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# Reducing Macronutrients and Increasing Micronutrient Fertilizers Are Key to Improving the Quality of Pomelo *Citrus grandis* (L.) *Osbeck Cv. "Guanxi"*

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**Abstract:** Due to long-term excessive fertilization, the fruit quality of the *Guanxi* pomelo (Citrus grandis) has been declining. The classification of fruit quality and its relationship with nutrients in soils and trees were studied to declaim the characteristics of nutrients in *Guanxi* pomelo orchards, ultimately guiding the fertilization for high-quality fruit production. By cluster analysis, 281 samples were grouped into four clusters. High-quality fruit (HF) showed a gourd shape with moderate weight size, high sweetness, edible rate (ER) up to 73%, and vitamin C content over 40 mg/100 g. Compared to sub-quality fruit (SF), common fruit (CF), and inferior fruit (IF), the content of magnesium (Mg) in the leaves of HF was 11.76, 11.76, and 18.75% higher, while the content of iron (Fe) was 6.45, 5.76 and 10.97% higher, respectively. Meanwhile, the contents of Zinc (Zn, 8.51, 6.44, and 11.22% higher than SF, CF, and IF, respectively) and Boron (B, 13.47, 13.83, and 25.40% higher than SF, CF, and IF, respectively) were also found to increase. However, the contents of Mn (35.34, 27.51, and 25.53% higher) and Cu (31.90, 31.99, and 5.64% higher) in IF were significantly higher than in HF, SF, and CF. Acid soils (4.24–4.40) with low OM content (23.00–26.71 g $kg^{-1}$) led to an imbalance uptake of nutrients of citrus, ultimately resulting in poor quality. These results indicated that farmers should reduce the application of nitrogen (N), phosphorus (P), and K fertilizer and pesticides and increase micronutrient and organic fertilizer, which provides a theoretical basis for scientific fertilization to improve the fruit quality of *Guanxi* pomelo *(Citrus grandis)* of Pinghe County.

**Keywords:** citrus; quality grading; excess fertilizer; nutrient imbalance; soil acidification



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## 1. Introduction

*Guanxi* pomelo *(Citrus grandis)* is one of the most important citrus fruits in Fujian province, China, with a history of more than 500 years and covering a planting area of more than 0.43 million ha. *Guanxi* pomelo has a yield of up to 1.2 million tons, where 150,000 tons were exported with an output value of CNY 4 billion [1]. The fruit quality and consumer recognition of citrus fruit, such as sweetness, shape, acidity, and flavor, are critical for its market competitiveness [2,3]. Meanwhile, fruit weight (FW), fruit shape index (SI), and edible rate (ER) are also decisive factors that influence consumers' choices. High total soluble solids (TSS) levels determine the sweetness, fruitiness, and flavor of fruits, but high titratable acidity (TA) levels can have detrimental effects [4]. Vitamin C plays an important role in maintaining proper function and good health in the human body, which was also considered one of the nutritional values of *Guanxi* pomelo (*Citrus grandis*).

Leaves played a central role in the transport of mineral nutrients [5], which directly indicates the absorption and utilization of nutrients in plants. In leaves, high K may reduce the absorption of magnesium (Mg), Calcium (Ca), and manganese (Mn) [6]. The photosynthetic rate of citrus was impacted by Mg deficiency in the leaves, which decreased yield and quality [7]. The content of Ca in leaves was related to the texture of the citrus pulp, thus affecting the chewiness [8]. However, the flesh firmness of the "Golden Smoothee" apple decreased with the increasing concentration of N [9]. Not only macronutrients, but also other microelement contents (Fe, Mn, Cu, Zn, and B) have been considered the critical factors for the growth and quality of citrus. The deficiency and excess of boron caused the disordered nutrition absorption, photosynthesis, and metabolism of organic acid in citrus [10]. Foliar application of zinc fertilizer could increase the concentration of zinc and iron in the leaves, thus increasing the fruit weight per fruit and the content of sugar [11]. Unbalanced leaf mineral nutrients may generate poor-quality fruit. The leaf requirements of mineral elements are complex and may vary depending on soil fertility [12].

It has been reported that soil nutrients are closely related to nutrient status, size, and yield of citrus [13]. Soil organic matter (OM) plays a significant role in soil fertility, which determines soil water retention, storage, the release of plant nutrients, adsorption of pesticides, and availability of N availability to plants [14]. A survey of the literature showed that the annual application rate of N, P, and K fertilizer is significantly higher in other main citrus-producing areas than that in the *Guanxi* pomelo orchard of Pinghe [15]. The excessive application of N, P, and K fertilizer and neglecting organic fertilizer and micro-fertilizers are the main reasons for the large spatial variation in soil nutrients in *Guanxi* pomelo orchard in Pinghe County. The unnecessary application of N fertilizer can lead to soil acidification [16,17]. Particularly, a high content of soil available phosphorus (avail-P) can cause acidification and decrease the contents of available calcium (avail-Ca) and available zinc (avail-Zn) in soil [18], and induce disease and pest attack [19], which, in turn, leads to the increasing application of pesticides. The long-term application of Cu-containing pesticides and fertilizers may increase the available copper (avail-Cu) in the soil of citrus orchards [20] and iron (Fe) deficiency with visible symptoms of chlorotic disorders and stunted tree growth [14]. These may result in an imbalance uptake of soil nutrients and, subsequently, imbalanced contents of leaf nutrients [21]. As explained above, the contents of nutrients in soil and plant leaves play vital roles in producing high-quality fruits.

The fruit quality is the most important factor determining the market competitiveness of citrus production. As of now, exorbitant utilization of macronutrient fertilizers and disregard of micronutrient fertilizers lead to uneven soil and leaf nutrients, eventually prompting a decreasing quality of the *Guanxi* pomelo (*Citrus grandis*). How to effectively improve the quality of *Guanxi* pomelo (*Citrus grandis*) is an urgent problem for fruit farmers. Through grading citrus quality, this study analyzed the relationship between leaf and soil nutrients and fruit quality in 281 orchards and clarified the effect of soil and leaf nutrients on fruit quality. In contrast to the results of other studies, we advocate that farmers reduce the application of macronutrient fertilizers and replace them with micronutrient and organic fertilizers. The results provide a scientific basis for farmers to apply fertilizers in an efficient and balanced way, save costs, and improve fruit quality.

## 2. Materials and Methods

### *2.1. Sample Collections and Preparation*

Pinghe County has a subtropical monsoon climate with an average elevation of 500–500 m and an annual rainfall of 1600 mm [21]. This area is sunny and rainy. The soil type is red loam, the parent materials of which are ferralsols or oxisols based on FAO (IUSS Working Group WRB) or USDA (Soil Survey Staff) [22]. The sampling of soil, leaves, and fruits was carried out in October 2011 (fruit harvesting time). The number and location of the collected samples are shown in Figure S1 and Table S1. Briefly, sampling (one composite sample for each orchard) was performed in an "S" path, and a total of 15–20 sample points were selected based on the principle of random, equal quantity, and multi-point mixing. The samples were collected from 10 towns in Pinghe County, Fujian province, and were divided into 281 sampling units according to soil type, history of land cultivation, yield level, and variety [21].

The 20-year-old *Guanxi* pomelo (*Citrus grandis*) grafted on sour grapefruit with consistent growth was used in the present study.

In total, 1 kg of soil sample was collected at a depth of 0–30 cm and 10 cm outside of the tree crown dripping line after removing impurities from the surface. Soil samples were screened through 20 meshes and 100 mesh sieves after drying and grinding. For the leaf samples, the third growing disease-free leaves from the top of the annual vegetative spring shoot were collected from four directions of an outer crown. A total of 8–10 leaves of citrus were collected from the tree, and more than 100 leaves were mixed to obtain a composite sample. The collected leaves were washed in 0.1% aqueous solution with neutral detergent for about 30 s. Next, leaves were washed in 0.2% HCl solution for about 30 s, and finally washed with deionized water and oven-dried at 105 °C for 30 min. Oven-dried leaves were smashed and screened through 60 mesh sieves.

Pomelo fruit samples were collected from four directions of the outer part of the crown. Between 60 and 80 fruits were collected from 4 trees (4 orientations). Then, 20 fruit was selected randomly to constitute 1 fruit sample.

### *2.2. Measurement Methods*

The fruit quality was evaluated based on the test method of citrus fresh fruit (FW). In brief, FW was weighted by electronic balance (precision 0.01 g). The fruit shape index (SI) was obtained by determining the transverse and longitudinal diameter by vernier calipers. The weight of the fruits before and after peeling was determined, and ER was the quotient between the weight before and after peeling (GB8210-87; a national standard method of inspection for export citrus fruit in China). TA was measured by standard base titration, and the digital sugar meter (ATAGO PAL-BX/ACID1) was used to analyze TSS. Finally, the content of VC was analyzed by 2, 6-dichlorophenol titration.

For the leaf samples, the contents of total N, P, and K were analyzed after digestion with $H_2SO_4$ and $H_2O_2$. The content of total N was analyzed with the employment of Kjeldahl (K9840, HANON, Jinan, China). The content of total P was analyzed by the Molybdenum antimony colorimetric method (UV-5200, METASH, Shanghai, China), and a flame photometer (AP1200, AOPU, Shanghai, China) was used for the determination of total K. The contents of Ca, Mg, Fe, Mn, Cu, and Zn in leaves were determined by atomic absorption spectrophotometry after samples were digested with $HNO_3$-$HClO_4$ (Z2000, HITACHI, Tokyo, Japan). In addition, the content of boron (B) was analyzed by the curcumin method [23].

Soil organic matter (SOM) was determined by the potassium dichromate oxidation method. The pH was determined in a ratio of 1:2.5 (soil: water) with water extraction-potentiometric titration. The alkaline hydrolysis diffusion method was used to measure the content of soil available nitrogen (soil avail-N). The content of soil available P (soil avail-P) was determined using Olsen's method. The level of soil available potassium (soil avail-K) was extracted with 1 mol $L^{-1}$ $CH_3COONH_4$ and determined by a flame photometer (AP1200, AOPU, Shanghai, China). The contents of soil available Ca (soil avail-Ca) and Mg (soil avail-Mg) were extracted with 1 mol $L^{-1}$ $CH_3COONH_4$ and determined using an atomic absorption spectrophotometer (Z2000, HITACHI, Tokyo, Japan). The contents of soil available manganese (soil avail-Mn), available Cu, and available Zn were extracted with diethylenetriaminepentaacetic acid (DTPA) and determined by an atomic absorption spectrophotometer (Z2000, HITACHI, Tokyo, Japan). The level of soil available boron (soil avail-B) was extracted with boiling water and determined by curcumin colorimetry [23].

### *2.3. Statistical Analysis*

Analysis of variance was performed using the ANOVA method with Duncan multiple comparisons ($p < 0.05$) by SPSS 25 software. A half-violin chart was plotted using Origin 2021 software (Northampton, MA, USA). The cluster analysis, principal component analysis (PCA), and correlation analysis were performed by R 4.1.1. The use of PCA analysis was employed to better validate the accuracy of cluster analysis for fruit quality grading [24]. Curve estimation was conducted by Origin 2021 software [25].

## 3. Results

### *3.1. Characteristics and Classification of Guanxi Pomelo (Citrus grandis) Fruit Quality*

The main fruit quality indexes of the experimental orchards, including fruit weight (FW), shape index (SI), edible rate (ER), titratable acidity (TA), total soluble solids (TSS), TSA, and vitamin C (Vc), were 1.12 kg, 0.96, 66.59%, 0.84%, 10.69%, 12.85, and 42.45 mg/100 g, respectively (Table 1). The variation coefficients (CV) of fruit quality indexes were from 5.25% to 20.68% and significantly different from 281 *Guanxi* pomelo orchards. The CV of single fruit weight (FW) was the highest, and the maximum value (max) was 2.54 times the minimum value (min). The CV of TSA was the second highest with a max/min value of 2.06, while CVs of SI, ER, TA, TSS, and VC were 1.67, 1.58, 1.59, 1.77, and 1.43, respectively with max/min values from 5.25 to 7.62, suggesting that the variation of fruit fresh weight was greater than the other indexes.

**Table 1.** Fruit quality of *Guanxi* pomelo orchards in Pinghe, Fujian, China.

| Index | Min | Max | Average | SD | CV |
|---|---|---|---|---|---|
| FW (g) | 683.24 | 1735.18 | 1119.36 ± 13.81 | 231.50 | 20.68% |
| SI | 0.77 | 1.29 | 0.96 ± 0.01 | 0.06 | 6.33% |
| ER | 48.46 | 76.69 | 66.59 ± 0.29 | 4.82 | 7.23% |
| TA | 0.66 | 1.05 | 0.84 ± 0.01 | 0.06 | 7.20% |
| TSS | 7.48 | 13.25 | 10.69 ± 0.05 | 0.81 | 7.62% |
| TSA | 8.22 | 16.98 | 12.85 ± 0.09 | 1.50 | 11.69% |
| Vc (mg/100 g) | 33.62 | 48.22 | 42.45 ± 0.13 | 2.23 | 5.25% |

FW: Single fruit weight; SI: Fruit shape index; ER: Edible rate; TA: Titratable acidity; TSS: Total soluble solids; TSA: Total soluble solids/Titratable acidity; VC: Vitamin C.

The cluster classification was used to analyze the trait indexes of the pomelo class, providing a more accurate and objective grading which can truly reflect the comprehensive traits of the variety. The results are stable, providing an objective basis for quality evaluation [24]. The main fruit quality indexes, including FW, SI, ER, TA, TSS, TSA, and VC, were analyzed by cluster analysis. The fruit samples were divided into four categories: -high-quality fruit (HF) (47 samples), sub-quality fruit (SF) (97 samples), common fruit (CF) (106 samples), and inferior fruit (IF) (31 samples) (Figure S2). It can be seen that the percentage of highly qualified fruits was merely 16.73% of *Guanxi* pomelo. In this research, the SI (4.30%, 3.19%), ER (5.05%, 17.50%), TSS (11.93%, 21.53%), TSA (19.29%, 42.69%), and Vc (2.71%, 3.73%) indexes in HF were significantly higher than those in CF and IF, while TA (4.82%, 12.22%) was lower than those in HF (Figure 1). HF was considered the best, with good appearance, flavor, and nutrition quality, while the IF was the worst. Principal component analysis (PCA) illustrated obvious segregation between the fruit quality of HF and IF for all samples, which was critically influenced by internal quality (i.e., TA, TSS, TSA, ER). Principal component 1 (PC1) contributed 40.03%, and principal component 2 (PC2) contributed 19.06% (Figure 2).

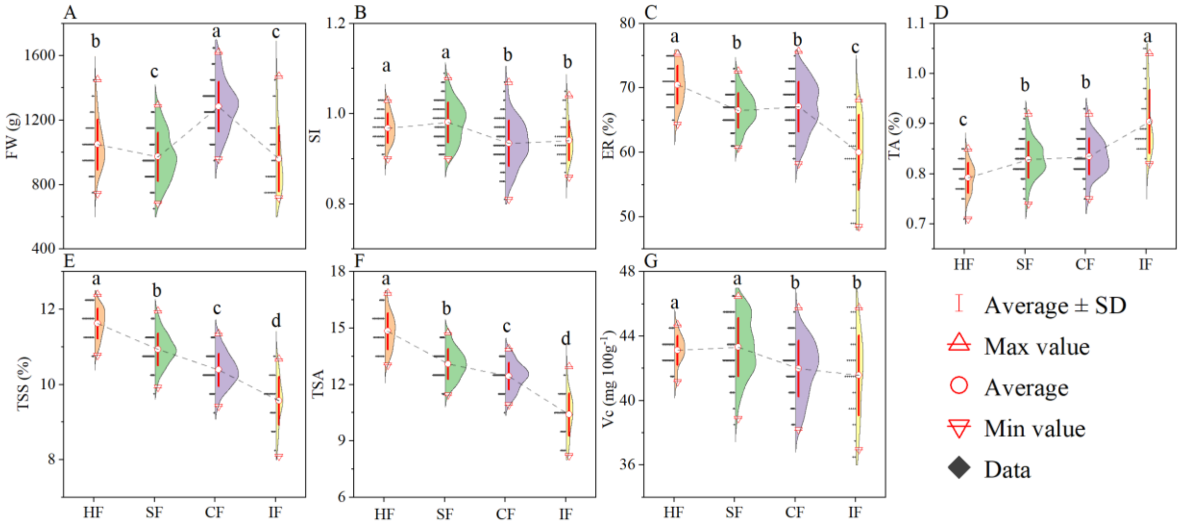


**Figure 1.** Classification of fruit quality indexes of *Guanxi* pomelo (*Citrus grandis*). HF (47 samples): high-quality fruit, SF (97 samples): sub-quality fruit, CF (106 samples): common fruit, and IF (31 samples): inferior fruit. (**A**) FW: Single fruit weight; (**B**) SI: Fruit shape index; (**C**) ER: Edible rate; (**D**) TA: Titratable acidity; (**E**) TSS: Total soluble solids; (**F**) TSA: Total soluble solids/Titratable acidity; (**G**) VC: Vitamin C. Each value represents mean ± standard errors. Different lowercase letters in the figure indicate significant differences in data ($p < 0.05$).

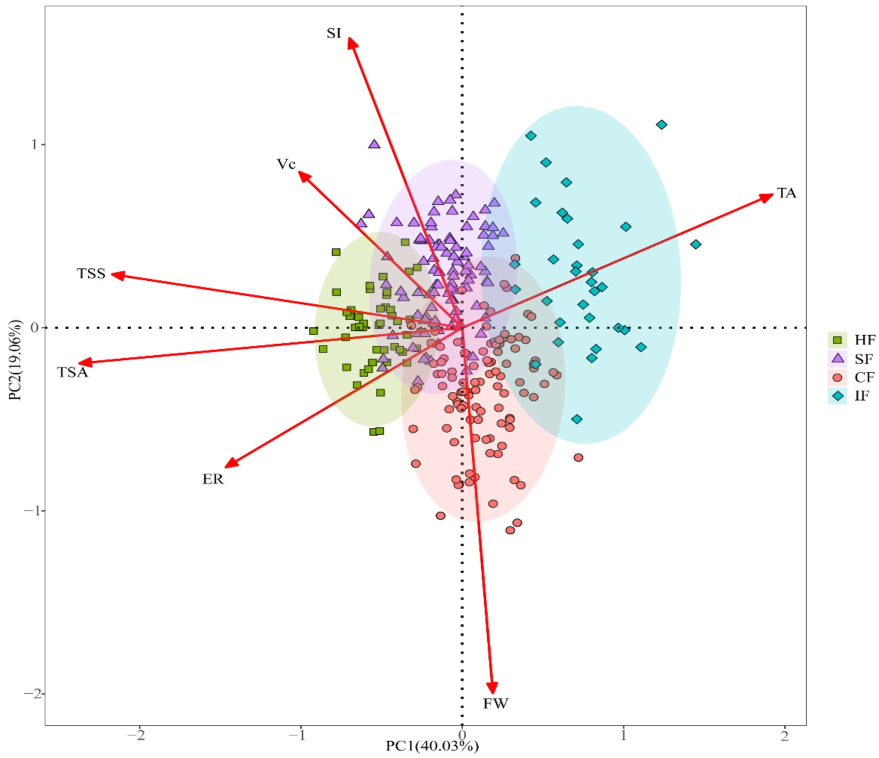


**Figure 2.** PCA analysis of fruit quality in 4 citrus cultivars. HF (47 samples): high-quality fruit, SF (97 samples): sub-quality fruit, CF (106 samples): Common fruit, and IF (31 samples): inferior fruit. FW: Single fruit weight; SI: Fruit shape index; ER: Edible rate; TA: Titratable acidity; TSS: Total soluble solids; TSA: Total soluble solids/Titratable acidity; VC: Vitamin C.

### *3.2. Differences in Leaf Nutrients among Four Guanxi Pomelo Orchards with Different Fruit Quality*

Similar to most plants, pomelo leaves had higher concentrations of N, P, K, Ca, and Mg than their uptake of Fe, Mn, Cu, Zn, and B (Figure 3). Compared with SF, CF, and IF, the content of Mg in the HF leaves was significant, with values 11.76, 11.76 and 18.75% higher, while the content of iron (Fe) was 6.45, 5.76 and 10.97% higher. Moreover, the content of Zinc (Zn) was 8.51, 6.44, and 11.22% higher, and the content of boron (B) was 13.47, 13.83, and 25.40% higher. Compared to HF, SF, and CF, IF has a significantly 35.34, 27.51, and 25.53% higher content of Mn, and the content of Cu was 31.90, 31.99, and 5.64% higher, respectively.

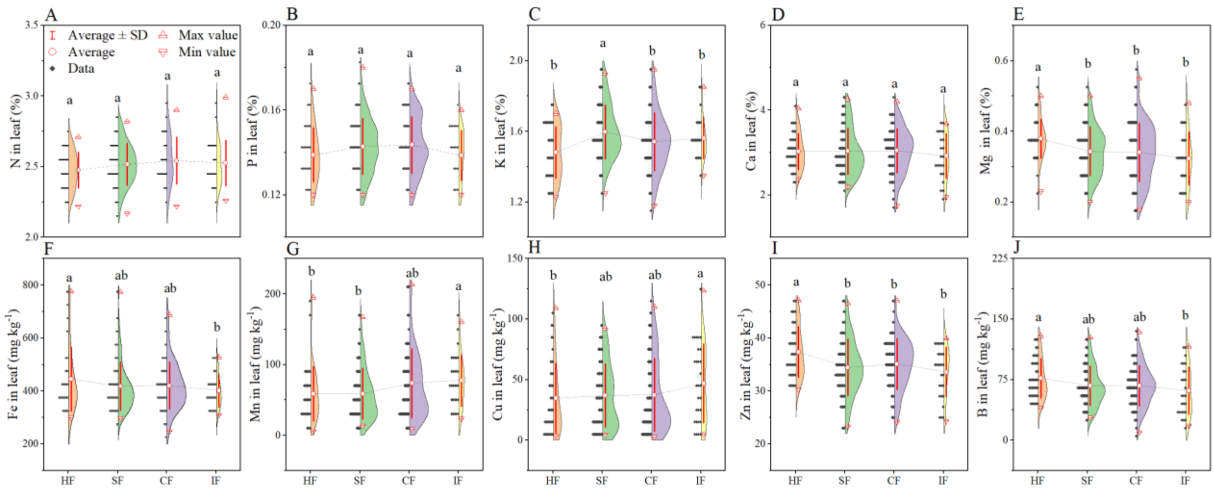


**Figure 3.** Contents of trace elements in leaves of *Guanxi* pomelo *(Citrus grandis)* with different grades. Each value represents mean ± standard errors. HF (47 samples): high-quality fruit, SF (97 samples): sub-quality fruit, CF (106 samples): Common fruit, and IF (31 samples): inferior fruit. (**A**) N: nitrogen, (**B**) P: phosphorus (**C**) K: potassium, (**D**) Ca: calcium, (**E**) Mg: magnesium, (**F**) Fe: iron, (**G**) Cu: Copper, (**H**) Mn: manganese, (**I**) Zn: zinc, (**J**) B: boron, same as below. HF: high-quality fruit, SF: sub-quality fruit, CF: common fruit, IF: inferior fruit. Different lowercase letters in the table indicate significant differences in data ($p < 0.05$).

### *3.3. Relationships between Leaf Nutrients and Fruit Quality*

It was discovered through the curve estimation that there was a significant correlation between changes in the contents of N, Mg, K, Cu, Mn, B, and Zn in leaves and fruit quality indicators (Figures 4 and S2). Specifically, the increasing content of N in the leaves was accompanied by the gradual decrease of SI (Figure 4A). Mg and B were significantly quadratic with ER, TSS, and TSA. When the content of Mg was 0.45, 0.41, and 0.42% (Figure 4B–D) and B was 76.32, 91.35, and 107.07 mg $kg^{-1}$ (Figure 4L,N), respectively, ER, TSS, and TSA reached maximum values. ER was found to decline with the increasing content of K (Figure 4E). Elevating levels of Cu led to a significantly increasing ER and a decreasing TA (Figure 4F,G). High contents of Mn increased the fruit weight per fruit but reduced the SI, TSS, and TSA (Figure 4H–K). An increase in Zn content improved the ER, TSS, and TSA of the fruit and reduced the TA (Figure 4O–R).

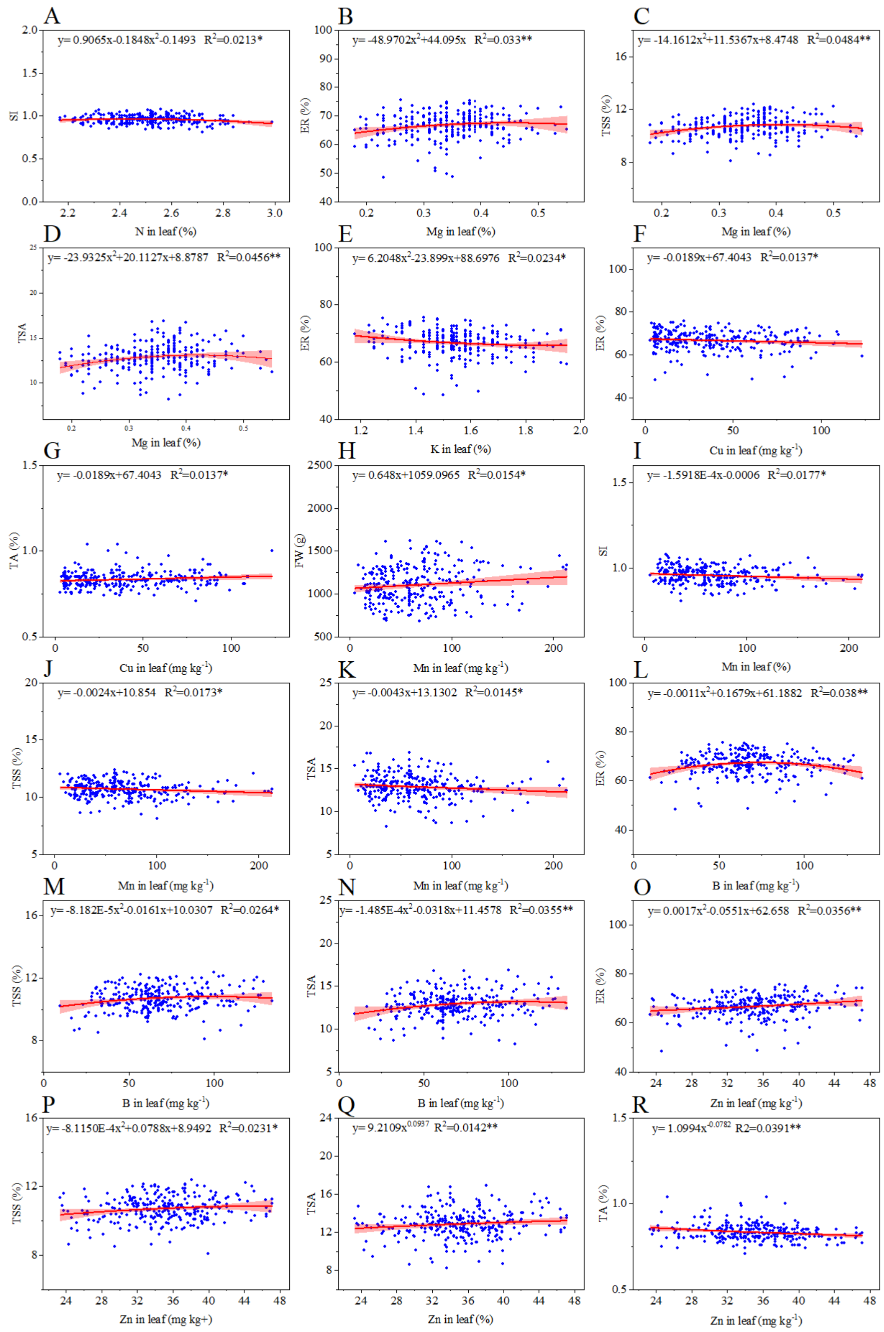


**Figure 4.** Response curves of leaf nutrient contents (*X*-axis) versus different fruit quality (*Y*-axis) in pomelo ($n$ = 281). FW: Single fruit weight; SI: Fruit shape index; ER: Edible rate; TA: Titratable acidity; TSS: Total soluble solids; TSA: Total soluble solids/Titratable acidity. (**A**) N, (**B**–**D**) Mg, (**E**) K, (**F**,**G**) Cu, (**H**–**K**) Mn, (**L**–**N**) B, (**O**–**R**) Zn. * and ** superscripts after $R^2$ values indicate statistically significant at $p < 0.05$ and $p < 0.01$, respectively.

### *3.4. Differences in Soil Nutrients among Four Categories of Guanxi Pomelo Orchards with Different Fruit Quality*

The abundance of mineral nutrients and the content of OM in acidic soil are important factors which can affect the quality of fruits. The physical and chemical properties of the collected soil sample are shown in Figure 5. The average pH was lower than 4.5 despite there being no appreciable difference between the treatments and the soil being slightly acidic (Figure 5A). The content of OM in the HF orchard soil was significant, with values 7.92, 16.13, and 12.23% higher than that of the SF, CF, and IF orchards (Figure 5B). In the orchard of IF, the contents of the avail-N (20.86, 12.38, and 9.72%), avail-K (44.10, 21.57 and 17.17%,), and avail-Mn (177.03, 112.88, and 10.84%) were much higher than that in the HF, CF, and CF orchards (Figure 5C,E,H). The contents of avail-Ca and avail-Mg were insufficient (Figure 5F,G), while the contents of avail-N, avail-P, avail-Cu, and avail-B were excessive in most orchards (Figure 5C,D,I,K).

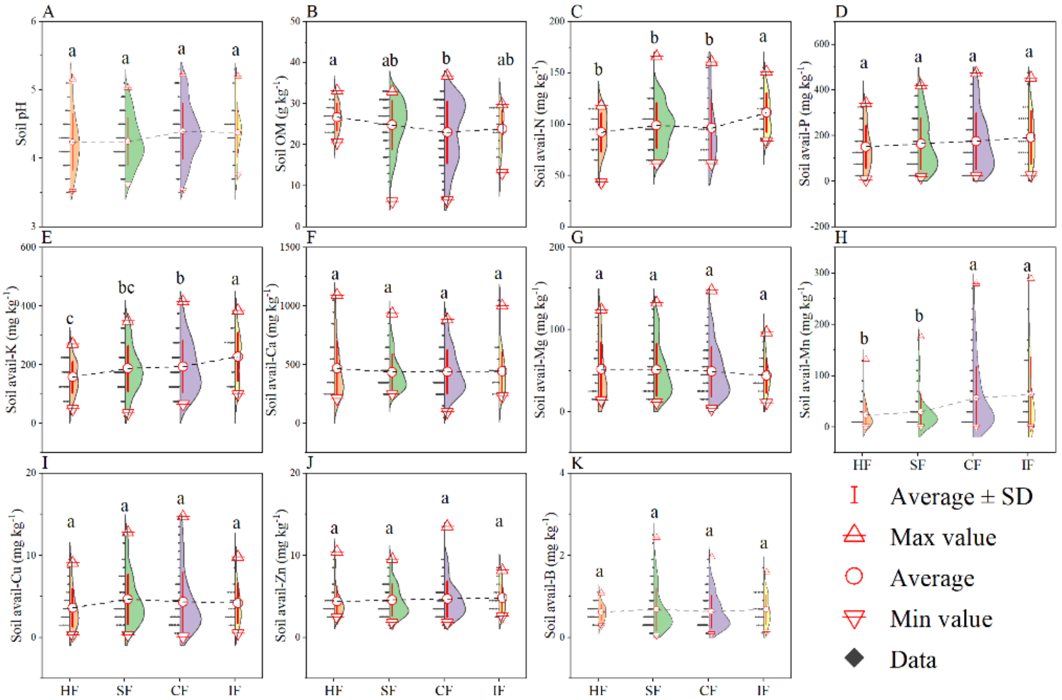


**Figure 5.** Content of trace elements in *Guanxi* pomelo soil in Pinghe. HF (47 samples): high-quality fruit, SF (97 samples): sub-quality fruit, CF (106 samples): Common fruit, and IF (31 samples): inferior fruit. Soil OM: soil organic matter; soil avail-N: soil available nitrogen; soil-P: soil available phosphorus; soil avail-K: soil available potassium; soil avail-Ca: soil available calcium; soil avail-Mg: soil available magnesium; soil avail-Mn: soil available manganese; soil avail-Cu: soil available copper; soil avail-Zn: soil available zinc; soil avail-B: soil available boron. Each value represents mean ± standard errors. Different lowercase letters in the table indicate significant differences in data ($p < 0.05$).

## 4. Discussion

### *4.1. Quality Characteristics of High-Quality Guanxi Pomelo Fruit*

The quality of *Guanxi* pomelo *(Citrus grandis)* is one of the most important indexes determining its economic value. The weight and shape of fruits directly affect the visual impression of consumers [26]. The content of Vc in fruits reflects their nutritional value and determines their nutritional quality. Moreover, the contents of TA, TSS, and TSA, which are involved in the flavor of fruits, directly influence the secondary selection of consumers. In a current survey, it was found that excessive sweetness or acidity is the least preferred flavor; therefore, a suitable TSA is critical for pomelo flavor [4]. The present results indicated the best quality of *Guanxi* pomelo fruit with a FW of 1.03 kg, the highest ER (70.50%), a sweet flavor (TSS: 11.63%, TA: 0.79%, and TSA: 14.84), and the highest Vc contents (exceeding 40 mg/100 g). The pomelo of HF has a higher content of Vc, which could meet our daily vitamin needs [27]. Obovoid *Guanxi* pomelo has the best fruit shape, and the FW and SI characteristics of HF were considered the apparent basis for high-quality pomelo. The unique appearance of HF would guide the consumer in making an easy selection. By previous findings, the optimal TSS and acidity levels of mandarin for high flavor were approximately 13.1% and 1.1%, respectively. The high acidity of early-season mandarin varieties significantly reduced TSA and flavor scores [12,28]. The quality indexes with FW

<10 kg, TSS < 10%, and ER < 60% belonged to lower-quality fruit pomelo [29]. Thus, the fruits with the worst quality were identified with a FW of 0.93 kg; an oblate shape; the lowest FW, ER, TSS, and TSA values; and the greatest intensity of acid taste. These results suggested that FW, SI, and ER could be the major indexes as a consumer-assisted selection. Meanwhile, appropriate TSA and Vc indicated better flavor and nutrition, which promoted the consumer acceptance of such products.

### *4.2. Leaf Nutrient Characteristics of High-Quality Fruit Guanxi Pomelo Orchard*

Leaf nutrient analysis and diagnosis are the most common technologies for the fertilization of citrus, and the contents of leaf nutrients provide information to correct fertilization and soil modification [30]. Mg, Fe, Zn, and B were significantly higher in HF orchard leaves than in IF, whereas K, Mn, and Cu were significantly lower (Figure 3). High levels of Mn and Cu in the leaves of IF orchards may be the result of excessive pesticide application. Meanwhile, leaf nutrient status is closely related to fruit quality. According to our analysis, higher contents of N, K, Mn, and Cu in the leaves decreased the fruit's quality indices. Higher ER, TSS, and TSA were the outcomes of appropriate Mg and B content. The decreasing TA decreased, and the increasing ER, TSS, and TSA were considered to result from the increasing Zn in the leaf. (Figures 4 and S3). A previous study showed the excessive content of K can result in thickening of the peel, bitterness in taste, and a decrease in juice yield [31]. Micro-nutrients are indispensable in all metabolic and cellular functions, such as energy metabolism, primary and secondary metabolism, cell protection, gene regulation, hormone perception, signal transduction, and reproduction, among others [32]. The appropriate contents of Mg, Zn, and B had positive effects on the increase of fruit ER of *Guanxi* pomelo (Figures 4 and S3). Mg, Zn, and B are key factors involved in photosynthesis and fruit growth and development. The appropriate amounts of Ca and Mg can promote the mastication characteristics of citrus [8]. Previous studies showed that TA was positively correlated with the content of Cu in the leaf, which is in agreement with the reducing TA in citrus induced by Cu deficiency [33]. The SI and ER of fruit were related to the content of Mn: The higher the content of Mn is, the lower ER will be [34]. Moreover, the high content of Mn inhibited the absorption of Ca and Fe. In summary, the maintenance of leaf mineral elements balance is a key factor in improving the quality of fruits.

### *4.3. Soil Nutrients Characteristics of High-Quality Fruit Guanxi Pomelo Orchard*

The quality of citrus is closely related to the contents of nutrients in the tree, which directly depends on their contents in the soil [35,36]. Our studies have shown that in most orchards, pH levels were low and acidic. The contents of soil avail-N, avail-P, and avail-K, avail-Cu, and avail-B were very high, but the contents of exchangeable avail-Ca and avail-Mg and OM contents were generally deficient (Figure 5). Due to the long-term heavy chemical fertilization and ignorance of organic fertilization, the contents of avail-N, avail-P, and avail-K were excessive in the soil, which is consistent with the leaf diagnosis results. The application of fertilizer significantly improves the contents of soil available nutrients [37], whereas the continuous high input of fertilizer also brought about unbalanced soil nutrients, nutrient leaching, polluted groundwater, and inhibited uptake [38]. The overuse of P fertilization leads to nutrient loss due to poor mobility and the leaching of avail-P in the soil, making it easily immobilized [39]. In addition, soil acidification could impede the absorption and transport of soil nutrients by plants consistent with the previous result [21,40]. Soil acidification led to a loss of soil Mg and reduced effectiveness, consequently reducing the contents of Mg and Zn in the leaves [41,42]. Liming application and limiting acidifying fertilizer [43] are regarded as suitable ways to improve soil pH. The content of TSS in fruits was decreased with the increasing contents of avail-K and avail-P in the soil. It was reported that reducing doses of N, P, and K fertilization significantly improved the quality of *Guanxi* pomelo in Pinghe County [24]. The avail-Mg, avail-Zn, and avail-B in the soil of the HF orchard soils were not significantly different from those of SF, CF, and IF, but the highest contents of Mg, Zn, and B were found in the leaves, probably due to the higher content of OM of HF soils, which facilitated the uptake and utilization of nutrients by the trees. Soil is a complex environment, and the content of the OM is closely related to the physical and chemical properties of soil. The humus resolved from OM contained humic acid, which can promote nutrient absorption by plants [44]. The availability of soil nutrients can directly affect the quality of fruits [45] and the nutrient status in leaves [46]. There was a relation between the content of OM and the quality of fruits: The higher OM, the better the fruit quality. A high level of avail-Cu and avail-Zn in the soil is antagonistic, which can lead to Zn deficiency in leaves [47]. Therefore, it is the key point to reduce the dosage of chemical fertilization and increase the supplement of organic and trace element fertilization.

## 5. Conclusions

In conclusion, through grading the quality of *Guanxi* pomelo (*Citrus grandis*), the difference in appearance due to HF and IF fruits helped consumers easily identify them. Excessive N, K, Cu, and Mn harmed fruit quality, whereas an appropriate increase in Mg, B, and Zn showed a positive effect. It was speculated that the acidification of soil and deficiency of OM in Pinghe County resulted in imbalanced nutrients in the soil and leaves, which, in turn, led to the difference in fruit quality. Therefore, a targeted reduction in the application of N, P, and K fertilizers and pesticides is needed, with emphasis on micronutrient and organic fertilizers. In the long term, this reduction can alleviate soil acidification, maintain the balance of soil and leaf nutrients, improve fruit quality, increase farmers' income, and promote economic development.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture12101711/s1, Figure S1: Number and location of sampled Guanxi pomelo orchards in Pinghe County, Fujian Province, China; Figure S2: Cluster analysis of fruit quality in 281 orchards. HF (47 samples): high-quality fruit, SF (97 samples): sub-quality fruit, CF (106 samples): Common fruit, and IF (31 samples): inferior fruit; Figure S3: Correlation analysis of leaf nutrients and fruit quality ($n$ = 281). *: $p < 0.05$, ** $p < 0.01$, ***: $p < 0.001$. FW: Single fruit weight; SI: Fruit shape index; ER: Edible rate; TA: Titratable acidity; TSS: Total soluble solids; TSA: Total soluble solids/Titratable acidity; VC: Vitamin C. N: nitrogen, P: phosphorus, K: potassium, Ca: calcium, Mg: magnesium, Fe: iron, Mn: manganese, Zn: zinc, B: boron; Table S1: Details the sampling locations in Pinghe County, Fujian Province.

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