Analysis of main agronomic traits in different varieties of carrots

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Abstract. In this study, twelve varieties of carrots were evaluated for their main agronomic traits. Main agronomic traits were significantly different among distinct varieties. In detail, weight of single root ranged from 75.29 g to 278.56 g, diameter of single root ranged from 2.34 cm to 5.50 cm, and length of single root ranged from 14.85 cm to 24.10 cm. Moreover, according to carrot color, twelve varieties of carrots could be divided into five groups: purple (Tianzi), purple with orange core (Zishengzi, Hongzishen, and Yanzi), purple with yellow core (Zs-h, Zs-z, Cs-z, Caohaihong, and Zhongzidan), orange (Chengzishen), and yellow (Huangzishen and Zishenghuang). The color values (L*, a*, b*) of each variety were also investigated. And all carrots were conical shape. This information could be a theoretical basis for the research and extension of carrots.

1. Introduction
Carrots (Daucus carota var. sativus), belongs to umbelliferae, are an annual or biennial herb [1]. Carrots with rich nutrition and contain a large amount of carotene, sugar, vitamins, and so on. So it is an excellent natural health food with a variety of health functions [2]. Carrots are one of the most economically important crops grown throughout the world [3]. Carrots are not strict in their choice of climate and can be cultivated everywhere, while they like coldness and plenty of sunlight [4].

Cultivated carrots originated in the Afghanistan region and were yellow and purple. From this center of domestication carrots were grown as a root crop to the East and West. The Eastern carrot spread to central and north Asia and then to Japan. Red colored carrot is typical for India and also was introduced to Japan. In contrast, Western carrot type is characterized initially by yellow and later by orange root color [5]. Furthermore, lots of previous research found that carrot is rich in health-promoting phytochemicals and antioxidant capacity [6-8].

This experiment compared and analyzed the main agronomic traits of 12 varieties of carrots in order to comprehensively evaluate the main agronomic traits of carrots, and provides a theoretical basis for the research and extension of carrots.

2. Materials and methods

2.1. Plant materials
Twelve varieties of carrots (Tianzi, Zishengzi, Hongzishen, Yanzi, Zs-h, Zs-z, Cs-z, Caohaihong, Zhongzidan, Chengzishen, Huangzishen, and Zishenghuang) were planted in the vegetable base of
Bijie Institute of Agriculture Science of Bijie City, Guizhou Province, China. The robust plants were selected as experimental materials at harvest stage.

2.2. Test methods

2.2.1. Weight. Ten plants of each carrot variety were randomly selected, and the fresh weight of single fleshy root was measured with an analytical balance.

2.2.2. Diameter. Ten plants of each carrot variety were randomly selected, and the diameter of single fleshy root was measured with a vernier caliper.

2.2.3. Length. Ten plants of each carrot variety were randomly selected, and the length of single fleshy root was measured with a ruler.

2.2.4. Color. Color of the peel, cross section, and longitudinal section of each variety of carrot were measured using an NR110 chromameter (3nh, Shenzhen, China). The color of each variety of four carrot was recorded as L* (lightness), a* (red to green), and b* (yellow to blue). The chromameter was calibrated via the standard white plate according to the manufacturer’s instructions.

2.3. Data analysis
Microsoft Excel 2016 was adopted for data processing. Differential significance analysis was performed using DPS7.5 software. The results were subjected to one-way analysis of variance and differences between means were located using LSD test.

3. Results

3.1. Appearance
According to carrots color, 12 varieties of carrots were divided into five groups: purple (Tianzi), purple with orange core (Zishengzi, Hongzishen, and Yanzi), purple with yellow core (Zs-h, Zs-z, Cs-z, Caohaihong, and Zhongzidan), orange (Chengzishen), and yellow (Huangzishen and Zishenghuang). All carrots were conical shape, the shapes of Hongzishen, Zhongzidan, Chengzishen, and Huangzishen were larger than those of other varieties. While the shapes of Tianzi, Zishengzi, and Zs-h were thinner than those of other varieties. From epidermal smoothness of fleshy roots of view, the surface of Zhongzidan was rough with obvious wrinkles, however other varieties were relatively smooth (Figure 1).
3.2. Weight, diameter, and length

The weight, diameter, and length of each variety of single carrot root were shown in Table 2. For all varieties of carrot, the fresh weight of Chengzishen (278.56 g) was the largest, followed by Zhongzidan (273.12 g), Huangzishen (239.72 g), Hongzishen (221.02 g), Zishenghuang (214.66 g), and Yanzi (75.29 g). The fresh weight of Zs-h (75.29 g) was the least. There are no significant differences of fresh weight in Chengzishen, Zhongzidan, Huangzishen, Hongzishen, Zishenghuang, and Yanzi. In addition, there are also no significant differences in Caohaihong, Tianzi, Cs-z, Zs-z, Zishengzi, and Zs-h. Regarding the diameter of carrots, the diameter of Zhongzidan (5.50 cm) was the largest, followed by Hongzishen (4.56 cm), Chengzishen (4.53 cm), Huangzishen (4.30 cm), and Yanzi (3.95 cm). The diameter of Zs-h (2.34 cm) was the least. There are significant differences of diameter between Zhongzidan and other varieties, and the diameter of Hongzishen, Chengzishen, Huangzishen, and Yanzi were significantly different from other varieties, however, there are no significant differences of diameter between other varieties. The root lengths of different carrot varieties were analyzed and compared. The length of 12 varieties of carrots ranged from 14.85 cm to 24.10 cm. The length of Zishenghuang was the largest, followed by Caohaihong and Huangzishen. The length of Zhongzidan was the least. The length of Zishenghuang was significantly different from Zishengzi, Chengzishen, Hongzishen, Yanzi, and Zhongzidan, but was not significantly different from other varieties.
Table 1. Weight, diameter, and length of single carrot roots

| Varieties    | Weight (g) | Diameter (cm) | Length (cm) |
|--------------|------------|---------------|-------------|
| Tianzi       | 128.04±15.32 c | 2.95±0.68 d   | 20.63±1.78 a-c |
| Zishengzi    | 97.43±10.24 c  | 2.38±0.21 d   | 20.45±1.68 b-d |
| Hongzishen   | 221.02±38.29 a | 4.56±0.07 bc  | 19.40±2.66 b-d |
| Yanzi        | 211.84±84.91 ab | 3.94±0.24 bc  | 17.80±1.44 cd |
| Zs-h         | 75.29±13.84 c  | 2.34±0.12 d   | 21.53±1.99 a-c |
| Zs-z         | 101.95±35.70 c | 2.50±0.37 d   | 20.60±1.91 a-c |
| Cs-z         | 115.13±26.46 c | 2.62±0.18 d   | 21.00±4.05 a-c |
| Caohaihong   | 136.40±6.62 bc | 2.89±0.21 d   | 23.28±1.02 ab |
| Zhongzidan   | 273.13±24.27 a | 5.50±0.70 a   | 14.85±0.49 d  |
| Chengzishen  | 278.56±44.10 a | 4.53±0.40 bc  | 19.97±1.65 bc |
| Huangzishen  | 239.72±34.51 a | 4.30±0.68 bc  | 22.27±1.90 ab |
| Zishenghuang | 214.66±104.10 a| 3.71±0.78 c   | 24.10±2.46 a  |

3.3. Color

The color of 12 varieties of carrots was measured using an NR110 chromameter in this study (Table 2). It was found that the $L^*$ values of the cross section, and longitudinal section of most carrot varieties were larger than that of the peel. In addition, the $L^*$ values of Zishenghuang and Huangzishen were larger than that of most carrot varieties, and the $L^*$ values of Tianzi was the least. Regarding the $a^*$ values of carrots, the $a^*$ values of the peel was significantly different from the cross section and longitudinal section, however there are no significant differences of $a^*$ values between the cross section and longitudinal section. The $a^*$ values of Chengzishen was the largest. Similarly, the $b^*$ values of the peel of most varieties was significantly different from the cross section and longitudinal section, however, there are no significant differences of $b^*$ values between the cross section and longitudinal section. Moreover, the $b^*$ values of Zishenghuang, Huangzishen, and Chengzishen were larger than those of most carrot varieties.

Table 2. The values of $L^*$, $a^*$, and $b^*$ of the peel, cross section, and longitudinal section of each variety of carrot

| Varieties     | Peel     | Cross section | Longitudinal section |
|---------------|----------|---------------|----------------------|
|               | $L^*$    | $a^*$         | $b^*$                |
|               |          |               |                      |
| Tianzi        | 33.50 d  | 22.37 d       | 26.77 f              |
| Zishengzi     | 35.47    | 52.69 c       | 44.95 e              |
| Hongzishen    | 36.37 cd | 53.07 c       | 61.60 b-d            |
| Yanzi         | 36.84 cd | 53.50 c       | 59.86 ab             |
| Zs-h          | 31.17 d  | 59.11 bc      | 65.91 a-d            |
| Zs-z          | 31.30 d  | 52.22 bc      | 56.75 d              |
| Cs-z          | 35.34 cd | 58.97 bc      | 61.26 bd             |
| Caohaihong    | 36.14 cd | 57.26 bc      | 58.38 cd             |
| Zhongzidan    | 40.58 c  | 58.80 bc      | 70.58 cd             |
| Chengzishen   | 49.10 b  | 53.83 c       | 56.89 d              |
| Huangzishen   | 52.89 ab | 61.76 bc      | 73.47 a              |
| Zishenghuang  | 56.75 a  | 71.04 a       | 67.74 a              |

3.3. Color

The color of 12 varieties of carrots was measured using an NR110 chromameter in this study (Table 2). It was found that the $L^*$ values of the cross section, and longitudinal section of most carrot varieties were larger than that of the peel. In addition, the $L^*$ values of Zishenghuang and Huangzishen were larger than that of most carrot varieties, and the $L^*$ values of Tianzi was the least. Regarding the $a^*$ values of carrots, the $a^*$ values of the peel was significantly different from the cross section and longitudinal section, however there are no significant differences of $a^*$ values between the cross section and longitudinal section. The $a^*$ values of Chengzishen was the largest. Similarly, the $b^*$ values of the peel of most varieties was significantly different from the cross section and longitudinal section, however, there are no significant differences of $b^*$ values between the cross section and longitudinal section. Moreover, the $b^*$ values of Zishenghuang, Huangzishen, and Chengzishen were larger than those of most carrot varieties.
4. Discussion

The present study assessed main agronomic traits in different varieties of carrots. Our results also indicated that there were significant discrepancies in weight, diameter, and length among different varieties of carrots. In detail, weight ranged from 75.29 g to 278.56 g, diameter ranged from 2.34 cm to 5.50 cm, and length ranged from 14.85 cm to 24.10 cm. Many studies have indicated that significant discrepancies exist among different varieties in terms of main agronomic traits. For example, Qi et al. found that there was distinct difference on the productive tillers, the developmental period, the plant height and the 1000-grains weight among the different varieties of wheat [9]. Vitanova et al. also found that the fruit mass of plum cultivars is very different [10]. The discrepancy of agronomic traits in carrots are due to the difference of variety.

In our study, twelve varieties of carrots according to color could be divided into five groups: purple (Tianzi), purple with orange core (Zishengzi, Hongzishen, and Yanzi), purple with yellow core (Zs-h, Zs-z, Cs-z, Caohaihong, and Zhongzidan), orange (Chengzishen), and yellow (Huangzishen and Zishenghuang). This result was consistent with the values of L*, a*, and b* of the carrots. The values of L*, a*, and b* of the peel, cross section, and longitudinal section of orange and yellow carrots were larger than that of most carrot varieties, while the values of L*, a*, and b* of the peel, cross section, and longitudinal section of purple carrots was less than that of most carrot varieties. All purple, purple with orange core, and purple with yellow core carrots had similar values of L* of the peel. The color of peel of purple with orange core and purple with yellow core carrot were different from that of core, so the values of L*, a*, and b* of the peel of orange core and purple with yellow core carrot were different from that of that of cross section, and longitudinal section. In previous research, besides common orange carrots, carrots with black, purple, white, etc. color were also mentioned [11-13].

In conclusion, there were significant discrepancies in the main agronomic traits (weight, diameter, length and color) in different varieties of carrots, and the discrepancy of agronomic traits in carrots were due to the difference of variety.

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References

[1] R. Baranski, A. Maksylewicz-Kaul, T. Nothnagel, P.F. Cavagnaro, P. W. Simon, D. Grzebelus, Genetic diversity of carrot (Daucus carota L.) cultivars revealed by analysis of SSR loci, Genetic Resources and Crop Evolution. 59 (2012) 163-170.
[2] S. Smoleń, W. Sady, The effect of various nitrogen fertilization and foliar nutrition regimes on the concentrations of sugars, carotenoids and phenolic compounds in carrot (Daucus carota L.), Scientia Horticulturae. 120 (2009) 0-324.
[3] P. Simona, V. Kestutis, R. Algirdas, Z. Renata, N. Vilma, The influence of ozone technology on reduction of carrot loss and environmental IMPACT, Journal of Cleaner Productio. 244 (2020) 118734.
[4] M. C. Shannon, C.M. Grieve, Tolerance of vegetable crops to salinity, Scientia Horticulturae. 78 (1998) 5-38.
[5] M. Leja, I. Kamińska, M. Kramer, A. Maksylewicz-Kaul, D. Kammerer, R. Carle, R. Baranski, The content of phenolic compounds and radical scavenging activity varies with carrot origin and root color, Plant Foods for Human Nutrition. 68 (2013) 163-170.
[6] L. Lemmens, I. Colle, G. Knockaert, S. Van-Buggenhout, A. Van-Loey, M. Hendrickx, Influence of pilot scale in pack pasteurization and sterilization treatments on nutritional and textural characteristics of carrot pieces, Food Research International. 50 (2013) 526-533.
[7] B. Pace, I. Capotorto, M. Cefola, P. Minasi, N. Montemurro, V. Carbone, Evaluation of quality,
phenolic and carotenoid composition of fresh-cut purple Polignano carrots stored in modified atmosphere, Journal of Food Composition and Analysis. 86(2020) 103363.

[8] M. Algarra, A. Fernandes, N. Mateus, V. De-Freitas, D. S. J. C. G. Esteves, J. Casado, Anthocyanin profile and antioxidant capacity of black carrots (daucus carota L. ssp. sativus var. atrorubens Alef.) from Cuevas Bajas, Spain, Journal of Food Composition and Analysis. 33 (2014) 71-76.

[9] Z. G. Qi, L. X. Yang, Q. Yang, Y. Z. Shen, The study on the agronomic traits of the wheat varieties resource, Acta Agriculturae Boreali—Sinica. (2004).

[10] I. Vitanova, S. Dimkova, D. Ivanova, N. Marinova, Evaluation of local bulgarian plum cultivars for agronomic traits and resistance to diseases, Journal of Fruit and Ornamental Plant Research. 2 (2004) 263-268.

[11] C. Alasalvar, J. M. Grigor, D. Zhang, P. C. Quantick, F. Shahidi, Comparison of volatiles, phenolics, sugars, antioxidant vitamins, and sensory quality of different colored carrot varieties, Journal of Agricultural and Food Chemistry. 49 (2001) 1410-1416.

[12] S. Akhtar, A. Rauf, M. Imran, M. Qamar, M. Riaz, M. S. Mubarak, Black carrot (Daucus carota L.), dietary and health promoting perspectives of its polyphenols: a review, Trends in Food Science & Technology. 66 (2017) 36–47.

[13] M. Cefola, B. Pace, M. Renna, P. Santamaria, A. Signore, F. Serio, Compositional analysis of yellow, orange and purple Polignano carrots, Italian Journal of Food Science. 24 (2012) 284–291.