Variation in the Performance of Fruit Maturing Time, Fruit Weight, and Soluble Solids Content in Oriental Persimmon Grown at Akitsu, Japan and Meixian, China

Masahiko Yamada¹*, Renzi Wang², Hiroyasu Yamane¹, Akihiko Sato¹ and Nobuyuki Hirakawa¹

¹Akitsu Branch, Fruit Tree Research Station, MAFF, Akitsu, Hiroshima 729-24
²Pomology Institute, Shaanxi Academy of Agricultural Sciences, Yanling, Shaanxi, China

Summary

Fruit maturing time (FMT), fruit weight (FW), and soluble solids content (SSC) in 15 identical persimmon (Diospyros kaki Thunb.) cultivars were evaluated at Akitsu, Hiroshima of Japan and Meixian, Shaanxi of China. The data were subjected to two-way analysis of variance, with the factors of location and cultivar. This model of analysis-of variance was applicable because the residue estimates approached a normal distribution as determined by the Kolmogorov-Smirnov one-sample test. FMT and FW were greatly and significantly affected by location and cultivar (P < 0.01), whereas SSC was not for location (P > 0.05). Coefficients of correlation between the two locations were 0.79**, 0.89**, and 0.52* for FMT, FW, and SSC, respectively. The cultivars evaluated at Akitsu, on the average, matured 18 days later and weighed 70g more than did those at Meixian. The mean values for SSC differed little between the two sites. These results indicated that cultivar performance in one location could be estimated from that in another location by incorporating the correction constant for the mean differences in FMT and FW between locations.

Introduction

The oriental persimmon (Diospyros kaki Thunb.) originated in eastern Asia, and has been mainly grown in China, Japan, and Korea, where many indigenous cultivars have been developed and grown. There seem to be wide variations in cultivars, both in China which has the longest history of persimmon cultivation, and Japan where pollination-variant, non-astringent (PVNA) and pollination-constant, non-astringent (PCNA) cultivars were developed. Many cultivars of Japanese and Chinese origin have been kept and evaluated at the Akitsu Branch of the Fruit Tree Research Station, Japan, and at the Shaanxi Academy of Agricultural Sciences, China, respectively. If the information on the characteristics of the cultivars originating in each of these countries could be compiled, the considerable variations that exist in the world could be described.

Commercially important characters such as fruit maturing time (FMT), fruit weight (FW), and soluble solids content (SSC), however, are quantitative and subject to environmental fluctuations. Because the climate and cultural techniques used are different for the two countries, a direct comparison of the data can not be made. However, if identical cultivars can be grown and evaluated at the two locations by using the same method to evaluate native cultivars of each country, the influence of the location and cultural methods can be determined.

The purpose of this study was to analyze the influences of climate and cultural practices at the two sites and find an effective means of tying together data of genetic resources in Japan and China.
Materials and Methods

One non-astringent and twelve astringent cultivars of Chinese origin, and two non-astringent cultivars of Japanese origin (Table 1) were evaluated at Akitsu Branch, Fruit Tree Research Station, Hiroshima, Japan and at the Farm of the Pomology Institute, Shaanxi Academy of Agricultural Sciences, Meixian, Shaanxi, China. These cultivars representing the range of Chinese cultivars varied widely in FMT, FW and SSC.

Cultivars of Chinese origin were top-grafted to mature trees at Akitsu in 1989 and the crop evaluated for FMT, FW and SSC in 1992. Bearing trees of two Japanese cultivars were evaluated in 1988 or 1990.

Trees at Akitsu were dormant-pruned; they were blossom-thinned before anthesis and fruit-thinned in late July to adjust the leaf/flower-bud and leaf/fruit ratio of about 10:1 and 20:1, respectively. Astringent cultivars were harvested a few times during the maturation period, packed the next day into 0.04mm polyethylene bags containing 35% ethanol, and kept at 18°C for a week to remove the astringency.

The optimum FMT was judged to be the time when the largest number of fruit with the best eating quality was harvested. FMT was rated on a scale of 1 to 8. A rating of 1 corresponds to late September, 2 to early October, 3 to mid-October, 4 to late October, 5 to early November, 6 to mid-November, 7 to late November and 8 to early December.

The FW was recorded from about 15 fruit and the data transformed logarithmically because mean and SD were correlated (Yamada et al., 1993). At Akitsu, SSC was determined with a calibrated refractometer on about 15 fruit harvested at appropriate FMT after a week’s storage to remove the astringency on astringent cultivars and at harvest on the non-astringent types. The juice samples were obtained from the equatorial portion of fruit according to Yamada et al. (1994c). Each cultivar was evaluated once with an annual repetition and the data adjusted for yearly fluctuation according to Yamada et al. (1994c) because FW and SSC normally fluctuate (Yamada et al., 1994a).

At Meixian, individual bearing trees were evaluated. They were pruned in winter, but flower-buds and fruit were not thinned. FMT was determined as the fruit became fully colored and the seed coat darkened. The mean FW was recorded on 20 fruit. On astringent cultivars, fruit were harvested at the appropriate FMT. After they became soft and no longer astringent, their SSC were determined refractometrically. On non-astringent cultivars, SSC was determined immediately after harvest.

The data for each trait were subjected to the two-way analysis of variance factoring in the location and cultivar. The monthly mean temperature and precipitation at Akitsu and Meixian were recorded (Fig. 1). The mean leafing time and flowering time for the 12 astringent cultivars were 9 April and 19 May at Meixian, and 11 April and 29 May at Akitsu.

Results and Discussion

The analysis of variance, the Kolmogorov-Smirnov one-sample test (Campbell, 1974) indicated that the residue estimates approximated a normal distribution at $P=0.05$, showing that the additive model in the analysis of variance could be assumed. It is, therefore, appropriate to correct additively the effect of location by adding the estimated difference between the two locations to the performance at one location. The effectiveness of the correction depends on the confidence of the estimated difference.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Origin</th>
<th>Astringency4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boaihuishi</td>
<td>Henan, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Chutoushi</td>
<td>Hubei, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Fongshi</td>
<td>Shaanxi, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Heixinshi</td>
<td>Shaanxi, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Houguan</td>
<td>Shaanxi, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Houjing</td>
<td>Shaanxi, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Jinshi</td>
<td>Shaanxi, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Lianghuashi</td>
<td>Shaanxi, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Meixianhuixinshi</td>
<td>Shaanxi, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Mopanshi</td>
<td>Beijing, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Raotianhong</td>
<td>Henan, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Zhaijiahong</td>
<td>Henan, China</td>
<td>PCA</td>
</tr>
<tr>
<td>Luotianianshi</td>
<td>Hubei, China</td>
<td>PCNA</td>
</tr>
<tr>
<td>Matsumotowasefuryu</td>
<td>Kyoto, Japan</td>
<td>PCNA</td>
</tr>
<tr>
<td>Zenjimaru</td>
<td>Kanagawa, Japan</td>
<td>PVNA</td>
</tr>
</tbody>
</table>

4 PCA : Pollination constant and astringent type.
PCNA : Pollination constant and non-astringent type.
PVNA : Pollination variant and non-astringent type.
There were very large and significant ($P < 0.01$) effects of location and cultivar for both FW and FMT (Table 2), whereas for SSC, the effect of cultivar was significant ($P < 0.05$) but not for location.

For FW, the variance between locations accounted for 23% of the total variance (Table 3). The error variance was 13% of the variance among cultivars, suggesting that the cultivar × location interaction was small. The high ratio of $\sigma_g^2$ to $\sigma_g^2 + \sigma^2$ indicates a high heritability for FW after an adjustment of the difference between locations. The coefficient of correlation ($r$) between the two locations was 0.89** (Fig. 2). Thus, the performance at one site can be effectively predicted from that at the other site.

The mean log FW of 15 cultivars were 2.344 (221g) and 2.182 (152g) at Akitsu and Meixian, respectively. Statistically, trees at Akitsu were expected to bear larger fruit than those at Meixian by 0.162 (about 70g on average) with the standard error of ±0.025 (Snedecor and Cochran, 1972).

For FW, the larger the mean, the larger the standard error in gram unit, and the larger the expected difference between locations. For example, fruit of a cultivar weighing 300g at Meixian was expected to weigh 436g at Akitsu, whereas fruit weighing 70g at Meixian was expected to weigh 102g at Akitsu. The difference is 136g in the former but only 32g in the latter.

The factors causing FW to be larger at Akitsu than at Meixian may be the flower-bud and fruit thinning, and greater rainfall at Akitsu (Fig. 1). It is well known that flower-bud and fruit thinning increase FW. The rainfall in the growing season from April to October was 534mm at Meixian which is about half that at Akitsu. Furthermore, the trees were irrigated three times during the summer dry spell at Akitsu. These factors may have influenced the difference in FW.

A very large variance in FMT was found between locations, accounting for 62% of the total variance (Table 2); thus, it is useful to correct the difference in FMT between two locations. The mean FMT were 5.33 and 3.57 for Akitsu and Meixian
Meixian, respectively, a difference of 1.76 ± 0.19 or approximately 18 days. The $r$ value for FMT between locations was 0.79** (Fig. 2). The ratio of $\sigma_x^2$ to $\sigma_y^2 + \sigma^2$ was fairly high (0.71), but it was less than that for FW. Therefore, when an early maturing cultivar needs to be introduced to one location on the basis of its performance at the other location, several cultivars showing early maturing should be introduced and reselection should be made.

The temperatures at Meixian with its continental climate rise in spring and fall in autumn more rapidly than do those at Akitsu (Fig. 1). Changes in the temperature are slower at Akitsu because of its proximity to the sea. The monthly mean temperature after August at Akitsu is the same as that recorded the previous month at Meixian. Zheng et al. (1989, 1990) showed that persimmon fruit entered the third stage of growth early and matured correspondingly early when the hot period in summer was short. Such early maturation at Meixian may be related to the rapid fall of temperature in autumn. Furthermore, the onset of leafing out and anthesis of the 12 astringent cultivars was two and ten days earlier, respectively, at Meixian than it was at Akitsu. This also may account for the early maturing at Meixian.

The mean SSC of 15 cultivars were 17.2% and 16.9% at Akitsu and Meixian, respectively. The effect of location was not significant at $P = 0.05$ (Table 2). The effect of cultivar was significant, but the $F$-value was not large. The $r$ value for SSC

![Fig. 2. Correlation of the performance at Akitsu, Japan and Meixian, China for fruit weight (A), fruit maturing time index (B) and soluble solids content (C) in 15 identical persimmon cultivars. For fruit maturing time index, a rating of 1 corresponding to late September, 2 to early October, 3 to mid-October, 4 to late October, 5 to early November, 6 to mid-November, 7 to late November and 8 to early December.](image-url)
between the two locations was 0.52* (Fig. 2).

A large error variance (Table 3) indicates that the SSC, based on our data, cannot be accurately predicted from one site to the other. Therefore, when cultivars with a high sugar content are desired for introduction at a distant site, many cultivars with a high SSC should be introduced for selection, because, unlike FW and FMT, there is a lower probability that a cultivar with a high SSC in one country will perform equally well in another. However, a comparison of the mean from a large population derived in one country can be made because the error and interaction can be assumed to be randomly distributed.

SSC generally has a small heritability, and it fluctuates more readily than FW and FMT (Yamada et al., 1993, 1994a). If heritability improves by taking more replications and more yearly repetitions in measurements, the error variance may be reduced.

In conclusion, a linear correction for the difference between locations was useful for FW and FMT, but less so for SSC.

**Literature Cited**


安芸津（日本）と眉県（中国）におけるカキの果実成熟期、果実重
および可溶性固形物含量の変異

山田 昌彦1*・王 仁栄2・山根 弘康1・佐藤 明彦1・平川 信之1
1果樹試験場安芸津支場 729-24 広島県豊田郡安芸津町
2中華人民共和国陝西省楊陵 陝西省農業科学院果樹研究所

摘　要

日本国広島県豊田郡安芸津町と中華人民共和国陝西省眉県においてカキ（Diospyros kaki Thunb.）15品種
を栽培し、果実成熟期、果実重および可溶性固形物含量を調査した。その成績を場所と品種を要因とする2
元分類の分散分析に供したところ、差異推定値の分布
はKolmogorov-Smirnovの一試料検定において有意
(5%水準)ではなく正規分布に近似できたため分散分
析のモデルは適合すると考えられた。可溶性固形物含
量は場所の効果は有意でなかった（5%水準）が、果
実成熟期と果実重は場所と品種の効果が大きかった。場
所間の相関係数は果実成熟期で0.79**, 果実重で
0.89**, 可溶性固形物含量で0.52*であった。平均
すると安芸津では眉県におけるより果実成熟期が約
18±2日早く、果実重が70 g（対数変換値では0.162
±0.025）大きかった。しかし、可溶性固形物含量は
場所間の差が非常に小さかった。これらの結果から、
果実成熟期と果実重については、一方の場所における
成績に補正定数（ここで得られた2場所間の平均値の
差）を加えることにより、他方の場所における成績を
かなり有効に推定できると考えられた。

*現在：農林水産省国際農林水産業研究センター沖縄支
所 907 沖縄県石垣市真栄里川良原