ISSN 1479-2621
Plant Genetic Resources: Characterization and Utilization (2019) **17**(1); 87–90
doi:10.1017/S147926211800028X

Short Communication

Pericarp thickness of Korean maize landraces

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Received 10 May 2018; Accepted 17 August 2018 – First published online 18 September 2018

Abstract

Thin pericarp is one of crucial selection criteria for high-tender waxy corn hybrid development. A pericarp thickness of 2414 maize landrace accessions including 87 public waxy inbred lines was investigated to select accessions with thin pericarp and to broaden genetic diversity among waxy corn cultivars. Observed pericarp thickness of the 2414 accessions ranged from 16.0 ± 1.56 to 139.2 ± 39.55 µm with the average of 47.7 ± 13.15 µm. More than half of the accessions were below the suggested thickness of <50 µm for high-tender waxy corn hybrid development. Large sample size resulted in significant differences among endosperm types and among collection provinces. This, however, may not translate into considerable difference in tenderness since most averages of different types and collection provinces were <50 µm. Positive correlation ($r = 0.55$) between the average and standard deviation of pericarp thickness implied that more samples are needed to achieve same level of precision when it comes to selection for thick pericarp than that for thin pericarp. Top 10% thin-pericarped waxy landrace accessions were intercrossed to form a new waxy corn population from this result.

Keywords: breeding, corn, genetic diversity, variation, waxy

Introduction

Waxy corn (*Zea mays* L. var. *ceratina* Kulesh) is a type of specialty corns. Unlike USA where it is grown to produce corn starch with 100% amylopectin (Fergason, 2001), direct human consumption of boiled or steamed ears is the purpose of cultivation in Asia (Lertrat and Thongnarin, 2008). The market for fresh waxy corn in South Korea began to grow from the 1990s through the introduction of F_1 waxy corn hybrid Yeonnong1 (YN1) (Lee *et al*., 1992). The hybrid is known to have exceptionally thin pericarp contributing to its high palatability among other eating qualities. This thin-pericarped hybrid has become an important breeding material in waxy corn breeding programmes in South Korea. Consequently, two leading waxy corn hybrids Ilmichal (KW35 × KW51) and Mibaek2 (HW10 × HW7) have one of its parents developed directly from or a cross with YN1 (Jung *et al*., 2006; Park *et al*., 2007). A follow-up hybrid, YN2 (BH20 × BH30) shares one of its parents BH20 with YN1 (Choe and Rocheford, 2012). Parents of YN1 hybrid were bred from domestic waxy corn landraces (Lee *et al*., 1992). Extensive use of YN1 as a breeding material in majority of breeding programmes would potentially narrow the genetic diversity among waxy corn cultivars. In search of new genetic resources for waxy corn breeding programmes, we examined pericarp thickness of maize landraces collected across the country and stored in the National Agrobiodiversity Center (NAC) of South Korea.

Experimental

This study included a set of 2414 maize accessions. There were 87 public waxy corn inbreds included which were developed and deposited by the National Institute of Crop

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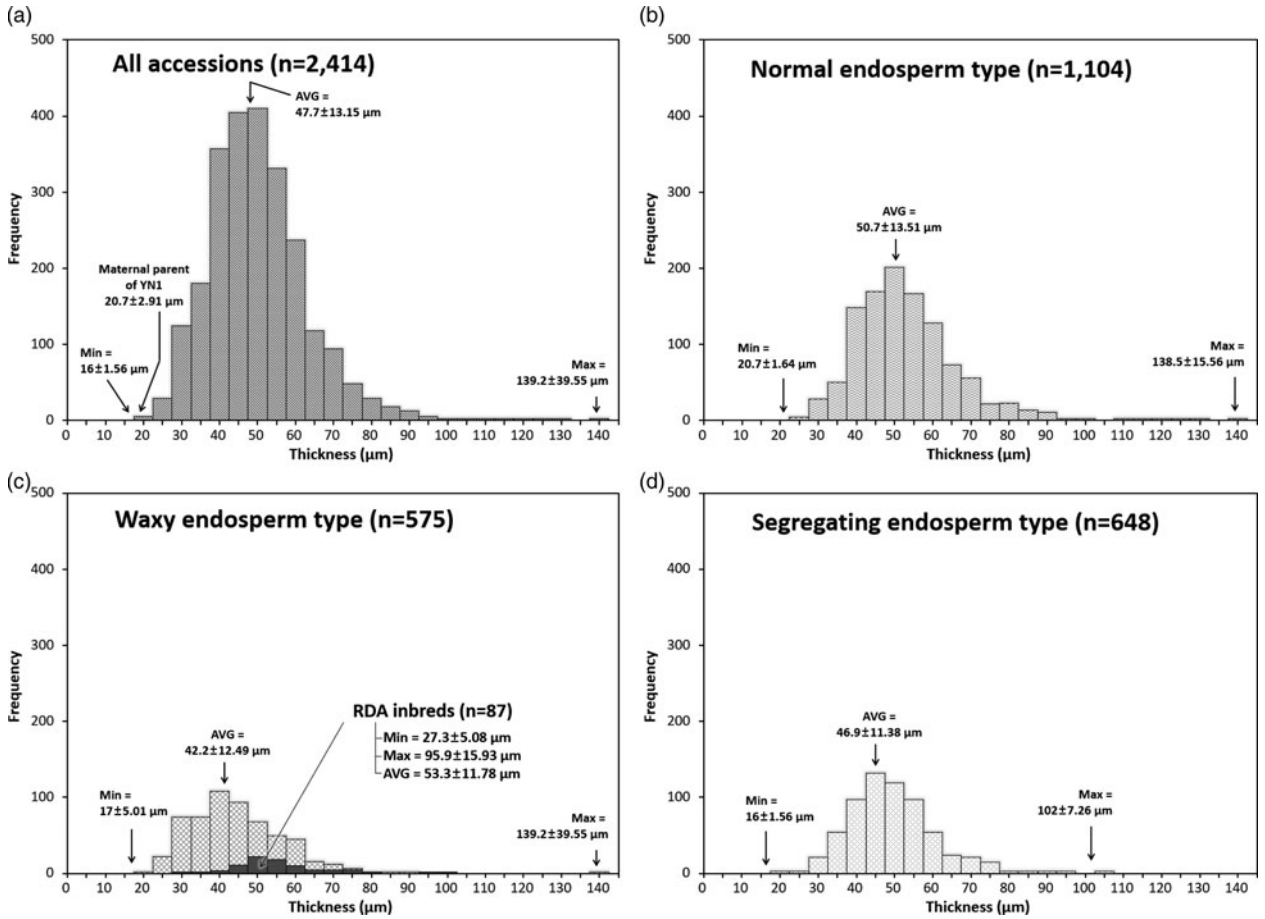

Fig. 1. Frequency distribution of pericarp thickness in 2414 maize accessions of South Korea. Average (AVG) was shown with standard deviation obtained from means of accessions used to make each frequency distribution. Accession with minimum (Min) and maximum (Max) pericarp thickness was indicated with 10 sample mean and standard deviation. The distribution of waxy endosperm type (c) did not include RDA waxy inbred lines. Instead, the distribution of RDA inbreds was overlapped to compare to that of waxy endosperm type from landrace accessions.

Science of Rural Development Administration (RDA) to the NAC. All the others were landraces collected across South Korea. The landraces with recorded collection site were chosen from a list of maize accessions in the NAC. The accessions were visually grouped into three endosperm types. When all 100 kernels provided had waxy or translucent endosperm, whether dent or flint, it was classified as waxy or normal type, respectively. Accessions with mixed endosperms were classified as segregating type. Also included was the F_1 waxy hybrid YN1 as a check. Since the pericarp is maternal tissue (Wang *et al.*, 2002), measured thickness of the hybrid represented the pericarp thickness of maternal parent of the hybrid.

Pericarp thickness was measured as described by Helm and Zuber (1972) with a modification. After soaking the seeds in distilled water for 24 h, the tip and crown was cut with a razor blade, a pericarp strip from abgerminal side was excised and dried at room temperature. A digital thickness gauge (MITUTOYO model no. ID-C112XBS, Japan) with 1 mm diameter contact point was used. Several readings were taken from the middle of an excised pericarp strip and averaged. Ten kernels were measured and averaged per accession.

Statistical analyses were performed using SAS ver. 9.2 (SAS Institute, Cary, NC). A two-way analysis of variance followed by mean separation via the Tukey–Kramer test was carried out for the differences among collection provinces and endosperm types. Pearson's correlation coefficient was also computed between the average and standard deviation.

Discussion

A total of 24,150 kernels from 2414 accessions and the check YN1 was examined. The overall mean of pericarp thickness was 47.7 µm and the standard deviation was 13.15 µm (Fig. 1). The frequency appeared to follow

https://doi.org/10.1017/S147926211800028X Published online by Cambridge University Press

Table 1. Average and standard deviation of pericarp thickness (μm) for maize landraces collected from different provinces of South Korea and their endosperm types

Province	Endosperm type			
	Normal	Segregating	Waxy	Across endosperm type**
ChungBuk	52.3 ± 17.87 (42)	48.4 ± 13.41 (45)	42.5 ± 14.20 (47)	47.5 ± 15.62^{bcd} (134)
ChungNam	48.1 ± 12.56 (80)	42.3 ± 10.00 (101)	40.1 ± 10.56 (151)	42.7 ± 11.34^{e} (332)
JunBuk	49.8 ± 15.67 (98)	45.1 ± 9.80 (53)	37.4 ± 10.73 (35)	46.1 ± 14.1^{cde} (186)
JunNam	48.5 ± 10.70 (263)	45.9 ± 10.59 (95)	40.9 ± 12.67 (22)	47.4 ± 10.95^{bcd} (380)
KyungBuk	53.1 ± 14.82 (190)	49.9 ± 12.49 (129)	41.2 ± 11.06 (62)	50.1 ± 14.11^{ab} (381)
KyungGi	50.7 ± 11.94 (50)	44.4 ± 11.54 (48)	40.8 ± 11.38 (58)	45.1 ± 12.25^{de} (156)
KyungNam	50.4 ± 13.61 (304)	47.8 ± 10.55 (112)	41.7 ± 17.06 (52)	48.8 ± 13.63^{abc} (468)
KangWon	55.8 ± 12.73 (77)	50.0 ± 10.55 (65)	46.6 ± 12.24 (148)	49.8 ± 12.59^{abc} (290)
RDA inbreds§			53.3 ± 11.78 (87)	53.3 ± 11.78^{a} (87)
Across Province*	50.7 ± 13.51^{a} (1104)	46.9 ± 11.38^{b} (648)	43.6 ± 12.94^{c} (662)	

Values in parenthesis indicate the number of accessions.
§RDA inbreds: public waxy corn inbred lines developed by the National Institute of Crop Science, Rural Development Administration, South Korea.
*, ** Means followed by the same letters are not significantly different at $\alpha = 0.05$ by Tukey–Kramer tests in 'Across Province' and 'Across Endosperm type', separately.

normal distribution with the minimum and maximum pericarp thickness of 16.0 ± 1.56 and 139.2 ± 39.55 μm, respectively. It, however, was skewed rightly meaning the tail was stretched to thick side. Since YN1 is a commercial hybrid, seeds of maternal and paternal parent of the hybrids were not available. Instead, pericarp measurement of the maternal parent was taken from F_1 seeds and was 20.7 ± 2.91 μm. Although we failed to find supporting evidences from the literature that there is no difference in pericarp thickness between homozygous maternal and heterozygous F_1 seeds, we generally observed that pericarp thickness of the two is not different.

Analyses of variance indicated that there were significant differences among endosperm types ($P < 0.0001$) and collection province ($P < 0.0001$) with no significant interaction between them ($P = 0.5541$) (online Supplementary Table S1). The average and standard deviation for waxy ($n = 662$), normal ($n = 1104$) and segregating ($n = 648$) types was 43.6 ± 12.94, 50.7 ± 13.51 and 46.9 ± 11.38 μm, respectively (Table 1) and was significantly different from each other at $\alpha = 0.05$. The differences were perhaps due to large sample sizes and may not be considered as practical differences in palatability. Lee *et al.* (1993) suggested that the pericarp thickness of waxy corn hybrids should be <50 μm to be acceptable for Korean fresh ear market. Since the overall mean was 47.7 μm, about half of the Korean landraces could be potentially used as genetic resources for high-tender waxy corn development. Although there were also significant differences among collection provinces, no geographical difference appears to be associated with such administrative district.

The 87 RDA inbreds had the thickest pericarp (53.3 ± 11.78 μm). Many of them were bred more than 20 years ago when agronomic traits for sustainable cultivation were more important than eating qualities. The parents of Ilmichal, KW35 and KW51 were still measured 40.9 ± 8.91 and 42.8 ± 4.29 μm, respectively.

Pearson's correlation showed that mean and standard deviation of pericarp thickness was positively correlated ($r = 0.55$, $P < 0.001$) (online Supplementary Fig. S1). This

https://doi.org/10.1017/S147926211800028X Published online by Cambridge University Press

may implement that we could sample less for thin-pericarped waxy corn selection and more for thick pericarp such as popcorn and field corn for mechanical harvest.

Accessions investigated in this study were not produced from a single environment, which poses a potential issue on the estimated thickness being confounded with environment effects such as year and location. Helm and Zuber (1972), however, reported that the narrow sense heritability for corn belt maize was very high ($h^2 = 80\%$). We conclude that selection for thin pericarp from such data could also be successful.

High palatability is a complex trait. Tenderness, sweetness, stickiness, texture and flavour of cooked corn ears all contribute to palatability in waxy corn. Tenderness is mostly represented by thin pericarp (Ito and Brewbaker, 1981). From the result, top 10% of the accessions in waxy endosperm type were selected and intercrossed to form a waxy corn population with thin pericarp.

Supplementary material

The supplementary material for this article can be found at https://doi.org/10.1017/S147926211800028X

Acknowledgements

This work was supported by the research grant of the Chungbuk National University in 2011. The author is thankful to National Agrobiodiversity Center (NAC) of South Korea for providing the maize accessions.

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