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Fruit Morphology and Fatty Acid Composition of *Swida wilsoniana* Populations Collected from Different Regions in Southern China

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Abstract: We examined the fruit morphology, oil content, and fatty acids (FAs) of 11 populations of *Swida wilsoniana* in four provinces in southern China. The fruit oil was extracted by the Soxhlet method, and the FA composition was determined by gas chromatography (GC). The variation in oil content ranged from 16.10 ± 4.94% to 33.08 ± 5.52%, and the major FAs were linoleic acid (44.85 ± 6.70%), oleic acid (29.45 ± 7.63%), palmitic acid (19.59 ± 3.98%), stearic acid (1.95 ± 0.39%), and linolenic acid (0.21 ± 0.07%). The unsaturated FAs accounted for 78.38 ± 3.74%. There was high genetic variation in the oil content and FA composition among the populations. We assessed the relationships between the ecological factors and the FA composition among the populations. The oil content was positively correlated with temperature ($r = 0.645$, $p < 0.05$) and negatively correlated with latitude ($r = -0.653$, $p < 0.05$). Interestingly, both latitude and temperature were strongly correlated with the unsaturated FAs of the fruits. Principal component analysis (PCA) showed that the populations in different areas could be separated based on oil quality and plant growth. In conclusion, the oil content and FA composition were influenced by geographical area. The findings could help to improve fruit oil quality in future *S. wilsoniana* breeding programs.

Keywords: *Swida wilsoniana*; fatty acids profile; geographical factors; climatic factors; fruit oil content; southern China

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1. Introduction

Vegetable oil is playing an increasingly vital role in the development of high-quality edible oil and clean energy due to an increased awareness of nutrition, which is motivating researchers to seek superior sources, especially those with higher oil content and desirable fatty acid (FA) composition [1,2]. Numerous studies [3–6] showed that oil characteristics were influenced by multiple factors, not only species and varieties but also regions, climate, degree of ripeness, harvesting, and processing conditions. Consequently, the research into the different conditions of the populations of woody oil plants and the analyses of phenotypic variation, oil content, and FA composition are of great significance for the improvement of the efficient utilization of woody oil resources [7].

Swida wilsoniana (Wanger.) Sojak, a perennial deciduous shrub or tree (Figure S1) of the genus Swida in the Cornaceae family, grows widely in natural and planted areas in China, with especially high levels of cultivation in the southern provinces [8]. Due to the high oil content in its fruits, its tolerance of drought and nutrient-poor soil, its beautiful tree shape, and its solid wood structure, *S. wilsoniana* is used in the forestry, ecological, and horticulture industries [9–11]. More importantly, due to its high-value oil, it is officially considered a promising woody oil tree species by the Chinese Forestry Bureau. As an ecologically and economically important woody oil tree, it has great potential for exploitation as a vegetable oil because it is suitable for human consumption and has distinct health benefits [11,12]. According to previous studies, the oil content of the *S. wilsoniana* dried fruit varied from 18% to 36%, and the unsaturated FA content was >70%, and it is especially rich in linoleic acid and oleic acid [1,9,13]. *S. wilsoniana* fruit oil possesses many pharmacological activities, including anti-hyperlipidemia effects and anti-hypertension, anti-inflammatory, and cholesterol-reducing activities [11,14,15]. Recently, *S. wilsoniana* fruit oil has been listed as a new food resource, and products with good nutrition and health value have been developed [11].

However, the previous research on fruit oil from *S. wilsoniana* mostly focused on either the determination of the chemical composition or the identification of FAs [11], but there are few reports on the differences between the populations and the environmental parameters related to oil content and FA profile. To fill this knowledge gap and develop premium breed resources, we investigated the morphology, oil content, and FA profiles of 219 samples of *S. wilsoniana* from four provinces in southern China. The material was collected from both wild forests and plantations (samples from Changsha, Hunan); hence, the samples essentially reflected *S. wilsoniana* in the main producing areas of southern China. We evaluated the oil content and FA composition and assessed the relationships between the environmental factors and the FA compositions among different populations, with the aim of generating excellent germplasm resources from different geographical areas.

2. Materials and Methods

2.1. Plant Materials and Ecological Factors

All the fruit samples of *S. wilsoniana* were obtained from 11 regional areas in four provinces (Hunan, Jiangxi, Guangdong, and Guangxi) in southern China: CSHN, LYHN, LSHN, CYJX, YDJX, ZGJX, SGGD, GXGX, NPGX, JXGX, and XPGX. The details are included in Table 1 and Figure 1. In October 2020, ripened fruit was collected from healthy, adult trees (more than 20 years old). The fruit samples were appropriately stored until needed for the experiments.

Table 1. Location and climatic conditions of different *S. wilsoniana* populations.

Code	Locality	Latitude (N)	Longitude (E)	Altitude (m)	Temp. (°C)	Sun. Dur. (h)	Prec. (mm)
CSHN	Chang Sha, Hu Nan	28.12	113.05	77	21.7	1125.8	1557.8
LYHN	Liu Yang, Hu Nan	28.56	113.72	85	22.5	2043.3	1646.2
LSHN	Long Shan, Hu Nan	29.58	109.85	641	18.7	3204.2	1673.7
CYJX	Chong Yi, Jiang Xi	25.48	114.11	384	21.8	1930.3	1768.0
YDJX	Yu Du, Jiang Xi	25.95	115.65	161	23.2	1916.4	1790.9
ZGJX	Zhang Gong, Jiang Xi	25.79	114.97	150	23.5	2646.1	1614.6
SGGD	Shao Guan, Guang Dong	25.38	113.61	163	21.5	2114.6	1780.3
DBGX	De Bao, Guang Xi	23.33	106.63	649	23.2	1348.3	987.3
NPGX	Na Po, Guang Xi	23.32	105.94	1049	21.5	1956.2	1524.3
JXGX	Jing Xi, Guang Xi	23.15	106.42	750	22.9	1612.6	1536.6
XPGX	Xiang Ping, Guang Xi	22.12	106.72	260	26.1	1652.0	1366.6

Abbreviations: Temp., average of monthly temperature; Sun. Dur., average of annual sunshine duration; Prec., average of annual precipitation.

The latitude, longitude, and altitude of the sampling locations were measured using a T16 hand-held global positioning system (GPS) device (Ubota China Holdings Co., Ltd., Shanghai, China). Annual temperature, annual precipitation, and annual sunshine data averaged over 20 years were obtained from the National Meteorological Information Center of the China Meteorological Administration [16] and the China Meteorological Data Network [17]. The details are listed in Table S1.

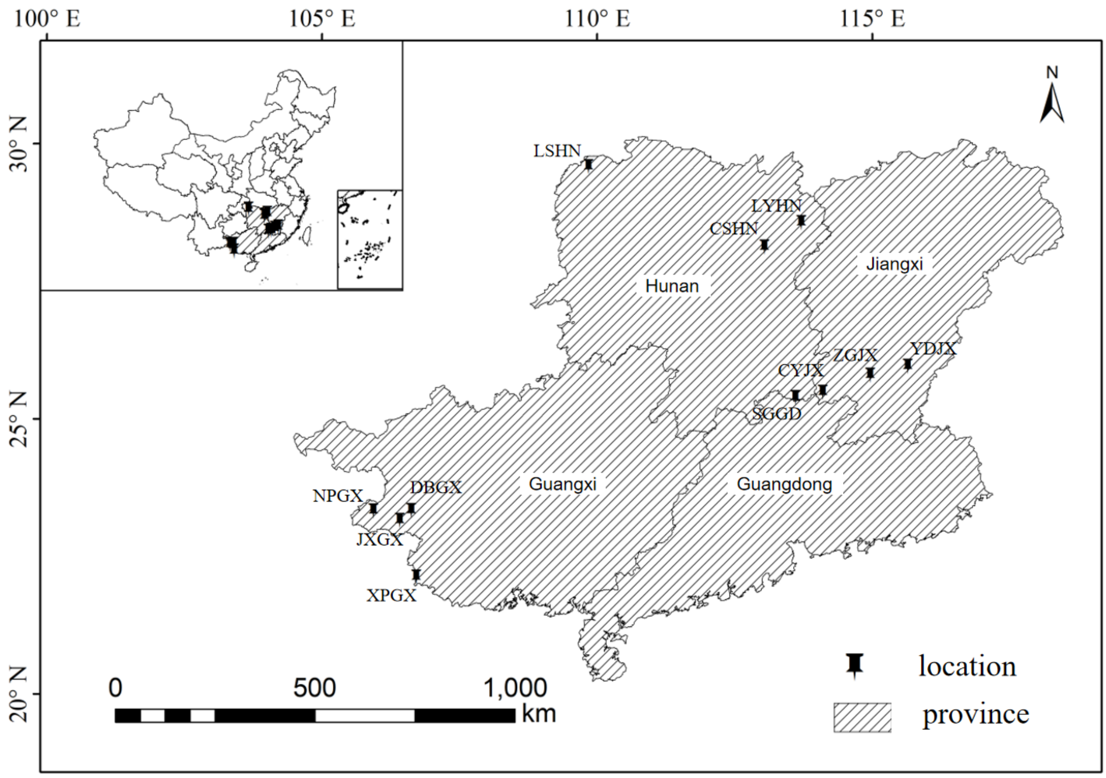

Figure 1. Map of *S. wilsoniana* locations showing different regional populations.

2.2. Fruit Morphological Investigation

The morphological traits of the fresh fruits were assessed in the Central Process Lab of the Hunan Academy of Forestry. Fruit length and fruit width were measured in each population using a DL3944 Electronic Digital Caliper (Deli Group Co. Ltd., Ningbo, China), with 10 replicates. To calculate the thousand fruit weight, we used an FA2004B Electronic Analytical Balance (Shanghai Yueping Scientific Instrument Co., Ltd., Shanghai, China), with five replicates.

2.3. Fruit Oil Extraction

Fruit oil extraction [18] was conducted using the China National Standard, Determination of Fat in Food (GB 5009.6—2016) method (Soxhlet extraction method), with three replicates. The percentage of dried fruit oil was determined using an SZE-101 Fat Analyzer (Shanghai ShineJan Instruments, Shanghai, China). After drying in a 101-1 A oven (Beijing Kewei Yongxing Co. Ltd., Beijing, China) to a constant weight (105 °C, ~24 h), the whole fruit was ground into fine powder using a DFY-500 mill (Shanghai Xinnuo Instrument Group Co. Ltd., Shanghai, China). The samples (~3 g) were weighed and extracted in petroleum ether (99.7%, boiling point range 30 to 60 °C) at 65 °C for 6 h. The residues were dried at 105 °C in a vacuum for more than 2 h and weighted, and the total fruit oil content (w) was calculated as follows:

$$W = (M_0 - M_1)/M_0 \times 100\%$$

where M_1 is the sample weight after extraction, and M_0 is the sample weight before extraction (weight determined to a precision of 0.0001 g).

2.4. Chromatographic Analysis of Fatty Acid Methyl Esters (FAMEs)

The FA composition [19] was determined using the China National Standard, Determination of Fatty Acids in Food (GB 5009.168—2016) method (normalization method), with three replicates. The FA composition was determined by gas chromatography on a 450-GC instrument (Bruker Corporation, Amsterdam, The Netherlands) after converting the FAs into FAMEs.

The FAMEs were prepared by refluxing oil (0.2 g) for 10 min in 8 mL of 2% sodium methylate (NaOMe), adding 7 mL of 15% boron trifluoride methanol solution, refluxing for 2 min, cooling, and adding 15 mL n-heptane. After shaking for 2 min, saturated sodium chloride aqueous solution was added, and ~5 mL of the upper n-heptane extraction solution was absorbed by static stratification. Next, 3–5 g anhydrous sodium sulfate was added; the samples were shaken for 1 min, left to stand for 5 min, and the upper solution was aspirated into an injection bottle for determination.

An HP-88 capillary column (100 m, 0.25 mm, 0.20 µm; Agilent Technologies Co. Ltd., Palo Alto, Santa Clara, CA, USA) was used for the separation. The injector temperature was 230 °C; the carrier flow rate was 1 mL/min; a split mode (1:50) was employed with an injection volume of 1 uL, nitrogen as carrier gas, and a detector temperature of 280 °C. The temperature program was as follows: an initial temperature of 100 °C for 13 min; 100 to 180 °C over 10 min; the maintenance of this temperature for 6 min; 180 to 200 °C over 1 min; the maintenance of this temperature for 20 min; 200 to 230 °C over 4 min; and the maintenance of this temperature for 10.5 min. Flame ionization detector peak area normalization was employed.

2.5. Statistical Analysis

The morphological results were expressed as mean ± standard deviation (SD). Microsoft Excel was used for basic data analysis and calculating the formulae for each indicator. One-way analysis of variance (ANOVA) was used to investigate the morphological quantitative characteristics and the significant differences in FAs ($p \leq 0.05$) among the studied populations.

The correlations between the FA pairs were explored using SPSS ver.18 and Origin ver. 2021. The relative content of each FA component was calculated using the peak area normalization method [19]. The principal component analysis (PCA) was conducted by Origin.

3. Results and Discussion

3.1. Fruit Morphological Traits

The phenotypic diversity of the fruits was determined not only at the genetic level but was also based on the environmental conditions. To a certain extent, this can reflect the genetic variation and reveal the relationships between the morphological variation and the adaptation to the environment. This is also essential for evaluating the quality of fruits [20]. Fruit length, fruit width, and the thousand fruit weight were calculated, and the results are summarized in Table 2. The range of the fruit length was 5.23 mm to 6.22 mm, while for the fruit width this was 5.33 mm to 6.65 mm, and for the thousand fruit weight, it was 94.68 g to 185.44 g; the coefficient of variation (CV) values among populations were 6.41% to 12.14%, 6.80% to 13.37%, and 5.25% to 31.61%, respectively. These results indicate that the size varied to some degree, which is consistent with previous studies [13,21,22]. Dai [23] suggested that *S. wilsoniana* fruit size varies, especially with regard to the thousand fruit weight, for which the CV was 19.06%. In our study, the longest (6.44 ± 0.70 mm) and widest (6.65 ± 0.61 mm) fruits were from the ZGJX population, which also had the maximum thousand fruit weight (185.44 ± 34.53 g), nearly twice that of CYJX (94.68 ± 8.74 g). ANOVA showed extremely significant variations ($p \leq 0.001$) for the fruit length, fruit width, and thousand fruit weight among the 11 populations. This indicates that *S. wilsoniana* fruits varied widely across the different habitats, manifesting as phenotypic changes.

Table 2. Statistics in phenotypic trait variation of *S. wilsoniana* fruits.

Code	Fruit Length		Fruit Width		Thousand Fruit Weight	
	Mean ± SD (mm)	CV (%)	Mean ± SD (mm)	CV (%)	Mean ± SD (g)	CV (%)
CSHN	6.02 ± 0.51 abc	8.47	6.00 ± 0.52 abc	8.74	146.40 ± 22.32 abc	15.25
LYHN	6.02 ± 0.57 abc	9.46	5.88 ± 0.69 bc	11.69	149.83 ± 28.95 abc	19.32
LSHN	5.23 ± 0.64 d	12.14	5.56 ± 0.68 bc	12.15	105.43 ± 29.71 de	28.18
CYJX	5.35 ± 0.44 cd	8.19	5.33 ± 0.46 c	8.54	94.68 ± 8.74 e	9.23
YDJX	6.22 ± 0.40 ab	6.41	6.36 ± 0.60 ab	9.39	175.34 ± 9.21 ab	5.25
ZGJX	6.44 ± 0.70 a	10.92	6.65 ± 0.61 a	9.34	185.44 ± 34.53 a	18.62
SGGD	5.66 ± 0.61 bcd	10.70	5.87 ± 0.78 bc	13.37	146.46 ± 30.46 abc	20.80
DBGX	6.13 ± 0.70 ab	11.41	6.12 ± 0.78 abc	12.80	155.99 ± 36.11 abc	23.15
NPGX	5.82 ± 0.53 abcd	9.05	5.81 ± 0.45 bc	7.68	137.63 ± 28.22 bcd	20.50
JXGX	5.79 ± 0.45 abcd	7.76	5.66 ± 0.39 bc	6.80	134.98 ± 23.38 bcd	17.32
XPGX	5.75 ± 0.63 abcd	10.89	5.58 ± 0.49 bc	8.71	121.21 ± 38.32 cde	31.61
F	16.023		9.533		19.401	
p	0.000		0.000		0.000	

Note: different lowercase letters in the same column indicate significant difference ($p < 0.05$).

3.2. Oil Content and Fatty Acid Composition

As oil content is a trait greatly affected by both genotype and environment, the growing location may impact the variation in oil content. Herein, we investigated the oil characteristics of *S. wilsoniana* fruits grown in southern China, and the results are shown in Table 3. The average oil content was 22.39 ± 7.55%, and there was an extremely significant variation in oil content among the populations ($p < 0.001$), which is consistent with the previous research [21,22]. The lowest (16.10 ± 4.94%) was observed for the fruits grown in LSHN, while the highest (33.08 ± 5.52) was for the SGGD population, and these locations were significantly different from the other nine populations (21.96% to 29.32%), which accounted for 81.82% of the 11 populations. Selecting high oil content clones or populations is important for maximizing the yields from woody oil crops. Our current results showed that the SGGD population may be the best candidate for higher oil content.

The chromatograms of the FAs obtained from the *S. wilsoniana* fruits in this study showed that the main FAs were linoleic acid (C18:3), oleic acid (C18:1), palmitic acid (C16:0), stearic acid (C18:0), and linolenic acid (C18:2), which is consistent with the results of previous studies [14]. Among them, linoleic acid was the most abundant unsaturated FA, and oleic acid was the second most abundant FA; the percentage content ranged from 31.88 ± 3.18% to 47.93 ± 7.91% and from 24.53 ± 2.05% to 39.10 ± 15.78%, with averages of 44.85 ± 6.70% and 29.45 ± 7.63, respectively. The abundance of unsaturated FAs in *S. wilsoniana* fruit oil mainly depends on the percentage of linoleic acid and oleic acid. Palmitic acid was the main saturated FA; the percent content ranged from 16.38 ± 3.53 to 25.53 ± 1.25, with an average of 19.59 ± 3.98. Additionally, small quantities of stearic acid and linolenic acid were detected, ranging from 1.68 ± 0.19 to 2.55 ± 0.63 and from 0.16 ± 0.04 to 0.26 ± 0.10, respectively. Previous studies [13] also demonstrated that the unsaturated FAs in *S. wilsoniana* seed oil were abundant, accounting for up to 76.02%–82.43%. Many studies have reported that unsaturated FAs have high nutritional and health care values [5,15].

Table 3. Oil content and fatty acid composition of different *S. wilsoniana* fruit populations.

Location	Oil Content (%)	Palmitic Acid (%)	Stearic Acid (%)	Oleic Acid (%)	Linoleic Acid (%)	Linolenic Acid (%)	UFA (%)	UFA/SFA
CSHN	21.96 ± 7.63 bc	19.20 ± 2.21 de	1.68 ± 0.19 e	28.63 ± 3.64 bc	46.78 ± 3.37 a	0.21 ± 0.07 ab	79.11 ± 2.18 a	3.84 ± 0.55 abcd
LYHN	22.04 ± 2.61 bc	18.61 ± 2.47 de	2.20 ± 0.20 bcd	31.38 ± 8.90 abc	44.05 ± 6.47 a	0.24 ± 0.04 ab	79.19 ± 2.42 a	3.87 ± 0.58 abc
LSHN	16.10 ± 4.94 c	16.38 ± 3.53 e	2.29 ± 0.40 ab	28.11 ± 9.90 bc	47.93 ± 7.91 a	0.24 ± 0.07 ab	81.33 ± 3.59 a	4.53 ± 0.98 a
CYJX	23.43 ± 3.96 b	18.73 ± 5.97 de	2.14 ± 0.33 bcd	39.10 ± 15.78 a	36.33 ± 9.41 b	0.26 ± 0.10 a	79.13 ± 5.67 a	4.21 ± 1.80 ab
YDJX	28.49 ± 0.74 ab	23.71 ± 1.74 ab	1.95 ± 0.17 cde	24.53 ± 2.05 c	45.57 ± 1.32 a	0.17 ± 0.04 b	74.34 ± 1.90 cd	2.91 ± 0.29 ef
ZGJX	26.09 ± 2.84 ab	23.29 ± 2.84 abc	1.88 ± 0.32 de	24.55 ± 4.20 c	45.85 ± 2.48 a	0.16 ± 0.04 b	74.82 ± 2.70 cd	3.02 ± 0.48 def
SGGD	33.08 ± 5.52 a	20.24 ± 2.76 bcd	1.70 ± 0.22 e	31.59 ± 3.90 abc	42.61 ± 2.90 a	0.21 ± 0.03 ab	78.06 ± 2.68 ab	3.62 ± 0.57 bcde
DBGX	28.70 ± 4.78 ab	24.36 ± 2.84 a	2.14 ± 0.28 bcd	36.82 ± 7.91 a	31.88 ± 3.18 b	0.17 ± 0.04 b	73.50 ± 2.78 cd	2.81 ± 0.41 ef
NPGX	22.16 ± 7.97 bc	19.76 ± 10.31 cde	2.55 ± 0.63 a	32.51 ± 8.63 abc	42.03 ± 6.04 a	0.22 ± 0.02 ab	73.31 ± 1.05 cd	2.75 ± 0.15 f
JXGX	27.85 ± 4.66 ab	21.94 ± 2.33 abcd	2.25 ± 0.18 abc	38.01 ± 5.06 a	35.29 ± 3.27 b	0.18 ± 0.01 b	75.81 ± 2.40 bc	3.16 ± 0.44 cdef
XPGX	29.32 ± 5.73 ab	25.53 ± 1.25 a	2.05 ± 0.25 bcd	35.35 ± 4.92 ab	33.72 ± 3.76 b	0.20 ± 0.09 ab	72.42 ± 1.28 d	2.63 ± 0.17 f
Mean	22.39 ± 7.55	19.59 ± 3.98	1.95 ± 0.39	29.45 ± 7.63	44.85 ± 6.70	0.21 ± 0.07	78.38 ± 3.74	3.78 ± 0.90
F	9.801	13.063	19.213	5.643	16.070	3.805	17.323	12.820
p	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Abbreviations: UFA, unsaturated fatty acid; SFA, saturated fatty acid. Different lowercase letters in the same column indicate significant difference ($p < 0.05$).

Importantly, the FA compositions were different among the 11 populations The LSHN (81.33 ± 3.59%), LYHN (79.19 ± 2.42%), CYJX (79.13 ± 5.67%), and CSHN (79.11 ± 2.18%) populations had the highest unsaturated FA levels, accounting for >79%, while XPGX (72.42 ± 1.28%), NPGX (73.31 ± 1.05%), and DBGX (73.50 ± 2.78%) had the lower unsaturated FA levels (<74%), and the mean value for all the populations was 78.38 ± 3.74%. In addition, we observed the highest UFA/SFA ratio for LSHN (4.53 ± 0.98) and the lowest UFA/SFA ratio for XPGX (2.63 ± 0.17). Previous research on *Eucommia ulmoides* seed oil [5] revealed that a higher UFA/SFA ratio in human diets is beneficial for health. The ANOVA results indicated significant variations ($p < 0.001$) for all the major FAs among the studied populations. The contribution of genetic variation to FA composition is therefore important when attempting to enhance oil quality by developing new cultivars through genetic modification.

3.3. Correlation Analysis of Oil Traits and Ecological Factors for S. wilsoniana Fruits

In probe studies of fruit oil quality, the correlations between geographic diversity and oil quality have been explored for many oil crops [24]. *S. wilsoniana* fruit oil is an edible oil widely used and appreciated in southern China, but there are few reports exploring the correlations between the oil quality differences and the environmental factors. Location and climate are among the environmental factors exerting strong influences on the fruit morphological traits and the oil traits in woody oil plants [23,25].

The results of the correlation analysis among those sub-traits are shown in Figure 2. Firstly, there were highly significant negative correlations between fruit length, fruit width, the thousand fruit weight, and linolenic acid; the correlation coefficients were −0.765, −0.758, and −0.778, respectively ($p < 0.01$). There were significant negative correlations between fruit width, the thousand fruit weight, and oleic acid; the correlation coefficients were −0.702 and −0.605, respectively ($p < 0.05$). Meanwhile, fruit length and UFA/SFA were significant negatively correlated ($r = -0.620$, $p < 0.05$). Moreover, our study also revealed that the fruit morphological traits are weakly correlated with the ecological factors, indicating that the fruit size was less affected by geographical factors in our studied populations.

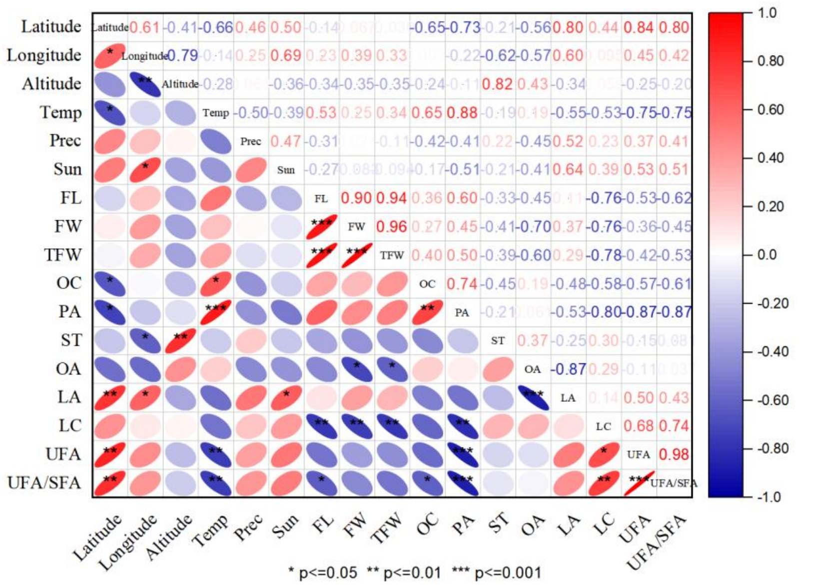

Figure 2. Correlation coefficients among indexes of *S. wilsoniana* fruits. Abbreviations: Temp., average monthly temperature; Sun. Dur., average annual sunshine duration; Prec., average annual precipitation; FL, fruit length; FW, fruit width; TFW, thousand fruit weight; OC, oil content; PA, palmitic acid; SA, stearic acid; OA, oleic acid; LA, linoleic acid; LC, linolenic acid; UFA, unsaturated fatty acid; SFA, saturated fatty acid.

Little is known about the oil composition of *S. wilsoniana* fruits grown in different environmental conditions; hence, the correlations were investigated in this study. Firstly, we measured the oil content, which was positively correlated with temperature ($r = 0.645$, $p < 0.05$) and negatively correlated with latitude ($r = -0.653$, $p < 0.05$). Among the saturated FAs, the palmitic acid abundance was extremely positively correlated with temperature ($r = 0.883$, $p < 0.001$) and negatively correlated with latitude ($r = -0.726$, $p < 0.05$), while stearic acid was strongly positively correlated with altitude ($r = 0.820$, $p < 0.001$) and negatively correlated with longitude ($r = -0.617$, $p < 0.05$). Linoleic acid, the most abundant FA of *S. wilsoniana* fruits, was strongly positively correlated with latitude ($r = 0.797$, $p < 0.01$) and positively correlated with longitude and sunshine duration, with the correlation coefficients of 0.603 and 0.637, respectively ($p < 0.05$). This indicates that the oil synthesis may be better affected by environmental temperature during fruit development for *S. wilsoniana*. Additionally, light, precipitation, and other meteorological elements are crucial for plant growth but not for determining FA content. According to previous research [26,27], remarkable correlation differences were found for the seed oil of *Jatropha curcas* L. and *Sapindus spp.* in plants experiencing different ecological conditions. The main reasons for the differences are not only related to the different years of collection, but also to whether the analyzed samples are truly representative.

Highly significant correlations were found between the unsaturated FAs and the latitude and temperature among the studied populations, with correlation coefficients of 0.844 and −0.754, respectively ($p < 0.01$). There were similar correlations between the UFA/SFA ratio and the latitude and temperature; the UFA/SFA ratio was strongly positively correlated with latitude ($r = 0.802$, $p < 0.01$) and strongly negatively correlated with temperature ($r = -0.751$, $p < 0.01$). In our study, there was an extremely positive correlation between linoleic acid content and latitude and highly significant correlations between the unsaturated FAs and latitude and temperature among the studied populations. Lower temperature during fruit development is often associated with more unsaturated FAs in the oil due to the increased activity of oleate desaturase, which promotes the synthesis of linoleic acid, and high latitude contributes to the synthesis of unsaturated FAs. Differences have been reported for other species. Studies on sunflower seed oil [28] showed that the average temperature of the area had the greatest influence on the FA composition. Another study on peony seed oil [29] indicated that the FA components were positively correlated with latitude, annual rainfall, and annual temperature. Studies on *E. ulmoides* seeds [5] showed that latitude and precipitation were key environmental factors and were significantly correlated with FA composition. According to earlier findings, *S. wilsoniana* oil has good potential for use in the food and health care industries [15], and our current results on oil variation and the relationships between the environmental factors suggested that selection approaches could increase the oil content and improve quality.

3.4. PCA of Traits of S. wilsoniana Fruits

The PCA can combine multiple variables into a few comprehensive indicators and thereby determine the most significant factors [4]. Two main principal components were extracted by the PCA in our study. PC1 explained 42.7% of the total variation and showed positive correlations for the UFA/SFA ratio, unsaturated FAs, linolenic acid, latitude, and sunshine duration and negative correlations for palmitic acid, temperature, oil content, and fruit length. PC2 explained 30.1% of the total variation and showed positive correlations for fruit width and longitude and negative correlations for oleic acid, altitude, and stearic acid.

According to the scatter plots constructed from PC1 and PC2 (Figure 3), the oil content and FA composition of the *S. wilsoniana* fruits from different populations were partly affected by geographical distribution. The 11 populations could be divided into four groups. The LSHN population showed a very high UFA/SFA ratio but a relatively low oil content. The CYJX population showed a relatively high UFA. The CSHN, SGGD, and LYHN populations were grouped together, with all of them showing higher unsaturated

FA levels as well as medium oil content. The DBGX, XPGX, JXGX, and NPGX populations were grouped together, with all of them possessing higher oleic acid content. The ZGJX and YDJX populations were grouped together and displayed a large fruit size. There were differences in the strength of the correlations. A combination of multiple environmental factors ultimately led to different populations of *S. wilsoniana* having clearly differing results, and this affects both oil content and FA composition [29,30]. However, exactly how geographical and climatic factors affect the FA composition of *S. wilsoniana* fruits requires further investigation.

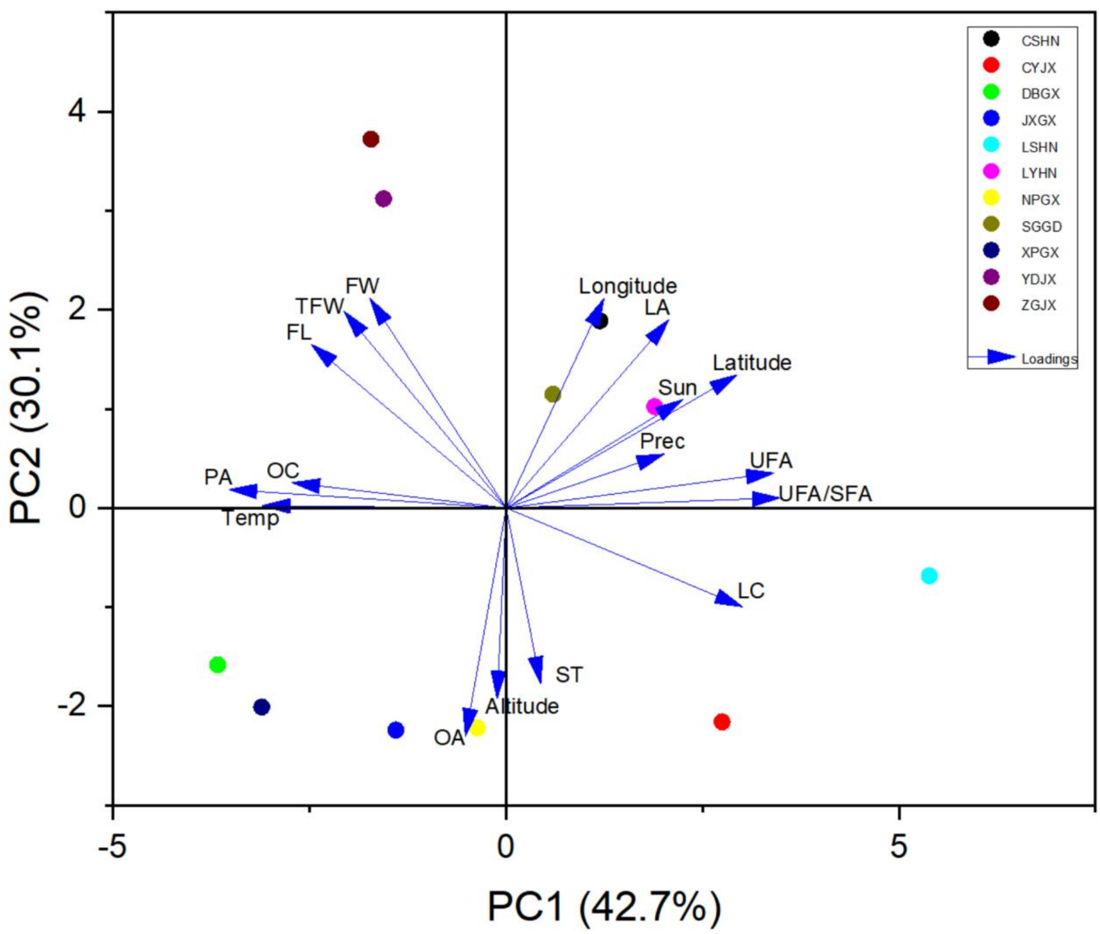

Figure 3. The relationship between 11 populations of *S. wilsoniana* based on PC1 and PC2. Abbreviations: Temp., average monthly temperature; Sun. Dur., average annual sunshine duration; Prec., average annual precipitation; FL, fruit length; FW, fruit width; TFW, thousand fruit weight; OC, oil content; PA, palmitic acid; SA, stearic acid; OA, oleic acid; LA, linoleic acid; LC, linolenic acid; UFA, unsaturated fatty acid; SFA, saturated fatty acid.

4. Conclusions

To improve the *S. wilsoniana* germplasm resources from different geographical areas in southern China, we evaluated fruit oil content and fatty acid composition and assessed the relationships between the environmental factors and fatty acid composition. The results revealed that the oil contents *of S. wilsoniana* populations ranged from 16.10 ± 4.94% to 33.08 ± 5.52%, and the most abundant fatty acids were linoleic acid, oleic acid, palmitic acid, stearic acid, and linolenic acid. Unsaturated fatty acids accounted 78.38 ± 3.74% of the total fatty acids. Furthermore, the results showed that oil content was positively correlated with temperature (r = 0.645, $p < 0.05$) and negatively correlated with latitude (r = −0.653, $p < 0.05$). Both latitude and temperature were significantly correlated with the unsaturated fatty acids in *S. wilsoniana* fruits, and they were key determining factors. These findings demonstrate the geographical variation in the oil content and fatty acid composition for *S. wilsoniana* fruits, and the knowledge could prove useful for germplasm resource collection and utilization.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/f13111811/s1, Figure S1: representative photographs of *S. wilsoniana*: (A) mature *S. wilsoniana* tree in its natural habitat; (B) unripe fruit; (C) matured fruit; (D) tree trunk. Table S1: annual temperature, annual sunshine duration, and annual precipitation data.

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