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The Potential Role of Macronutrients N, P, and K in *Prunus Armeniaca* × *Sibirica* during Transition from Juvenile Stage to Adults

Wei Duan[1#], Lu-Ying Feng[1#], Xiao-Kui Hou[2], Gang Zhang[3], Ning Zhang[3], Meng-Sha Xu[1], Ta-Na Wuyun[1], Fang-Dong Li[1], Han Zhao[1*], Gao-Pu Zhu[1*]

[1 a] Research Institute of Non-timber Forestry, Chinese Academy of Forestry, [b] Kernel-Apricot Engineering and Technology Research Center of National Forestry and Grassland Administration, and [c] Key Laboratory of Non-timber Forest Germplasm Enhancement & Utilization of State Forestry Administraion, Zhengzhou 450003, P. R. China

[2] Huanghe Jiaotong University, Jiaozuo 454950, P. R. China

[3] Henan Provincial Institute of Science and Technology Information, Zhengzhou 450003, P. R. China

[#]Joint first author, [*]Corresponding author's

E-mail address: poog502@hotmail.com

Abstract: - The goal of this study was to develop recommended macronutrient fertilization rates with the amount based on soil chemical analysis, yield, and leaf macronutrients, and to build a fast identification nutriture standard during the transition from the juvenile stage to adult in *Prunus armeniaca* × *sibirica* cultivation. The soil chemical and leaf macronutrients N, P, and K were the three main elements, and three yields at high, middle, and low levels were analyzed. The orthogonality experiment for the macronutrients N, P, K, and organic fertilizer in pot experiments was designed with four factors and five levels ($L_{25}5^4$). The results showed that the production of apricot kernels was high when total nitrogen content was 0.075% ~ 0.089%, available nitrogen was 62.42 ~ 87.05 mg·kg^{-1}, organic matter was 1.31% ~ 2.19% in soil, and the total nitrogen, phosphorus, and potassium, respectively, were 17.50~19.48 mg·g^{-1}, 0.29 ~ 0.67 mg·g^{-1}, and 20.17 ~ 25.04 mg·g^{-1} in leaves. Based on above results, the fertilizer amounts of 20 g pure nitrogen, 15 g pure phosphorus, 40 g pure potassium, and 400 g organic fertilizer were suitable for transition from the juvenile stage to adult in kernel-apricots.

Keywords: *Prunus armeniaca × sibirica, Kernel-apricot, Foliar nutrient diagnosis, macronutrients*

I. INTRODUCTION

China is the only country that produces and exports apricot kernels [1]. The cultivated area of kernel apricots is approximately 1.35 million hm^2, with an annual output of 250,000 to 300,000 tons of apricot kernels [2]. The apricot kernels produced by *Prunus armeniaca* × *sibirica* in kernel apricots are fragrant, sweet, and nutrient-rich (containing 44% to 59% fatty acids, 24% to 34% protein, 18 trace elements, and multiple amino acids). Cultivation management is simple, such that their economic value is very high [1，3]. In addition, the *P. armeniaca* × *sibirica* have significant drought tolerance (approximately one month for soil volume water content of 5.0%), cold tolerance (normally growth and development at -35 ° C), and can grow in barren soil, which is widely distributed in China's north latitudes 39° －43° , and in arid and

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semi-arid areas [1，3]. The *P. armeniaca* × *sibirica* can produce about 115,000 tons of apricot kernels per year, which makes it an important ecologic and economic tree in China.

Nitrogen (N), phosphorus (P), and potassium (K) are the primary nutrients for plant growth and development. The lack of these elements directly hinders the growth of plants. When the lack of elements is supplemented in time, the development of plants can be quickly improved [4-10]. For example, nitrogen is a key element affecting crop yield and quality [11-12], and nitrogen deficiency can lead to leaf yellowing [13]. Potassium deficiency can result in leaf detachment and necrosis at the edge of the leaves [14]. These physiological deficiencies can alter plant photosynthetic processes, resulting in a significant decrease in photosynthetic product accumulation [15-17]. At the same time, excessive nutrient elements are also not conducive to crop production. Administration of excess nitrogen can cause relatively sour fruit [18], and exacerbation of the incidence of pitburn [19]. Excessive levels of phosphorus can result in a decrease in the stomatal conductance of the leaves, which in turn leads to a significant decrease in photosynthetic rate [20]. Therefore, reasonable levels of nutrients N, P, and K are important for crops to achieve high yields. The nutrient content in leaves not only reflects the overall nutrient level of the fruit trees and the nutrient supply capacity of the soil, but is also an important indicator for non-destructive nutrition diagnosis, judging soil fertility levels, and assessing economic yield [21-23].

In the production of kernel apricots, the diagnosis of soil fertility mainly relies on soil chemical analysis and production experience, but using soil chemical analysis alone may lead to errors because the nutrient content presented in the analysis is only an availability index and not a quantification of the nutrient actually available to the kernel apricots. Until now, the non-destructive nutrition diagnosis technology based on leaf nutrient levels has not been established. Long-term experience caused the application of a large amount of nitrogen fertilizer during the key period of the transition from juvenile phase to adult (the third year after planting), resulting in vegetative growth and reproductive growth disorders. The vegetative growth is strong, and the juvenile phase is significantly prolonged, which significantly reduces the economic output and increases management cost. Establishing a non-destructive nutrition diagnosis technology for kernel apricots, and real-time adjustment of fertilization according to the nutrient content of plants is an inevitable event necessary in the future to achieve the integration of water, fertilizer, mechanization, and precision cultivation, to improve the yield and quality of apricot kernels. This study is based on the relationship between soil nutrients and the content of macro elements in the leaves of the *P. armeniaca* × *sibirica* in different cultivated areas, the effects of nitrogen, phosphorus, potassium, and organic fertilizers on leaf nutrient accumulation, and biomass change of kernel-apricots as studied by pot exogenous fertilization, which provided a theoretical basis for macronutrients N, P and K fertilizer application and accurate nutrition diagnosis in cultivation.

II. MATERIALS AND METHODS

Experiment Design

By studying the relationship between soil nutrient content and leaf nutrient content of *P. armeniaca* × *sibirica* under different yield levels (high, medium, and low) in adulthood, the content and proportion of macroelements in the leaves under the conditions of high-yield can be determined, and the criteria for

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judging the leaf nutrients of high-yield gardens can be established. Artificially regulating the application amount and proportion of exogenous nutrients N, P, and K for potted 3-year-old *P. armeniaca* × *sibirica*, the effects of different fertilization ratios on leaf nutrient content and photosynthetic physiological indexes were studied, and the application amount and proportion of macronutrients suitable for *P. armeniaca* × *sibirica* from the juvenile phase to adulthood were determined.

Study Site

There were three sampling areas for adult apricot leaves and soil, which were located in Lingyuan City, Liaoning Province, Kalaqin County, Inner Mongolia; and Zhuolu County, Hebei Province. The leaf nutrient simulation test period from the juvenile phase to adulthood was located in Yuanyang County, Henan Province. The climate characteristics of the experimental site are shown in Table 1.

Table 1 The growth conditions of sampling sites in this study

Sampling sites / Growth conditions	Kalaqin County, Inner Mongolia	Lingyuan City, Liaoning Province	Zhuolu County, Hebei Province	Yuanyang County, Henan Province
Climate type	Temperate continental semi-arid monsoon	Temperate continental semi-arid monsoon	Temperate continental semi-humid monsoon	Temperate continental semi-humid monsoon
Average annual tempreture / ℃	7.4	8.7	8.8	14.0
Average duration of sunshine / h	2619.3	2748.1	2768	2345
Average annual rainfall / mm	444.7	479.4	398.4	571.7
multi-year average evaporation capacity / mm	1639.3	1143.2	1326.0	1599.0
Annual average frost-free period lasts / d	146	150	130	229
Soil type	Red-clay soil	Cinnamon soil	Sandy-loam soil	Sandy

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Fig. 1 Plant material - *P. armeniaca* × *sibirica* cultivar 'Youyi'

Plant Material

P. armeniaca × *sibirica* cultivar 'Youyi' was studied in this paper and was selected by hybridization between *P. armeniaca* and *P. sibirica* and named 'Youyi' during production. It has features of high yield, sweet kernel, pulp, drought and cold resistance (Fig. 1). This has been the largest cultivation area for kernel apricots in China [3].

Experiment Treatment

Apricots have a significant delay from the absorption to utilization of fertilizers [1]. In the first ten days of December 2014, an even-growth annual 'Youyi' grafted seedling (*Prunus sibirica* as rootstock) was planted in pots with a depth of 0.5 m and diameter of 0.6 m. We conducted routine field management of all saplings after planting. From the beginning of March 2015, we set 4 factors and 5 levels according to local fertilization habits (Table 2), and designed an orthogonal test according to L2554. The four factors were: N(CO(NH2)2, N≥46% (Yunnan Yuntianhua Limited Company, Kunming, China), phosphorus (Ca(H2PO4)2·H2O, P2O5≥12% (Yunnan Yuntianhua Limited Company, Kunming, China), potassium K2SO4, K2O ≥ 50% (Yunnan Yuntianhua Limited Company, Kunming, China), and organic fertilizer (fermented chicken manure, organic matter ≥ 45%, total nutrients ≥ 5%; Shuanghui Group, Luohe, China). Five plants were used for each treatment, and repeated 3 times. The fertilization was repeated once in March 2016. In May 2016, various indexes were measured.

Table 2 The elements of the orthogonal test in this study

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Levels	Factors			
	Pure nitrogen / g	Pure phosphorus / g	Pure potassium / g	Organic fertilizer / g
1	0	0	0	200
2	10	5	10	400
3	20	10	20	600
4	30	15	30	800
5	40	20	40	1000

Sampling and Nutrient Determination

Sampling method for adults: Selected ‘Youyi’ with a tree age of 8–10 years were the experimental unit, using LY / T1588-2000 "Technical regulations for high yield and quality cultivation of kernel-apricot," 7~10-year-old sweet kernel apricot production index as a reference standard. Individual plants producing 0.8 to 1.0 kg kernels were classified as high-yield forests, between 0.5 kg and 0.8 kg were classified as middle-class forests, and those below 0.5 kg were classified as low-yield forest types. The three production levels were sampled separately as sample plots. During the ‘Youy’’ maturity period, from June 20 to July 5, samples and measurements were taken according to the five-point sampling method, and 50 samples were taken from each production level from a total of 450 locations. The detailed sampling method was as follows: collect soil directly below the canopy with a sampling shovel at 20~30 cm deep (the main distribution area of the root with absorption functions). In each location, 200.0 g soil was collected, total nitrogen, total phosphorus, total potassium, available nitrogen, phosphorus, potassium, soil organic matter, pH, and total salt content was measured for 9 indexes. The leaf sampling method was as follows: mature leaves in four directions around the outside of the ‘Youyi’ were selected for sampling. The sampling amount was 100.0 g for each pot, and the contents of total nitrogen, total phosphorus, and total potassium in the leaves were detected. The soil nutrient content was determined by the Institute of Soil, Fertilizer and Water-saving Agriculture, Gansu Academy of Agricultural Science. The specific experimental methods used were to determine total potassium by alkali fusion-flame photometry, organic matter content by the K2Cr2O7 oxidation-oil bath heating method, pH value by glass electrode method, available phosphorus by NaHCO3 extraction-molybdenum antimony colorimetric method, available potassium by flame photometry ammonium acetate extraction, hydrolysis of nitrogen by alkaline hydrolysis method, and total salt content in soil by the conductivity method. Leaf nutrient content was determined by the method of Xu et al. [24].

Photosynthetic physiological indicators and chlorophyll content were determined using the method of Zhu et al. [25]. Biomass was determined in the second year after the end of the fertilization test in mid-October 2016, after the ‘Youyi’ stopped growing and before the first frost, Vernier calipers and tape measures were used to measure the diameter, crown width, and accumulation that were indicators of biomass accumulation of each treated plant.

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Data Selection and Processing

The data entry, collation, preliminary analysis, and related graphs were all conducted in Microsoft Excel 2010. DPS (Data Processing System) 7.05 software [26] was used to analyse the variance of the experimental data obtained. For comparison and correlation analysis, the significance level was $P \leq 0.05$ and multiple comparisons were performed using the Duncan new complex range method. The orthogonal test analysis method used an intuitive analysis method.

III. RESULTS

Relationship between soil physicochemical properties and leaf nitrogen, phosphorus, and potassium content of adult *P. armeniaca* × *sibirica* at different yield levels.

Differences in Soil Physicochemical Properties at Different Yield Leves

The content and proportion of fertilizer nutrients in the soil determined the level of apricot kernel production. Under the high yield and low yield of the three main producing areas, the content of soil organic matter, total nitrogen, total phosphorus, available nitrogen, and available potassium showed significant differences ($P \leq 0.05$) (Table 3). The results showed that there was a positive correlation between yield and nutrient content, indicating that these nutrient indexes played an important role in jointly determining kernel yield. In terms of organic matter content, the average content of Kalaqin was higher (maximum 21.9‰), whereas the minimum (9.1‰) appeared in low-yield forest land in Lingyuan, but the difference between Lingyuan and Zhuolu was not significant ($P \leq 0.05$). In terms of total nitrogen content, the highest content (0.89‰) appeared in Kalaqin and was significantly different from that of the other two regions ($P \leq 0.05$). The minimum value appeared in Lingyuan and the difference was significantly different from that of the other regions ($P \leq 0.05$). The total phosphorus content was the highest in the high-yield orchard of Kalaqin (1.89‰) and was significantly different from that of the other regions ($P \leq 0.05$). Furthermore, total phosphorus content in the low-yield orchard in Kalaqin was at the lowest level (minimum value 0.46‰), which was significantly different from that of the Zhuolu region ($P \leq 0.05$). In terms of available nitrogen content, the overall level of Kalaqin was higher (maximum of 87.50 $mg \cdot g^{-1}$) and was different than that of the other regions. Lingyuan had the lowest nitrogen content (minimum of 42.00 $mg \cdot g^{-1}$) but the difference with the Zhuolu area was not significant in rapidly available phosphorus content. Lingyuan had the highest content in the high-yield orchard (13.83 $mg \cdot g^{-1}$) and was significantly ($P \leq 0.05$) different from that of other regions. The Kalalin region had the lowest content (0.10 $mg \cdot g^{-1}$) with low-yield (0.10 $mg \cdot g^{-1}$) and was significantly different with that of other regions (Table 3). The organic matter content and available nitrogen content of Kalaqin were the highest in different yield areas in the same region, and the difference was significant ($P \leq 0.05$) with that of the other two regions (Table 3), indicating that the nutritional conditions in Kalaqin were the best of the three sampling areas.

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Soil salinity showed significant differences in different regions and areas of different yield levels (Table 3). Zhuolu had the highest total salt content in different regions with the same production level, its maximum value of 0.79‰ appeared in the Zhuolu low-yield stands, and it was significantly different ($P \leq 0.05$) from that of the other two regions. There was a negative correlation between apricot kernel yield levels and soil salt content. Kalaqin had the lowest total salt content, but the minimum value of 0.17‰ appeared in the high-yield stands in Lingyuan, although it was not significantly different from that of the Kalaqin area (Table 3). We believe that soil with a salt content of 0.17 ~ 0.48‰ is most suitable for the growth and development of *P. armeniaca* × *sibirica*.

Soil pH was also a key factor in determining apricot kernel yield. The soil pH of Zhuolu was the highest among different regions of the same production level. The maximum pH value of 8.45 appeared in the low-yield forest area of Zhoulou, and the difference was significant with that of other areas. The minimum value of 6.99 appeared in the middle-yield level in Lingyuan. However, there was no significant difference in pH between Lingyuan and Kalaqin ($P \leq 0.05$). In different yield levels in the same region, the Lingyuan area showed significant pH differences, and there was no significant difference in soil pH in Zhuolu (Table 3). We believe that the pH range most suitable for the growth of kernel apricots is between 7.48 to 8.25.

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Table 3 The variance analysis of the soil nutrients in high-, middle-, and low-yield areas in *Prunus armeniaca* × *sibirica*

Locations	Production levels	Organic matter / ‰	Total nitrogen / ‰	Total phosphorus /	Total potassium /	Available nitrogen	Available phosphorus	Available potassium /mg·g^{-}	Total salt / ‰	pH
Lingyuan	High	15.1±0.2a2	0.75±0.1a2	0.73±0.1a3	23.9±0.0a2	66.06±5.42a2	***13.83±2.82a1***	175.00±9.37a1	***0.17±0.0b2***	7.82±0.46a2
	Middle	11.5±0.2b2	0.63±0.0b1	0.68±0.0ab2	22.9±0.0ab1	52.50±0.00b2	2.05±0.04b1	148.08±9.91b1	0.21±0.0b3	***6.99±0.11c2***
	Low	***9.1±0.4c2***	***0.54±0.0c2***	0.62±0.0b2	21.8±0.0b1	***42.00±3.50c2***	0.57±0.14c2	130.67±4.25c1	0.66±0.1a2	7.13±0.005b2
Kalaqin	High	***21.9±2.4a1***	***0.89±0.1a1***	***1.89±0.1a1***	***26.3±5.1a1***	***87.50±3.83a1***	0.40±0.03a2	168.00±17.17a1	0.19±0.0b2	7.48±0.13a2
	Middle	17.4±1.8b1	0.63±0.1b1	0.55±0.1b3	19.2±0.5bc2	70.00±4.95b1	0.18±0.05a2	118.50±5.72b2	0.29±0.0a2	7.07±0.02b2
	Low	11.9±0.5c1	0.59±0.0b1	***0.46±0.0c2***	***16.3±1.3c2***	55.13±3.35c1	***0.10±0.03a3***	109.00±0.21b2	0.35±0.0a3	7.12±0.05b2
Zhuolu	High	13.1±0.3a2	0.79±0.0a2	1.42±0.1a2	22.0±0.3a2	62.42±1.01a2	2.23±0.41a3	***183.00±4.96a1***	***0.48±0.0b1***	8.25±0.28a1
	Middle	11.5±0.1ab2	0.69±0.0ab1	1.12±0.1b1	20.8±0.0a1	56.00±0.00b2	1.85±0.22ab1	145.58±2.48b1	0.53±0.0b1	8.27±0.10a1
	Low	10.5±0.3b2	0.60±0.0b1	0.90±0.0c1	19.8±0.0a2	46.67±4.04c2	1.23±0.16b1	***96.67±2.52c2***	0.79±0.1a1	***8.45±0.08a1***

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Difference in N, P, and K Contents in Leaves of Kernel Apricots at Different Yield Levels

Table 4 The variance analysis of the leaf nutrients in high-, middle-, and low-yield areas in *Prunus armeniaca* × *sibirica*

Site	Level	Total nitrogen / $mg \cdot g^{-1}$	Total phosphorus / $mg \cdot g^{-1}$	Total potassium / $mg \cdot g^{-1}$
Lingyuan	High	17.50±0.48a1	***0.67±0.15a1***	20.30±0.54a2
	Middle	15.12±0.20b1	0.48±0.01ab1	14.93±0.59b2
	Low	***10.71±0.47c1***	0.40±0.02b1	8.42±0.82c1
Kalaqin	High	***19.48±2.87a1***	0.59±0.32a1	20.17±1.73a2
	Middle	15.26±0.73b1	0.32±0.03b12	10.92±2.49b2
	Low	12.26±0.32c1	0.25±0.01b1	***3.45±0.04c2***
Zhuolu	High	17.99±0.44a1	0.29±0.01a2	***25.04±4.18a1***
	Middle	14.52±1.18b1	0.24±0.01a2	16.20±0.33b1
	Low	12.76±0.02c1	***0.22±0.01b1***	9.49±0.02c1

The degree of tree nutrients is mainly determined by the soil nutrient content [19], which can be reflected by the nutrient content of the leaves. In this experiment, there were some differences in the total nitrogen content of *P. armeniaca* × *sibirica* in different areas. The maximum value of 19.48 $mg \cdot g^{-1}$ appeared in the high-yield in Kalaqin, and the minimum value of 10.71 $mg \cdot g^{-1}$ appeared in Lingyuan. In the low-yield area of the region, the differences between the three regions did not reach significant levels (Table 4). The differences in the high, medium, and low yield levels were significant ($P \leq 0.05$) at different yield levels in the same region. The difference showed a trend wherein the total nitrogen content of the leaves was positively correlated with the yield of apricot kernels (Table 4). In the high-yield area, the total nitrogen content in the leaves ranged from 17.50 to 19.48 $mg \cdot g^{-1}$.

There were also differences in total phosphorus content in leaves of *P. armeniaca* × *sibirica* trees in different regions. The highest content of 0.67 $mg \cdot g^{-1}$ appeared in the high-yield area of Lingyuan, and the difference was significantly different from that of Zhuolu, but not significantly different with that of Kalaqin. The minimum value of 0.22 $mg \cdot g^{-1}$ appeared in the low-yield forest in the Zhuolu area, and the difference was not significantly different among regions (Table 4). Under the different yield levels in the same area, the difference between high-yield and middle-yield trees was not significant, but the difference in low-yield samples was significant, and the overall phosphorus content in leaves was positively correlated with apricot kernel yield (Table 4). In the high-yield samples, the total phosphorus content in the leaves ranged from 0.29 to 0.67 $mg \cdot g^{-1}$.

In terms of total potassium content of leaves, there were differences between different regions. In the high-yield area in Zhuolu, the total potassium content of leaves was the highest (25.04 $mg \cdot g^{-1}$), and the difference was significant compared to the other two regions. In the low-yielding stands of Kalaqin, the leaf

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potassium content was the lowest (3.45 $mg \cdot g^{-1}$), and the difference was significant with that of the other two regions (Table 4). In the same region, the yield of potassium in the high-, middle- and low-level areas reached a significant level, and the total potassium content in the leaves was positively correlated with the yield of apricot kernels (Table 4). For high yield samples, the total potassium content in the leaves ranged from 20.17 to 25.4 $mg \cdot g^{-1}$.

Main Components of Soil and Leaves that Affect the Yield of Apricot Kernels

Nine indexes of soil nutrient content and three leaf nutrient content were analysed by principal component analysis. The contribution values of the four principal components were 4.945, 2.681, 1.662, and 1.095, respectively. The first main component contained nutrients of soil total N, soil organic matter, and soil available N, with a contribution rate of 41.21%. The second principal component included leaf P and N with a contribution rate of 22.35%. The third principal component was soil pH with a contribution of 13.85%. The fourth principal component was the total K of the leaves, and the contribution rate was 9.13%. The cumulative contribution rate of the four components was 86.53% (Table 5). Based on the results of principal component analysis, the contribution rate of organic matter and available nitrogen content in the soil, total nitrogen, and total potassium content in leaves reached 60%. Therefore, these four factors could the main factors with which to judge the soil nutrients and apricot kernel yield levels in real time.

Table 5 Matrix of principal components of environmental factors

Factor	Compoment			
	1	2	3	4
Eigenvalue	4.945	2.681	1.662	1.095
Contribution rate	41.21	22.35	13.85	9.13
Accumlation contribution rate	41.21	63.55	77.40	86.53
Organic matter of soil	***0.899***	0.116	-0.262	0.261
Total nitrogen of soil	***0.901***	-0.011	-0.165	0.304
Total phosphorus of soil	0.815	-0.344	0.279	0.259
Total potassium of soil	0.707	0.025	0.299	-0.109
Available phosphorus of soil	0.091	0.649	0.548	-0.373
Available potassium of soil	0.691	0.163	0.428	-0.327
Available nitrogen of soil	***0.925***	0.072	-0.186	0.181
pH value of soil	0.002	-0.136	***0.872***	0.381
Total salt of soil	-0.657	-0.447	0.323	0.350
Total potassium of leaf	-0.374	0.740	0.090	***0.414***
Total nitrogen of leaf	-0.409	***0.793***	-0.074	0.368
Total phosphorus of leaf	0.282	***0.837***	-0.047	-0.051

The effects of nutrients N, P, and K in the soil for nutrient accumulation, photosynthetic physiological response of the leaves, and biomass accumulation during the transition from the juvenile phase to adult.

Effects of Soil Nutrients on the Accumulation of N, P, and K Content in *P. armeniaca* × *sibirica* Leaves

The orthogonal experiment was used to analyse the accumulation of macroelements in the leaves of *P. armeniaca* × *sibirica* under artificially regulated soil nutrient. Under potted conditions, the total nitrogen content in leaves was the highest (20.1±1.33 $mg \cdot g^{-1}$) when using pure nitrogen 40 g, pure phosphorus 10 g,

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pure potassium 30 g, and organic fertilizer 400 g. With the application of exogenous pure nitrogen 40 g, pure phosphorus 10 g, pure potassium 40 g, and organic fertilizer 400 g (Table 6), the total phosphorus content in the leaves was the highest and could be up to 0.65 ±0 .02 mg·g^{-1}. The total potassium content in the leaves was the highest with pure nitrogen 40 g, pure phosphorus 10 g, pure potassium 30 g, and organic fertilizer 800 g, which reach up to 29.39 ± 3.11 mg·g^{-1} (Table 6). Based on the above results, with the application of pure nitrogen 40 g, pure phosphorus 10 g, pure potassium 30 g, and organic fertilizer 400 g in the soil, the content of total nitrogen, total phosphorus, and total potassium in the leaves of the *P. armeniaca* × *sibirica* was the highest, and this content was positively correlated with the nutrient content in the leaves.

Table 6 The intuitive and significance test analysis of variance table of the orthogonal experiment on leaf nutrient accumulation in *Prunus armeniaca* × *sibirica*

Factor	Level	Nitrogen content / mg·g^{-1}	Phosphorus content / mg·g^{-1}	Potassium content / mg·g^{-1}
Pure nitrogen	0	13.31±0.92d	0.54±0.05a	22.70±1.27b
	10	16.29±1.13c	0.50±0.01a	24.33±1.38ab
	20	17.72±2.01bc	0.51±0.02a	26.38±2.44ab
	30	18.38±1.89b	0.50±0.02a	27.75±1.79ab
	40	***20.10±1.33a***	***0.55±0.02a***	***27.83±3.05a***
Pure phosphorus	0	15.59±1.12b	0.42±0.04c	21.94±1.64c
	5	16.34±1.25ab	0.54±0.01b	25.80±1.29b
	10	***18.63±1.34a***	***0.65±0.02a***	***29.39±3.11a***
	15	17.45±1.29ab	0.50±0.00b	27.05±2.59ab
	20	17.78±2.11ab	0.53±0.01b	25.80±2.17b
Pure potassium	0	16.79±0.98a	0.48±0.01a	17.93±1.34c
	10	17.19±1.77a	0.53±0.03a	23.25±1.28b
	20	17.16±1.21a	0.53±0.00a	26.37±0.92a
	30	***17.62±1.47a***	0.52±0.07a	***28.98±1.28a***
	40	17.04±1.51a	***0.54±0.07a***	26.04±0.78ab
Organic fertilizer	200	17.09±1.29a	0.54±0.04ab	23.29±1.59a
	400	***17.79±1.47a***	***0.58±0.11a***	26.52±3.07a
	600	17.34±1.09a	0.52±0.02b	25.06±2.90a

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800	16.98±0.99a	0.44±0.01c	***26.68±2.18a***
1000	16.63±1.20a	0.52±0.07b	26.45±2.07a

Effects of Soil Nutrient on Photosynthetic Physiology Response of *P. armeniaca* × *sibirica*

In the pot treatment, the orthogonal experiment was used to analyse the effects of photosynthetic physiology response of *P. armeniaca* × *sibirica* under artificially regulated soil nutrients. The content of chlorophyll a in leaves was the highest (1.19 ± 0.02 $mg \cdot g^{-1}$) with the application of pure nitrogen 20 g, pure phosphorus 15 g, pure potassium 40 g, and organic fertilizer 400 g in the soil, and the total chlorophyll content was consistent with the chlorophyll, which was up to 1.56 ± 0.03 $mg \cdot g^{-1}$ (Table 7). Pn had the highest photosynthesis rate with the application of exogenous pure nitrogen 20 g, pure phosphorus 15 g, pure potassium 10 g, and organic fertilizer 400 g in soil, being up to 10.61 ± 0.17 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (Table 7). Gs and Tr had the optimal combination of pure nitrogen 20 g, pure phosphorus 15 g, pure potassium 30 g, and organic fertilizer 400 g, respectively, at 0.23 ± 0.01 $mol \cdot m^{-2} \cdot s^{-1}$, 4.89 ± 0.23 $mmol \cdot m^{-2} \cdot s^{-1}$ (Table 7). Ci had the optimal combination with pure nitrogen content 20 g, pure phosphorus 5 g, pure potassium 10 g, and organic fertilizer 1000 g, being up to 287.52 ± 19.23 $\mu mol \cdot mol^{-1}$ (Table 7). WUE with pure nitrogen 40 g had the optimal combination with pure phosphorus 5 g, pure potassium 20 g, and organic fertilizer 400 g, and was 3.09 ± 0.18 $\mu mol \cdot mmol^{-1}$ (Table 7). According to the above parameters, when the fertilizer applied to a single plant in the exogenous soil was 20 g of pure nitrogen, 15 g of pure phosphorus, 40 g of pure potassium, and 400 g of organic fertilizer, the photosynthesis index of the *P. armeniaca* × *sibirica* was the best and the photosynthetic efficiency was the highest.

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Table 7 The intuitive and significance test analysis of variance table of the orthogonal experiment on the photosynthetic indexes of *Prunus armeniaca × sibirica*

Factor	level	Chlorophyll a content/mg·g^{-1}	Total chlorophyll content/mg·g^{-1}	P_n / μmol·m^{-2}·s^{-1}	G_s /mol·m^{-2}·s^{-1}	C_i / μmol·mol^{-1}	T_r / mmol·m^{-2}·s^{-1}	WUE/ μmol·mmol^{-1}
Pure nitrogen	0	0.77±0.01b	1.02±0.01b	8.06±0.21b	0.18±0.00a	***287.52±19.23a***	3.42±0.11b	2.70±0.09ab
	10	0.95±0.01ab	1.24±0.02ab	9.41±0.18ab	0.21±0.01a	270.28±23.01ab	4.78±0.15a	2.02±0.07b
	20	***1.19±0.02a***	***1.56±0.03a***	***10.61±0.17a***	***0.23±0.01a***	260.30±25.00b	***4.83±0.10a***	2.23±0.10ab
	30	1.18±0.03a	1.54±0.05a	10.06±0.14a	0.20±0.01a	264.84±31.89ab	3.79±0.19b	2.73±0.07ab
	40	1.02±0.05a	1.33±0.04ab	9.65±0.22a	0.19±0.01a	276.20±15.07ab	3.54±0.22b	***3.02±0.11a***
Pure phosphorus	0	0.79±0.01b	1.06±0.09a	8.10±0.25b	0.17±0.00b	269.54±10.98a	3.37±0.17b	2.52±0.19a
	5	1.09±0.04a	1.40±0.05a	9.70±0.14a	0.18±0.00ab	268.06±8.99a	3.74±0.09ab	***2.92±0.13a***
	10	1.06±0.04a	1.41±0.04a	10.31±0.29a	0.22±0.00a	268.16±11.04a	4.53±0.21a	2.37±0.08a
	15	***1.11±0.06a***	**1.42**±0.10***a***	***10.40±0.10a***	***0.23±0.01a***	***277.50±37.01a***	***4.55±0.21a***	2.53±0.13a
	20	1.05±0.03a	1.39±0.07a	9.28±0.41ab	0.20±0.00ab	275.88±24.33a	4.17±0.19ab	2.35±0.17a

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Pure potassium	0	1.01±0.03a	1.32±0.10a	8.66±0.09a	0.18±0.01a	267.94±20.07a	3.50±0.07b	2.61±0.09a
	10	0.98±0.02a	1.32±0.09a	***10.19±0.27a***	0.20±0.01a	266.28±18.37a	4.04±0.11ab	2.76±0.07a
	20	1.01±0.05a	1.33±0.07a	8.88±0.09a	0.18±0.00a	***279.26±21.55a***	3.27±0.21b	***2.89±0.33a***
	30	1.01±0.12a	1.27±0.09a	10.03±0.11a	***0.23±0.00a***	275.14±23.47a	***4.89±0.23a***	2.13±0.45a
	40	***1.08±0.09a***	***1.44±0.11a***	10.04±0.18a	0.22±0.00a	270.52±17.03a	4.66±0.20a	2.30±0.36a
Organic fertilizer	200	0.94±0.04a	1.26±0.04a	9.84±0.20a	0.20±0.00a	266.90±18.22a	4.26±0.19ab	2.47±0.33a
	400	***1.14±0.19a***	***1.47±0.05a***	9.66±0.13a	0.21±0.01a	277.76±17.55a	3.47±0.17b	***3.09±0.18a***
	600	1.01±0.04a	1.32±0.13a	***10.24±0.11a***	***0.22±0.00a***	270.16±21.49a	***4.64±0.17a***	2.29±0.16a
	800	1.10±0.07a	1.42±0.12a	8.83±0.21a	0.19±0.01a	***277.86±17.33a***	3.50±0.11b	2.66±0.11a
	1000	1.01±0.22a	1.31±0.09a	9.23±0.09a	0.19±0.01a	266.46±17.66a	4.50±0.19a	2.18±0.10a

Note: Different lowercase letters mean they are significance ($P \leq 0.05$), the same as below.

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Effects of Soil Nutrients on Biomass Accumulation of *P. armeniaca* × *sibirica*

The orthogonal experiment was used to directly analyse the biomass accumulation of the aboveground part. Under potted conditions, the plant height of the *P. armeniaca* × *sibirica* was the greatest when applying pure nitrogen 40 g, pure phosphorus 10 g, pure potassium 30 g, and organic fertilizer 200 g, and could be up to 1.75 ± 0.03 m (Table 8). The ground diameter was the thickest when the application of pure nitrogen 40 g, pure phosphorus 10 g, pure potassium 40 g, and organic fertilizer 200 g reached 33.59 ± 3.23 mm (Table 8). The crown amplitude reached a maximum value of 1.77 ± 0.04 m when the application of pure nitrogen was 40 g, pure phosphorus was 10 g, pure potassium was 40 g, and organic fertilizer was 400 g (Table 7). According to various indexes, the maximum biomass accumulation could be obtained when the application of pure nitrogen was 40 g, pure phosphorus was 10 g, pure potassium was 40 g, and organic fertilizer was 200 g.

Table 8 The intuitive and significance test analysis of variance table of the orthogonal experiment of the vegetative growth of *Prunus armeniaca* × *sibirica*

Factor	Level	Plant height / m	Ground diameter / mm	Crown / m
Pure nitrogen	0	1.50±0.03e	21.14±3.99b	1.49±0.03c
	10	1.56±0.04d	29.25±4.01a	1.32±0.32d
	20	1.61±0.02c	30.40±3.12a	1.56±0.07bc
	30	1.68±0.05b	30.95±3.29a	1.63±0.08b
	40	***1.75±0.03a***	***33.59±3.23a***	***1.77±0.04a***
Pure phosphorus	0	1.45±0.03c	30.21±4.88a	1.48±0.09b
	5	1.59±0.05b	30.61±2.89a	1.50±0.06b
	10	***1.70±0.09a***	***33.19±1.78a***	***1.68±0.03a***
	15	1.56±0.07b	30.99±2.17a	1.54±0.47ab
	20	1.61±0.09a	31.33±3.01a	1.60±0.02ab
Pure potassium	0	1.55±0.04b	21.58±2.55b	1.41±0.03c
	10	1.51±0.03c	29.10±4.82a	1.51±0.98bc
	20	1.64±0.07a	31.54±4.33a	1.60±0.83a
	30	***1.67±0.08a***	32.23±3.85a	1.52±0.05b
	40	1.65±0.07a	***32.87±2.46a***	***1.65±0.05a***
Organic fertilizer	***200***	***1.68±0.06a***	***33.05±1.46a***	1.55±0.04a
	400	1.63±0.03a	31.75±1.22a	***1.67±0.08a***
	600	1.49±0.07a	30.21±2.08a	1.49±0.09a
	800	1.52±0.09a	30.08±2.43a	1.51±0.02a
	1000	1.59±0.06a	31.24±1.09a	1.63±0.07a

IV. DISCUSSION

Different nutrient elements play key roles in the growth and development of apricot trees [19,27-28]. It is generally believed that the element N can promote the growth of apricot trees and increase yield without hindering fruit quality. Element P promotes the growth of apricot leaves and branches and increases yield

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[19,29], K mainly promotes the development of the endocarp of apricots, similar to the case of other fruits, such as grapes [30] and peaches [31]. This study found that there were significant differences in the contents of organic matter, total nitrogen, total phosphorus, available nitrogen, and available potassium in the main nutrient contents of the high-yield and low-yield areas of *P. armeniaca* × *sibirica*. This indicated that the sampling area of this study was representative; in particular, the organic matter content and available nitrogen were significantly different ($P \leq 0.05$), which indicated that the content of organic matter and available nitrogen in soil could be used as the main factors and to judge the soil nutrient status and yield of *P. armeniaca* × *sibirica*. In particular, under different yield levels in different regions, the contents of available nitrogen in soil were significantly different ($P \leq 0.05$) (Table 3), indicating that available nitrogen might be a limiting nutrient determining different yield levels of apricot kernels.

The total N and total K contents in the leaves showed significant differences at the high, medium, and low levels of the same region, indicating that the total N and K content in the leaves were the key factors for measuring apricot kernel yield. Almaliotis found in their study on 24 fresh apricots in northern Greece that the yield was highly correlated with the content of total N, total P, and total K in leaves, and in particular, the relative content of N and K in leaves was closely related to the yield [32]. This was similar to our results. At the same time, the content of K in both soil and leaves was much higher than that of other nutrient types, which further confirmed the conclusion that kernel apricots preferred the element potassium [1]. It should be noted that factors affecting the accumulation of nutrients in leaves, in addition to cultivation management and genotypes, leaf age, rootstock type, and physiological and phenological stages, also cause differences in nutrient accumulation in leaves [33], and the impact of these factors was not studied in this article.

The photosynthetic capacity of plants is not only influenced by their genotypes, but also by the type and amount of fertilizer applied. It is generally believed that rational application of nitrogen, phosphorus, and potassium can significantly enhance the photosynthetic capacity, and improve the quality and yield of fruits [34]. Previous studies have found that nitrogen significantly increases the yield and quality of herbaceous crops, whereas potassium significantly improves the yield and dry matter quality, which is related to the fact that both nitrogen and potassium improve the photosynthetic capacity of crops [10,12-13]. In this study, we found that nitrogen and phosphorus had a significant effect on photosynthetic capacity of *P. armeniaca* × *sibirica*, whereas the effect of potassium on various treatments was not significant ($P \leq 0.05$). This phenomenon also existed in Pyrus pyrifolia var Yuluxiang [35]. It was suggested that during the transition period from the juvenile stage to adulthood, the proportion of phosphate fertilizer should be appropriately increased to enhance the photosynthetic efficiency and produce more photosynthetic products. In actual production, people have realized the important role of nitrogen fertilizer and potassium fertilizer, but ignored the application of phosphate fertilizer, and the lack of phosphate has become a new key factor restricting the quality and yield of fruits [36]. Therefore, *P. armeniaca* × *sibirica* cultivation should pay special attention to

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the rational application of phosphate fertilizer. There could be three reasons: first, excessive accumulation of nutrients in leaves may lead to antagonism of ions of nutrients in trees and decrease of nutrient absorption efficiency; second, excessive accumulation of biomass will cause tree canopy closure, leading to the imbalance between vegetative growth and reproductive, which is not conducive to the transition from vegetative growth to reproduction, this is also the main reason for the prolongation of the juvenile stage caused by excessive application of nitrogen fertilizer; third, improving the physiological function of the tree (photosynthesis) is beneficial to the redistribution of nutrients inside the tree and promotes the formation of an efficient "source-sink-translocation" circulation pathway. Therefore, we believe that 20 g of pure nitrogen, 15 g of pure phosphorus, 40 g of pure potassium, and 400 g of organic fertilizer applied to a single tree is the appropriate nutrient ratio for the transition from vegetative growth to reproductive in kernel apricot cultivation (Table 9). Under this condition, the economic input of fertilizer is approximately 49.5 yuan per 667 m2 (55 plants per 667 m2) (Table 9).

Table 9 The effect of optimal combination for growth and development of *Prunus armeniaca* × *sibirica* with different fertilizer types

Optimal combination	Nitrogen fertilizer / g		Phosphorus fertilizer /g		Potassium fertilizer /g		Organic fertilizer /g	Economic input / RMB·hm 2
	Pure nitrogen	Commercial nitrogen	Pure phosphorus	Commercial phosphorus	Pure potassium	Commercial potassium		
Leaf nutrient accumulation	40.0	87.0	10	83.3	30	60.0	400	742.50
Photosynthetic physiology	20.0	43.5	15	125.0	40	80.0	400	740.44
Biomass accumulation	40.0	87.0	10	83.3	40	80.0	200	466.13

Note: Commercial nitrogen with NO of 46% is 100 RMB per 50 kg, commercial phosphorus with P_2O_5 of 12% is 125 RMB per 50 kg, commercial potassium with K_2O of 50% is 125 RMB per 50 kg, and organic fertilizer with organic matter of 45% and total nutrients of 5% is 85 RMB per 50 kg. The cultivation density of kernel apricots in production is 825 plants per ha.

This experiment had some limitations because it may not be exactly the same as the actual production because of the results were from pot cultivation. In the case of potted plants, we precisely regulate the soil moisture content in the daily management process and limit the roots of *P. armeniaca × sibirica* to the basin. Thus, it is difficult to achieve such precise water and fertilizer and root regulation in actual field production. Therefore, the results of this experiment are applicable to apricot orchard with integrated water and fertilizer, drip irrigation and accurate water control and management. In areas where these conditions are not available, the amount of fertilizer applied should be appropriately increased. According to experience in production, the annual application amount of chemical fertilizer is generally 2.0 to 3.0 times that of a pot experiment after *P. armeniaca × sibirica* enters the fruiting stage. The organic matter in the soil plough layer (20–30 cm deep under the soil surface) should have a content over 1.0% [1] and can achieve a high-yield target.

V. CONCLUSION

When the total nitrogen content in the soil was 0.075%–0.089%, the available nitrogen content was 62.42–87.05 mg·kg^{-1}, the organic matter content was 1.31%–2.19%, and the contents of total N, total P, and total K in leaves were 17.50–19.48 mg·g^{-1}, 0.29–0.67 mg·g^{-1} and 20.17–25.04 mg·g^{-1}, respectively, when the yield of apricot kernels was the highest. These indexes were the key factors for evaluating yield. According to the content of total N, P, and K in the leaves in real time, the soil fertility status and apricot kernel yield could be quickly evaluated.

According to studies of different fertilization ratios on the accumulation of nutrient N, P, and K, the response of photosynthetic physiological processes and the accumulation of biomass of kernel apricots, under potted conditions, the nutrition provided by applying 20 g of pure nitrogen, 15 g of pure phosphorus, 40 g of pure potassium, and 400 g of organic fertilizer to each seedling was most appropriate for the transformation of kernel apricots from vegetative growth to the reproductive stage.

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REFERENCES

[1] Li Fangdong, Wuyun Tana, Zhu Gaopu (2019) Cultivation operative technology of kernel-apricot. China forestry publishing house; Beijing (China)

[2] National forestry administration (2017) China forestry statistical yearbook. Beijing (China)

[3] Xu Mengsha, Zhao Han, Zhou Xiaoxing (2016) Responses of photosynthetic physiology and biomass accumulation of sweet kernel apricot (*Prunus armeniaca×sibirica*) seedling to soil drought stress in the ancient course of the middle Yellow River. Taiwan Journal of Forest Research 31: 271-84P

[4] Gopikumar K, Varghese V (2004) Sand culture studies of Teak (*Tectona grandis*) in relation to nutritional deficiency symptoms, growth and vigour. Journal of Tropical Forest Science 16: 46-61

[5] Ferreira JFS (2007) Nutrient deficiency in the production of artemisinin, dihydroartemisinic acid, and artemisinic acid in Artemisia annua L. Journal of Agricultural and Food Chemistry 55(5): 1686-1694

[6] Afrousheh M, Ardalan M, Hokmabadi H (2009) Nutrient deficiency disorders in Pistacia vera seedling rootstock in relation to eco-physiological, biochemical characteristics and uptake pattern of nutrients. Scientia

Horticulturae 124(2): 141-148 [7] Chen K, Li Y, Tao J (2015) Environmental impact assessment of river habitat. Environmental impact assessment 37 (03): 1-5

[7] Chen Yimin, Tang Xu, Kapoore RV (2015) Influence of nutrient status on the accumulation of biomass and lipid in Nannochloropsis salina and Dunaliella salina. Energy Conversion and Management 106: 61-72

[8] Florinda G, Teresa S, Díaz I (2015) Fe deficiency induction in Poncirus trifoliata rootstock growing in nutrient solution changes its performance after transplant to soil. Scientia Horticulturae 182: 102-109

[9] Deus JAL, Neves JCL, Corrêa MCD (2018) Balance design for robust foliar nutrient diagnosis of “Prata” banana (*Musa spp.*). Scientific Reports 8(1): 15040

[10] Hossain SAAM, Lixue W, Liu Haisheng (2018) Improved greenhouse cucumber production under deficit water and fertilization in Northern China. International Journal of Agricultural and Biological Engineering 11(4): 42-46

[11] Umesh CG (1997) Symptoms of molybdenum deficiency and toxicity in crops. Molybdenum in Agriculture 160-170

[12] Afonso S, Arrobas M, Ferreira IQ (2018) Leaf nutrient concentration standards for lemon verbena (Aloysia citrodora Paláu) obtained from field and pot fertilization experiments. Journal of Applied Research on Medicinal and Aromatic Plants 8: 33-40

[13] Fang Xiaomei, Li Yingshuang, Nie Jiao (2018) Effects of nitrogen fertilizer and planting density on the leaf photosynthetic characteristics, agronomic traits and grain yield in common buckwheat (*Fagopyrum esculentum M.*) Field Crops Research 219: 160-168

[14] Tran Le Linh (2012) Effect of fertilization on yield and quality of kiwifruit in Shanxi. M.Sc. thesis. Northwest A&F University, Xi’An

[15] Congming Lu, Zhang Jianhua, Zhang Qide (2001) Modification of photosystem II photochemistry in nitrogen deficient maize and wheat plants. Journal of Plant Physiology 158(11): 1423-1430

[16] William L, Greer D, Sun O (2000). Physiological impacts of Mg deficiency in Pinus radiata: growth and photosynthesis. New Phytologist 146(1): 47-57

[17] Molassiotis A, Tanou G, Diamantidis G (2006) Effects of 4-month Fe deficiency exposure on Fe reduction mechanism, photosynthetic gas exchange, chlorophyll fluorescence and antioxidant defense in two peach rootstocks differing in Fe deficiency tolerance. Journal of Plant Physiology 163(2): 76-85

[18] Jivan C, Sala F (2014). Relationship between tree nutritional status and apple quality. Horticultural Science 41(1): 1-9

[19] Bussi C, Besset J, Girard T (2003) Effects of fertilizer rates and dates of application on apricot (cv Bergeron) cropping and pitburn. Scientia Horticulturae 98(2): 139-147

[20] Jacob J, Lawlor DW (1991) Stomatal and mesophyll limitations of photosynthesis in phosphate deficient sunflower, maize and wheat plants. Journal of Experimental Botany 42(241): 1003-1011

[21] Lima JSD, Alves DI, Coelho RI (2016) Spatial variability in the diagnosis of nutritional status in the papaya. Revista Ciencia Agronomica 47(2): 264-274

[22] Behera SK, Suresh K, Rao BN (2017) Soil fertility and yield-limiting nutrients in oil palm plantations of north-eastern state Mizoram of India. Journal of Plant Nutrition 40(8): 1165-1171

[23] Silber A, Naor A, Cohen H (2018). Avocado fertilization: matching the periodic demand for nutrients. Scientia Horticulturae 241: 231-240

[24] Xu Mengsha, Zhu Gaopu, Fu Quangui (2017) Effect of N, P and K deficiency on growth and nutrient uptake of *Prunus armeniaca* seedings. Journal of Northwest A &F University (Natural Science Edition) 45(05): 81-90

[25] Zhu Gaopu (2008) Research of Banana Anti-chilling with Different Measures. M.Sc. thesis. Guangxi University, Nanning

[26] Tang Qiyi, Zhang Chuanxi (2013) Data Processing System (DPS) software with experimental design, statistical analysis and data mining developed for use in entomological research. Insect Science 20(2): 254-260

[27] Han J.H, Cho JG, Son IC (2012). Effects of elevated carbon dioxide and temperature on photosynthesis and fruit characteristics of ‘Niitaka’ pear (Pyrus pyrifolia Nakai). Horticulture Environment and Biotechnology 53(5): 357-361

[28] Auzmendi I, Marsal J, Girona J (2013) Daily photosynthetic radiation use efficiency for apple and pear leaves: seasonal changes and estimation of canopy net carbon exchange rate. European Journal of Agronomy 51: 1–8

[29] Dariusz Wach (2008). Effect of soil mulching with some organic materials on the size of berries highbush blueberries. Annales UMSC, Horticultura 18(2): 9-14

[30] Ruhie H. (1989) Effect of potassium and nitrogen supply on the distributi on of minerals and organic acids and the composition of grape juice of Sultanavines. Australian Journal of Experimental Agriculture 29: 133-137

[31] Andrew G. H. Lea, Colin F. Timberlake (1978) The Phenolics of Ciders: Effect of processing conditions. Journal of the Science of Food and Agriculture 29(5): 484-492

[32] Tian Ying, Li Yaguang, Jiang Hang (2010) On the regional ecological planning of the ancient yellow river course in Shangqiu city. Journal of Landscape Research 2(03): 35-39

[33] Salazar-Garćıa S, González-Durán IJL, Ibarra-Estrada ME (2015) Identification of the appropriate leaf sampling period for nutrient analysis in ‘Hass’ avocado. Horticultural Science 50(1): 130-136

[34] Sun Guili. Xu Min, Li Jiang (2013) Study on characteristics of net photosynthetic rate of two kinds of tree shape and impact factors in korla fragrant pear. Acta Ecologica Sinica 33(18): 5565-5573

[35] Zhang Xiaowei, Bai Mudan, Gao Peng (2018) ‘Yuluxiang’ pear: nitrogen, phosphorus and potassium fertilizers affect chlorophyll content and photosynthetic characteristics. Journal of Agriculture 8(12): 79-83

[36] Yi Xiaotong, Zhang Bochao, Li Youfang (2019) Characteristics analysis of marco-elements and mid-elements of citrus leaves in Guangxi. Journal of Fruit Science 36(02):153-162