.52	40.96	43.71	44.35	42.37	39.00	41.33	39.40
Fruit yield (kg/tree)										
1st Year	3.17^{b}	4.07^{ab}	4.25^{a}	3.88^{ab}	3.67^{ab}	4.18^{a}	3.33^{b}	3.57^{b}	3.95^{ab}	1.83^{c}
2nd Year	8.40^{bc}	10.25^{a}	10.41^{a}	8.58^{b}	8.83^{b}	10.87^{a}	7.67^{c}	8.51^{b}	8.54^{b}	4.11^{d}
3rd Year	11.92^{bc}	12.83^{b}	14.92^{a}	11.50^{c}	11.33^{c}	13.17^{b}	8.98^{d}	8.67^{d}	10.75^{c}	7.20^{e}
4th Year	16.75^{d}	19.10^{c}	27.86^{a}	14.36^{e}	16.49^{d}	23.45^{b}	11.42^{fg}	11.87^{f}	13.34^{e}	10.51^{g}
Mean	10.06	11.56	14.36	9.58	10.08	12.92	7.85	8.16	9.15	5.91

*Different alphabetical letters in each cropping season (one row) indicate significant differences in the index at p=0.05.







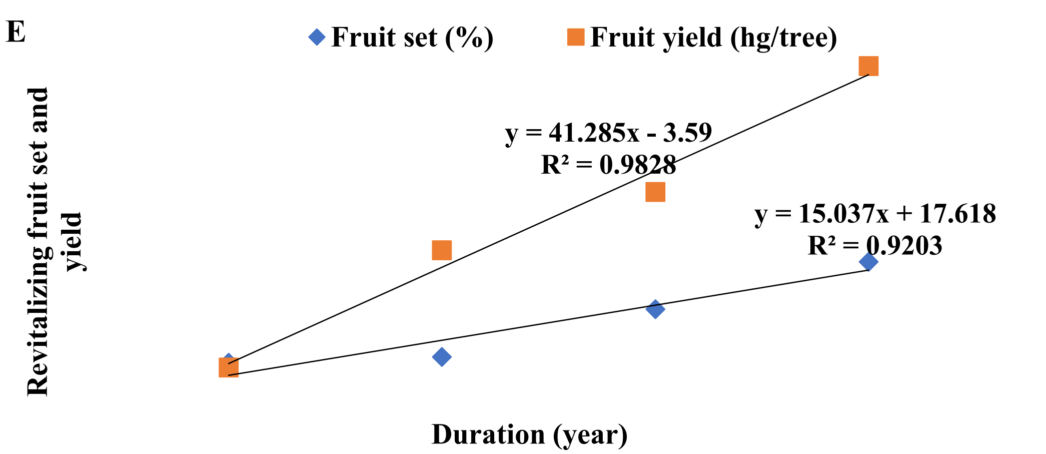


Figure 1 A-E. Impact of pruning and nitrogen fertilization synergy in revitalizing the growth and productivity of aging "New Castle" apricots tree over the course of the experimental year. The equations expression in the graphs represents a linear regression equation and its associated coefficient of determination (R-squared).

DISCUSSION

The notable enhancement in parameters associated with plant growth, such as trunk girth or diameter, tree height, and tree volume, as a consequence of applying interaction treatments involving various levels of pruning and nitrogen fertilization doses, highlights the pivotal role of these interactions in rejuvenating the growth and productivity of declining “New Castle” apricot trees (Tables 3 and 5; Figure 1A and 1C). This augmentation can be attributed to the trees' physiological response to increase photosynthetic rates in the remaining foliage following pruning, as documented in previous studies by Maurin and DesRochers (2013) and Hart *et al.* (2000). Additionally, nitrogen fertilization plays a pivotal role in promoting tree growth and development, given its involvement in vital biological processes that govern the growth of above ground plant components (Frink *et al*., 1999). Notably, an inverse relationship between trunk diameter, tree height, and tree volume with the intensity of pruning (Figure 1A and 1C). This inverse correlation can be attributed to the removal of photosynthetically active portions of the top crown and its branches, which is directly linked to the level of pruning intensity (Forrester, 2013). Similarly, reductions in tree height and volume can be attributed to the removal of tree tissue resulting from pruning cuts, with the reduction being directly proportional to the level of pruning intensity (Stiles, 1984).

The mean annual shoot extension, canopy expansion, weight of pruning wood of the aging apricot trees displayed significant increases regardless of the severity of pruning and nitrogen doses (Tables 3, 4 and 5). This increase was substantial, progressing from the first year to the fourth year (Figure 1B). The increase in annual shoot growth, leading to expanded canopy spread and pruning wood weight, was observed irrespective of the level of pruning severity (20% < 40% < 60%). The vigorous re-growth observed in response to severe pruning, which removes a significant proportion of floral buds, likely contributed to these results (Webster and Palmer, 2016). Additionally, nitrogen fertilization played a role in enhancing plant morphology by influencing cytokinin production, stimulating the multiplication of meristematic cells, increasing cell wall elasticity, and promoting cell elongation (Lawlor, 2002; Bloom *et al*., 2006). Nitrogen is also a key component in amino acid formation, essential for protoplasm formation, a critical site for cell division and, consequently, plant growth and development (Uchida, 2000). Previous research by several investigators reported similar findings regarding the enhancement of tree vigour in temperate fruit crops through the integrated application of pruning and optimal nitrogen-base fertilization (Ahmed and Raza, 2005; Gholiyan *et al*., 2013).

The expanded leaf area, and elevated chlorophyll content of apricot trees displayed an increase in response to the pruning intensity and nitrogen-based fertilization, regardless of the specific treatments employed (Table 6). This increase was significant, progressing from the first year to the fourth year (Figure 1D). The heightened leaf areas noted in the severe pruning treatments can be ascribed to the amplified vigorous shoot growth, a consequence of the alteration of apical dominance through pruning (Singh *et al*., 2001a). An additional possible explanation for the expanded leaf area may be the decrease in the number of shoots per branch and the elongation of shoots, resulting from improved nutrient availability for these shoots (Gopikrishna, 1997). The elevated chlorophyll contents in the leaves can be attributed to nitrogen's role in amino acid and thylakoid protein synthesis in leaves, crucial for the development of essential plant structures, including plastids (Taiz and Zeiger, 2002). These findings align with the results of Sharma and Chauhan (2004), who reported a significant improvement in leaf chlorophyll contents in declining plum trees when treated with substantial pruning combined with higher nitrogen doses.

Within the array of treatments, the interaction treatment involving 20% pruning of main scaffold branches with soil application of 750g nitrogen fertilizer per tree exhibited the most impressive average fruit set percentage and yield per tree (Table 7). Furthermore, a consistent and notable increase in these parameters was observed from the initial year through to the fourth year of the experiment, as depicted in Figure 1E. The enhancement noticed in both fruit set percentage and yield attributed to pruning intensity are consistent with the physiological discoveries by Bagchi *et al* (2008). They documented substantial elevations in proline, catalase, polyphenol oxidase, tryptophan, and peroxidase concentrations in the bark, leaves, and fruit following pruning. The alterations in chemical composition, particularly the synthesis of proline triggered by pruning, could potentially contribute to heightened flowering and fruiting. Ultimately, these changes may lead to an augmented fruit set percentage and increased yield per tree. In addition to pruning, nitrogen fertilization enhanced flowering by elevating the levels of ammonia metabolites in fruit trees (Lovatt *et al*., 1988a and 1988b) and increased the levels of polyamines, growth rate, size of developing fruit, and their potential to set and produce. Similar findings regarding fruit set and yield per tree were reported by Singh and Chauhan (2002) and Ahmed and Raza (2005) in different temperate fruit trees, with decreased fruit set and yield per tree with increasing pruning intensity and increased nitrogen levels.

The growth and productivity of “New Castle” apricot trees are profoundly influenced by climatic variables, particularly temperature, humidity, and rainfall, which interact with pruning and nitrogen fertilization practices. Table 2 data across years (2011-2014) highlight how these variables fluctuate throughout the growing season in Nauni, Solan. Temperature plays a crucial role in metabolic activities, impacting nutrient uptake and growth. In spring months (March-May), when temperatures rise from 21°C to 32°C, nitrogen fertilization becomes more effective, enhancing nutrient absorption and photosynthesis rates (Cai *et al*., 2021; Zhang *et al*., 2020). Pruning in late winter or early spring optimizes canopy structure for light penetration just before the active growth period, allowing the warmer months to support vegetative growth and resource allocation toward productivity (Núñez-Elisea and Crane, 2000; Al-Saif *et al*., 2023; Lodolini *et al*., 2019). Relative humidity also affects growth; high humidity reduces transpiration, limiting nutrient uptake, while low humidity increases water loss, potentially causing water stress (Gislerod *et al*., 1987; Chia and Lim, 2022; van de Sanden and Veen, 1992). In Nauni, where humidity fluctuates between 55% in April to peaks of 86% in August, growth varies seasonally, with high humidity during the monsoon potentially hindering growth. During the monsoon (July-August), high humidity combined with intense rainfall (up to 360 mm) can reduce WUE and may increase fungal infections due to moisture retention within pruned canopies (Aung *et al*., 2018). Rainfall in Nauni varies seasonally (Table 2), moderate rainfall and deficit irrigation can improve fruit quality traits such as total soluble solids, vitamin C, and fruit firmness, while slightly reducing yield (Guida *et al*., 2017; Shao *et al*., 2015). Excessive rainfall can lead to increased fruit cracking, reduced fruit quality and yield particularly in crops like cherries (Tian *et al*., 2019). Pruning, especially when combined with nitrogen fertilization, can enhance vegetative growth and improve water use efficiency, which is crucial during dry periods (Fang *et al*., 2017; Forshey, 1982). The synchronization of pruning and nitrogen application with climatic cycles is critical. For instance, applying nitrogen in late winter supports early bud break (Rettke *et al*., 2006a; Rettke *et al*., 2006b), while pruning prepares the canopy to maximize spring sunlight exposure (Neri and Massetani, 2011), critical for apricot productivity in Nauni's climate.

Conclusion: Through careful experimentation, the study concluded that combined nitrogen fertilization and pruning treatments can substantially enhance tree vigor and fruit yield, offering a practical alternative to costly orchard replanting. The findings reveal that strategic light pruning (20%) paired with high nitrogen levels (750g per tree) optimally enhances trunk girth, tree height, volume, and fruit productivity, while more intensive pruning (60%) with the same nitrogen dosage maximizes canopy spread, annual shoot growth, and chlorophyll content. By demonstrating positive impacts on growth parameters and productivity, Importantly, all these parameters displayed a consistent and steady growth pattern, increasing from the study's initiation to its conclusion due to the diverse rejuvenation treatments' application. These findings provide valuable insights into effective strategies for revitalizing aging fruit trees and ensuring their continued productivity.

Contribution of the Authors: The authors of this research were involved in conceptualization, experimental design, data collection, data analysis, and manuscript preparation. We affirm the absence of any conflicts of interest.

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