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Source: Canadian Journal of Plant Science, 102(2) : 488-495

Published By: Canadian Science Publishing

URL: https://doi.org/10.1139/CJPS-2021-0071

Canadian Science Publishing

CULTIVAR DESCRIPTION

# CO477, CO478, CO479, and CO480 inbred lines

A.Z. Kebede, L.M. Reid, C. Voloaca, R. De Schiffart, J. Wu, T. Woldemariam, K.K. Jindal, X. Zhu, and M.J. Morrison

**Abstract:** CO477, CO478, CO479, and CO480 are mid- to late-season [75–81 d to flowering, crop heat units (CHU) = 1720–1855] corn (*Zea mays* L.) inbred lines with high stalk sugar levels. The level of sugar in the stalks are very high especially when grown as inbred lines. On average, the inbred lines yield three times more sugar than their testcrosses. These inbred lines are the first to be developed and released for biofuel production, from the corn breeding program of Agriculture and Agri-Food Canada. Additionally, these inbred lines can be used for sugar and (or) silage production. They have moderate to intermediate resistance to common rust, eyespot, northern corn leaf blight and fusarium stalk rot but are susceptible to gibberella ear rot.

*Key words:* silage corn, *Zea mays* L., cultivar description, sugarcorn, biofuel production.

**Résumé :** CO477, CO478, CO479 et CO480 sont des lignées autogames de maïs (*Zea mays* L.) de mi-saison à tardives (75 à 81 jours avant la floraison, 1 720 à 1 855 UTM) à la tige très sucrée. La teneur en sucre de la tige est très élevée, surtout chez la lignée autogame. En moyenne, cette dernière synthétise trois fois plus de sucre que le croisement expérimental. Ces lignées sont les premières à avoir été développées et homologuées pour la production de biocarburant dans le cadre du programme d'hybridation d'Agriculture et Agroalimentaire Canada. On peut également s'en servir pour la production de sucre ou comme ensilage. Elles se caractérisent par une résistance modérée à intermédiaire à la rouille commune, à la kabatiellose, à l'helminthosporiose du Nord et à la pourriture de la tige causée par *Fusarium*, mais sont sensibles à la pourriture de l'épi causée par *Gibberella*. [Traduit par la Rédaction]

*Mots-clés :* maïs d'ensilage, *Zea mays* L., description de cultivar, maïs sucré, production de biocarburant.

## Introduction

The corn or maize (*Zea mays* L.) inbred lines CO477, CO478, CO479, and CO480 were developed at the Ottawa Research and Development Centre (ORDC), Agriculture and Agri-Food Canada (AAFC), Ottawa, ON. These lines are best suited for mid- to late-season growing regions of North America with up to 3000 crop heat units (CHU) (Brown and Bootsma 1993) and the primary intent of growing is biofuel, silage, and (or) sugar production.

Climate change and the rise of atmospheric carbon dioxide concentration stirred the need to reduce the use of non-renewable fossil fuel resources and substitute with crop-based renewable energy sources. Several crops, including oil palm, sugarcane and sweet sorghum, are recognized for ethanol production (Sims et al. 2006). Despite the lower efficiency (cost per liter of ethanol production), corn grain is dominant as a biofuel source in North America because sugarcane and other more efficient crop sources are restricted to growth within tropical and sub-tropical regions. Juice from corn stalks has been pilot tested and proven for biofuel production with promising ethanol yield comparable to sugarcane and sweet sorghum (Gomez-Flores et al. 2018).

Corn with high stalk sugar, commonly referred as sugarcorn (Reid et al. 2015) is a fast-growing biofuel energy crop suited for Canadian environments with readily fermentable sugars and a potential to save on energy and enzyme cost, as compared with corn grain-based biofuel production systems. High stalk sugar is a heritable trait in corn with mostly additive gene effects and acceptable selection gains have been achieved using pedigree breeding methods at AAFC (Reid et al. 2016). These four sugarcorn inbred lines are among the first to be developed from the ORDC, AAFC maize breeding program.

Received 19 March 2021. Accepted 26 August 2021.

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Can. J. Plant Sci. **102:** 488–495 (2022) dx.doi.org/10.1139/cjps-2021-0071

## Pedigree and Breeding Methods

CO477, CO478, CO479 and CO480 were developed from four crosses CO384 × C103, CO388 × C103, CO442 × C103 and CO444 × C103, respectively. The common parent in the four crosses, C103, was developed at the Connecticut Agricultural Experiment Station, New Haven, CT, USA (Singleton 1948) and it is a high stalk sugar containing inbred line belonging to the Lancaster heterotic group. CO384, CO388, CO442 and CO444 were developed and released by AAFC for their high grain yield and other desirable traits when in hybrid combinations (Reid et al. 2001, 2008). CO384 is an early European flint type inbred line. CO388 is a medium maturing stiff stalk (BSSS) type inbred line with intermediate resistance to gibberella ear rot caused by *Fusarium graminearum*. CO442 is an iodent type inbred line and CO444 is an early European flint type inbred line.

Initial crosses for the development of CO477, CO478, CO479 and CO480 were made in 2007. Successful ears from self-pollination in 2008 were advanced 10 more generations using a modified pedigree method with selection for high levels of sugar in the stalk juice as well as other desirable corn traits such as low stalk breakage, lodging resistant and overall good agronomic performance. Sugar in the stalk juice were measured following the protocol described by Reid et al. (2015). Briefly, the above ground biomass of corn plants were harvested 30 days after silking, which is 10–15 d earlier than a standard silage harvest time. Juice from the stalks was extracted in the field immediately after harvest using a custom diesel sugarcane crusher/juicer machine with 4 ton capacity. A digital brix refractometer (PR-32, Atago Co. Ltd, Bellevue, WA, USA) calibrated with known sucrose solutions from a composite juice sample obtained from 5 cm of stalk tissue was used to estimate the sucrose concentration as degree brix ($^\circ B_x$). One degree Brix is 1 g of sucrose in 100 g of solution.

Juice weight harvested per hectare was calculated as:

$$\text{juice weight}(\text{kg}\cdot\text{ha}^{-1}) = \text{fresh biomass weight} \\ \text{weight}(\text{kg}\cdot\text{ha}^{-1}) \times \text{ juice\%}$$

$$\text{juice \%} = \frac{\text{juice weight}}{\text{sample weight}} \times 100$$

Sugar harvested per hectare was calculated as:

$$\text{sugar}(\text{kg}\cdot\text{ha}^{-1}) = \text{juice weight}(\text{kg}\cdot\text{ha}^{-1}) \times {}^\circ B_x$$

Combining ability with testers of different heterotic patterns was conducted at the S4, S6 and S9 generations. At S8 and S9 generations, resistance screening for 6 different diseases namely, gibberella ear rot, common smut, fusarium stalk rot, Northern Corn Leaf Blight, Eyespot, and common rust were conducted. All experiments from the initial crossing to the final inbred line testcross performance evaluation for grain yield and high stalk sugar content/silage were done at the ORDC experimental field station in Ottawa, ON.

The data reported here were from sets of field experiments conducted using S10–S12 generations. Testcross performance evaluations of CO477, CO478, CO479 and CO480 for grain yield were conducted in 2017, 2018 and 2019 and for high stalk sugar content/silage in 2017 and 2019. Two sets of testcross performance evaluation experiments were conducted in 2017 and 2019. Set 1 was for evaluating grain yield and Set 2 was for evaluating high stalk sugar content/silage. Set 3, which was conducted only in 2017, was for evaluation of the inbred lines for high stalk sugar content/silage on per se basis. Testcross performance evaluation experiment for high stalk sugar content/silage was not conducted in 2018 due to limited testcross seed availability for that year.

For the high sugar content/silage testcross performance evaluation, five testers were used in 2017. One tester, CL30 was developed by AAFC and has a European flint type heterotic pattern. Four of the five testers were commercially sourced and belong to the stiff stalk B14 (MBS Genetics MBS1130GT, Thurston Genetics TR2040 RMQZ) and iodent (MBS8148, TR1995) heterotic groups. In 2019, the testers were MBS1130GT and TR2040 RR2 from the stiff stalk B14 type heterotic group while MBS8148 and TR1633 were from iodent. Most of the commercially available testers including the ones used in evaluating the combining ability of the current inbred lines aim to test grain yield performance. These testers were used in both grain yield and high stalk sugar content/silage experiments because there were no commercially available testers to evaluate the combining ability for high stalk sugar content. In addition, the aim of developing these inbred lines was to combine high grain yield with high stalk sugar content.

For Set 1 and 2, field trials were conducted with three replications in two-row plots of 8 m length, 0.16 m and 0.76 m within and between row spacing. Sample for estimating juice, sugar, and biomass of the stalks in Set 2 experiments were collected from plants growing within 1 m of the middle of each row. Set 3 was conducted with two replications and single-row plot of 3.7 m length, 0.16 m and 0.76 m within and between row spacing. In Set 3, juice, sugar, and biomass data were collected from 5 plants in the middle of each row. Check hybrids used in Set 1 and 2 varied based on their end use, grain yield or silage. In Set 1, check hybrids for grain yield namely Dekalb DKC38-03RIB, MAIZEX MZ 395x, Pioneer P9188AM and Pride A6015 were used. In Set 2, check hybrids known for silage production Pioneer P9644AMX, Pioneer P9789AMXT and Pride A5892G3 EDF RIB were used in 2017 and Brevant B96R17SX, Pioneer P0242AMXT and Pioneer P9789AMXT were used in 2019.

**Table 1.** Inbred line per se performance evaluations for stalk sugar content and biomass in 2017.

| | Stalk extract | | | Biomass | |
|---|---|---|---|---|---|
| Inbred line | Juice (kg·ha$^{-1}$) | Sugar (kg·ha$^{-1}$) | Brix (%) | Wet* (kg·ha$^{-1}$) | Dry (kg·ha$^{-1}$) |
| CO477 | 36773.7 | 3787.7 | 10.3 | 29684.7 | 10389.6 |
| CO478 | 29006.7 | 4119.0 | 14.2 | 28796.1 | 10078.6 |
| CO479 | 23808.8 | 3618.9 | 15.2 | 24934.9 | 8727.2 |
| CO480 | 19298.0 | 2547.3 | 13.2 | 21830.5 | 7640.7 |
| C103 | 14961.4 | 1930.0 | 12.9 | 35174.0 | 12310.9 |
| CO384 | 6273.3 | 545.8 | 8.7 | 21617.0 | 7565.9 |
| CO442 | 6273.3 | 796.7 | 12.7 | 19986.8 | 6995.4 |
| CO444 | 1294.5 | 152.8 | 11.8 | 10820.9 | 3787.3 |
| LSD (0.05) | 10662.13 | 1024.15 | 0.99 | 6629.70 | 2320.39 |

**Note:** *Wet biomass was measured at 65% moisture content.

**Table 2.** Testcross performance evaluations for stalk sugar content and biomass in 2017.

| | Stalk extract | | | Biomass | |
|---|---|---|---|---|---|
| Hybrid | Juice (kg·ha$^{-1}$) | Sugar (kg·ha$^{-1}$) | Brix (%) | Wet* (kg·ha$^{-1}$) | Dry (kg·ha$^{-1}$) |
| CO477 × CO478 | 11314.8 | 1000.0 | 8.9 | 23926.4 | 8374.2 |
| CO477 × CO479 | 11907.1 | 1069.1 | 9.0 | 32236.2 | 11282.7 |
| CO477 × CO480 | 8082.9 | 663.6 | 8.2 | 22115.8 | 7740.5 |
| CO478 × CO479 | 9992.2 | 868.3 | 8.6 | 29251.3 | 10238.0 |
| CO478 × CO480 | 6721.9 | 498.9 | 7.5 | 25182.7 | 8813.9 |
| CO479 × CO480 | 9474.4 | 836.8 | 8.8 | 29060.8 | 10171.3 |
| CO477 × CL30 | 7821.5 | 1116.7 | 14.1 | 27802.0 | 9730.7 |
| CO477 × MBS1130GT | 9622.8 | 849.4 | 8.8 | 23683.2 | 8289.1 |
| CO477 × MBS8148 | 12271.0 | 1186.1 | 9.6 | 26182.2 | 9163.8 |
| CO477 × TR1633 HXT | 9841.9 | 954.0 | 9.7 | 24908.5 | 8718.0 |
| CO477 × TR1995 | 10018.3 | 967.0 | 9.6 | 31803.5 | 11131.2 |
| CO477 × TR2040 RMQZ | 10820.5 | 1065.8 | 9.9 | 30778.7 | 10772.5 |
| CO478 × CL30 | 5759.0 | 701.1 | 12.1 | 25863.9 | 9052.4 |
| CO478 × MBS1130GT | 9034.4 | 727.5 | 8.2 | 26808.5 | 9383.0 |
| CO478 × MBS8148 | 8593.9 | 748.2 | 8.7 | 28895.9 | 10113.6 |
| CO478 × TR1633 HXT | 7433.0 | 659.3 | 8.8 | 24550.8 | 8592.8 |
| CO478 × TR1995 | 9434.5 | 941.3 | 10.0 | 31267.0 | 10943.4 |
| CO478×TR2040 RMQZ | 8770.4 | 1012.2 | 11.3 | 27939.9 | 9779.0 |
| CO479 × CL30 | 7948.1 | 914.4 | 11.6 | 28997.3 | 10149.1 |
| CO479 × MBS1130GT | 12878.8 | 1286.8 | 10.0 | 35480.8 | 12418.3 |
| CO479 × TR1633 HXT | 11925.2 | 1256.4 | 10.6 | 31195.0 | 10918.2 |
| CO479 × TR1995 | 5212.6 | 489.6 | 9.4 | 24953.5 | 8733.7 |
| CO479 × TR2040 RMQZ | 10038.3 | 1086.1 | 10.9 | 30837.5 | 10793.1 |
| CO480 × CL30 | 8215.9 | 821.2 | 9.9 | 27593.1 | 9657.6 |
| CO480 × MBS1130GT | 9276.4 | 796.8 | 8.2 | 24751.6 | 8663.1 |
| CO480 × MBS8148 | 7767.8 | 719.7 | 9.3 | 24651.6 | 8628.1 |
| CO480 × TR1633 HXT | 8227.4 | 746.1 | 9.1 | 34180.6 | 11963.2 |
| CO480 × TR2040 RMQZ | 8282.9 | 842.2 | 10.2 | 35099.7 | 12284.9 |
| Pioneer P9644AMX | 6999.4 | 701.3 | 10.1 | 27198.3 | 9519.4 |
| Pioneer P9789AMXT | 8611.3 | 841.1 | 9.9 | 31434.2 | 11002.0 |
| Pride A5892G3 EDF RIB | 13028.6 | 1107.6 | 8.6 | 31034.4 | 10862.0 |
| LSD (0.05) | 3159.5 | 332.0 | 1.3 | 6962.5 | 2436.9 |

**Note:** *Wet biomass was measured at 65% moisture content.

**Table 3.** Testcross performance evaluations for biomass and stalk sugar content in 2019.

| Germplasm | Stalk extract: Juice ($kg{\cdot}ha^{-1}$) | Stalk extract: Sugar ($kg{\cdot}ha^{-1}$) | Brix (%) | Biomass: Wet* ($kg{\cdot}ha^{-1}$) | Biomass: Dry ($kg{\cdot}ha^{-1}$) |
|---|---|---|---|---|---|
| CO477 × CO478 | 11837.3 | 880.6 | 7.5 | 31505.9 | 12369.3 |
| CO477 × CO479 | 10704.4 | 1076.7 | 10.0 | 27692.6 | 11367.1 |
| CO477 × CO480 | 10000.0 | 1036.6 | 10.3 | 37879.0 | 12365.5 |
| CO478 × CO479 | 10167.0 | 1029.2 | 10.1 | 36253.3 | 12517.9 |
| CO480 × CO478 | 8238.9 | 767.5 | 9.4 | 29799.3 | 10429.8 |
| CO479 × CO480 | 8489.5 | 963.8 | 11.3 | 33649.1 | 11777.2 |
| CO477 × MBS1130GT | 10856.9 | 991.9 | 9.1 | 33500.9 | 11725.3 |
| CO477 × MBS8148 | 8765.4 | 818.1 | 9.2 | 35100.2 | 12285.1 |
| CO477 × TR1633 | 7618.0 | 679.3 | 9.0 | 35160.2 | 12306.1 |
| CO478 × MBS1130GT | 5003.6 | 448.6 | 9.1 | 37903.7 | 13266.3 |
| CO478 × MBS8148 | 6862.7 | 640.9 | 9.8 | 36336.7 | 12717.9 |
| CO478 × TR1633 | 6485.1 | 659.8 | 10.1 | 32946.4 | 11531.2 |
| CO478 × TR2040 RR2 | 9360.9 | 813.3 | 8.7 | 38924.9 | 13623.7 |
| CO479 × MBS1130GT | 9259.3 | 960.1 | 10.3 | 33991.2 | 11896.9 |
| CO479 × TR2040 RR2 | 9862.0 | 1080.7 | 11.0 | 36680.5 | 12838.2 |
| CO480 × MBS1130GT | 7792.3 | 544.9 | 7.2 | 30344.8 | 11423.6 |
| CO480 × MBS8148 | 8620.2 | 704.1 | 8.2 | 36268.8 | 12693.9 |
| CO480 × TR1633 HXT | 5650.0 | 447.9 | 7.9 | 30517.7 | 11510.4 |
| CO480 × TR2040 RR2 | 7008.0 | 520.3 | 7.4 | 35017.5 | 13548.6 |
| Brevant B96R17SX | 9578.8 | 811.4 | 8.5 | 26520.8 | 10535.4 |
| Pioneer P0242AMXT | 10493.8 | 1015.9 | 9.8 | 39877.2 | 13957.0 |
| Pioneer P9789AMXT | 5787.9 | 564.2 | 9.8 | 36757.5 | 12964.3 |
| LSD (0.05) | 3809.4 | 357.5 | 1.7 | 6074.4 | 2415.4 |

**Note**: *Wet biomass was measured at 65% moisture content.

## Performance

When compared with the high-stalk-sugar parent C103, CO477 and CO478 had significantly higher ($P < 0.05$) stalk juice and sugar yield on a per se basis while CO479 had only significantly higher ($P < 0.05$) sugar yield (Table 1). In terms of biomass yield, the inbred lines CO479 and CO480 had significantly lower biomass than C103 but CO477 and CO478 were not significantly different. CO480 was an exception, having the lowest biomass, stalk juice and sugar yield of the four sugarcorn inbred lines and had a sugar yield that was not significantly greater than C103.

In sugarcorn hybrids, the amount of stalk juice harvested and the proportion of sugar in the juice are equally important factors determining the final sugar yield per unit area of production. Unlike sugarcorn, some silage corn cultivars are developed with traits that promote easy digestion and nutrient acquisition by ruminants. The brown mid-rib trait is responsible for the easy digestion (Cherney et al. 1991) and it is branded by some private corn breeding companies as effective digestion fiber (EDF). EDF branded hybrids have high moisture in the stalks and ears. One of the check hybrids used in the current study, Pride A5892G3 EDF RIB had substantially high juice (13028.6 $kg{\cdot}ha^{-1}$) and sugar yield (1107.6 $kg{\cdot}ha^{-1}$) than any of the other check hybrids tested although the degree brix (8.6%) is lower than most of the testcrosses of the sugarcorn inbred lines (Table 2). This can be a confounding factor affecting the total sugar yield per hectare given Pride A5892G3 EDF RIB is not the ideal sugarcorn hybrid.

The testcross performances of CO477, CO478, CO479 and CO480 in 2017 for stalk juice, sugar content and biomass yield are shown in Table 2. CO477 had the highest amount of sugar yield (1186.1 $kg{\cdot}ha^{-1}$) when crossed with the tester MBS8148 although the proportion of sugar in stalk juice or degrees brix was the highest (14.1%) when crossed with a different tester CL30. CO477 also combined well with CL30 and had the second highest amount of sugar yield (1116.7 $kg{\cdot}ha^{-1}$) despite the low juice yield. For biomass yield, CO477 combined the best with TR1995 (wet biomass = 31803.5 $kg{\cdot}ha^{-1}$, dry biomass = 11131.2 $kg{\cdot}ha^{-1}$) followed by TR2040 RMQZ (wet biomass = 30778.7 $kg{\cdot}ha^{-1}$, dry biomass = 10772.5 $kg{\cdot}ha^{-1}$). CO478 and CO479 combined the best with CL30 for degree brix, at 12.1% and 11.6%, respectively, but total juice harvested was lower than some of the other testers resulting in low sugar yield per hectare by comparison. CO478 had the highest juice (9434.5 kg·ha$^{-1}$), sugar (941.3 kg·ha$^{-1}$) and biomass yield (wet biomass = 31267.0 kg·ha$^{-1}$, dry biomass = 10943.4 kg·ha$^{-1}$) when crossed with TR1995. CO479 performed the best when crossed with MBS1130GT yielding 12878.8 kg·ha$^{-1}$ of juice, 1286.8 kg·ha$^{-1}$ of sugar and 35480.8 kg·ha$^{-1}$ of wet biomass and 12418.3 kg·ha$^{-1}$ of dry biomass. CO480 combined the best with TR2040 RMQZ for sugar yield (842.2 kg·ha$^{-1}$) and biomass (wet biomass = 35099.7 kg·ha$^{-1}$, dry biomass =12284.9 kg·ha$^{-1}$).

In 2019, CO477 had the highest stalk juice (10856.9 kg·ha$^{-1}$) and sugar yield (991.9 kg·ha$^{-1}$) when crossed with the tester MBS1130GT but still non-significantly ($P < 0.05$) different from testers MBS8148 and TR1633 (Table 3). CO478 combined best with tester TR2040 RR2 for stalk juice (9360.9 kg·ha$^{-1}$), sugar (813.3 kg·ha$^{-1}$) and biomass yield (wet biomass = 38924.9 kg·ha$^{-1}$, dry biomass = 13623.7 kg·ha$^{-1}$). CO479 performed equally well with testers MBS1130GT and TR2040 RR2 for stalk juice (9259.3–9862.0 kg·ha$^{-1}$), sugar (960.1–1080.7 kg·ha$^{-1}$) and biomass yield (wet biomass = 33991.2 – 36680.5 kg·ha$^{-1}$, dry biomass = 11896.9–12838.2 kg·ha$^{-1}$). CO480 had non-significant difference in juice, sugar and biomass yield irrespective of the tester used and ranged 5650.0–8620.2 kg·ha$^{-1}$ stalk juice, 447.9–704.1 kg·ha$^{-1}$ sugar, 30344.8–36268.8 kg·ha$^{-1}$ wet biomass and 11423.6–13548.6 kg·ha$^{-1}$ dry biomass.

The four inbred lines had comparable grain yield with two of the check hybrids Dekalb DKC38-03RIB and Pioneer P9188AM when crossed with at least one or two of the testers but had significantly ($P < 0.05$) lower grain yield than the hybrid check Pride A6015 (Table 4). When comparing combining ability of the inbred lines with the different heterotic group testers, CO477 had the highest grain yield when crossed with the iodent tester MBS8148 (6.93 t·ha$^{-1}$). CO478 had the highest grain yield when crossed with either the iodent tester TR1995 (7.04 t·ha$^{-1}$) or the stiff stalk B14 tester TR2040 RMQZ (7.03 t·ha$^{-1}$). CO479 and CO480 had the highest grain yield when crossed with the stiff stalk B14 testers MBS1130GT and TR2040 RMQZ (6.74–6.95 t·ha$^{-1}$).

The testcross grain yield performance of these inbred lines did not outperform the check hybrids indicating there is still room for grain yield improvement if the intention of use is for dual production of grain yield and stalk juice or sugar. On an inbred line per se basis, these four inbred lines on average appear to produce three times more sugar than their corresponding test-crosses. One reason for such a difference in stalk sugar levels could be that the hybrids are able to mobilize the photo-assimilates and store in the developing kernels more efficiently than the inbred lines. It is to be noted that the data for per se performance is from one year experiment in Ottawa, ON. It is suggestive but not conclusive. More data from multi location and year experiments will confirm the claim.

**Table 4.** Grain yield performance averaged over three years testing (2017–2019) in Ottawa, ON.

| Germplasm | Moisture (%) | Grain yield (t·ha$^{-1}$) |
|---|---|---|
| CO477 × CO478 | 27.7 | 3.44 |
| CO477 × CO479 | 33.0 | 3.85 |
| CO478 × CO479 | 39.7 | 4.15 |
| CO478 × CO480 | 35.2 | 4.04 |
| CO479 × CO480 | 36.5 | 4.11 |
| CO480 × CO477 | 38.9 | 3.98 |
| CO477 × CL30 | 25.7 | 5.68 |
| CO477 × MBS1130GT | 25.5 | 5.78 |
| CO477 × MBS8148 | 27.1 | 6.93 |
| CO477 × TR1633 HXT | 27.0 | 6.35 |
| CO477 × TR1995 | 26.4 | 6.10 |
| CO477 × TR2040 RMQZ | 26.9 | 6.24 |
| CO478 × CL30 | 26.2 | 6.14 |
| CO478 × MBS1130GT | 27.0 | 6.93 |
| CO478 × MBS8148 | 27.0 | 5.02 |
| CO478 × TR1633 HXT | 24.4 | 5.88 |
| CO478 × TR1995 | 27.1 | 7.04 |
| CO478 × TR2040 RMQZ | 27.2 | 7.03 |
| CO479 × CL30 | 26.9 | 6.24 |
| CO479 × MBS1130GT | 25.8 | 6.89 |
| CO479 × TR2040 RMQZ | 27.4 | 6.74 |
| CO480 × CL30 | 25.6 | 4.82 |
| CO480 × MBS1130GT | 26.3 | 6.95 |
| CO480 × MBS8148 | 27.0 | 5.84 |
| CO480 × TR1633 HXT | 26.0 | 6.11 |
| CO480 × TR2040 RMQZ | 27.1 | 6.95 |
| Dekalb DKC38-03RIB | 26.1 | 8.04 |
| MAIZEX MZ 395x | 27.2 | 8.30 |
| Pioneer P9188AM | 25.6 | 7.83 |
| Pride A6015 | 26.6 | 8.53 |
| LSD (0.05) | 1.74 | 1.36 |

## Other Characteristics

To determine the distinctness, uniformity, and stability of the newly released AAFC maize genotypes, 44 characteristics are reported of which 26 are used by the International Union for the Protection of New Varieties of Plants (UPOV) (Table 5). CO477 is 2.0 m in height with 14–16 semi-erect leaves. It takes 78–80 d for both 50% anthesis and silking (Table 5). It has a red cob with wedge shaped yellow flint kernels arranged in 16 rows. CO478 is 2.2 m in height and has 18 semi-erect leaves. It takes 79 d to 50% anthesis and 80 d to 50% silking. Cobs are red with 14–16 kernel rows and round yellow flint-like kernels. CO479 is similar in height to CO477 (2.0 m) and has 16–18 semi-erect leaves and flowers the latest from the rest i.e., 79 d to 50% anthesis and

**Table 5.** Characteristics of corn inbred lines CO477, CO478, CO479 and CO480; description and UPOV scores*.

| Characteristic | CO477 | CO478 | CO479 | CO480 |
|---|---|---|---|---|
| Emergence rate | Good | Very good | Excellent | Excellent |
| Early seedling vigour | Good | Excellent | Very good | Very good |
| Leaf characteristics | | | | |
| Leaf angle between blade and stalk* | Semi-erect (3) | Semi-erect (3) | Semi-erect (3) | Semi-erect (3) |
| Anthocyanin colour of leaf edge | Very weak | Absent | Very weak | Absent |
| Degree of surface hair on leaves | Medium | Medium | Weak | Medium |
| Degree of hair on leaf edge | Medium | Medium | Weak | Medium |
| Anthocyanin coloration of leaf sheath* | Medium (5) | Weak (3) | Medium (5) | Medium (5) |
| Width of leaf blade (at highest ear) (cm)* | 9–10 (7) | 8–9 (5) | 8–9 (5) | 9 (5) |
| Number of leaves | 14–16 | 18 | 16–18 | 16–18 |
| Tassel characteristics | | | | |
| Time of anthesis (days from planting to mid pollen shed)* | 78–80 (6) | 79 (6) | 79 (6) | 75 (5) |
| Degree of tassel extension | Very good | Very good | Very good | Good |
| Degree of pollen shed | Excellent | Excellent | Excellent | Excellent |
| Anthocyanin coloration at base of glumes (glume ring)* | Weak (3) | Weak (3) | Weak (3) | Absent or very weak (1) |
| Anthocyanin coloration of glumes excluding base (body of glume)* | Medium (5) | Weak (3) | Weak (3) | Weak (3) |
| Anthocyanin coloration of glume tip | Medium | Medium | Weak | Weak |
| Anthocyanin coloration of anthers* | Weak (3) | Absent or very weak (1) | Weak (3) | Weak (3) |
| Angle between main axis and lateral branches* | Medium (5) | Large (7) | Large (7) | Small (3) |
| Curvature of lateral branches* | Slightly recurved (3) | Slightly recurved (3) | Slightly recurved (3) | Absent or very slightly recurved (1) |
| Density of spikelets* | Moderate (7) | Medium (5) | Moderate (7) | Medium (5) |
| Length of main axis above lowest lateral branch (cm)* | 30 (5) | 34 (7) | 36 (9) | 28 (5) |
| Length of main axis above highest lateral branch (cm)* | 28 (9) | 24 (7) | 24 (7) | 22 (7) |
| Tendency to secondary branching | Present | Present | Present | Present |
| Ear characteristics | | | | |
| Time of silk emergence (days from planting to mid silk)* | 78–80 (5) | 80 (5) | 81 (6) | 78 (5) |
| Degree of silk emergence | Excellent | Very good | Excellent | Very good |
| Anthocyanin coloration of silks* | Absent or very weak (1) | Absent or very weak (1) | Absent or very weak (1) | Weak (3) |
| Peduncle (shank) length (cm)* | 10–12 (5) | 8–9.5 (5) | 8–9 (5) | 12–16 (7) |
| Husk cover from ear tip (cm) | 4–5 | 4–5 | 4–7 | 6–9 |
| Length of husked ear (cm)* | 14–15 (5) | 15–17 (5) | 12–14 (5) | 14–16 (5) |
| Diameter of husked ear (middle third of primary ear) (cm)* | 3.5 (3) | 3.5–4 (5) | 3.5–4 (5) | 3.5 (5) |
| Shape of husked ear* | Cylindrical (3) | Conical/Cylindrical (2) | Cylindrical (3) | Conical/Cylindrical (2) |
| Number of kernel rows (middle third of primary ear)* | 16 (6) | 14–16 (5) | 14–16 (5) | 12–14 (5) |
| Kernel type* | Flint (1) | Flint-like (2) | Flint-like (2) | Dent-like (3) |
| Kernel shape | Wedge | Round | Wedge | Wedge |

**Table 5.** (*concluded*).

| Characteristic | CO477 | CO478 | CO479 | CO480 |
|---|---|---|---|---|
| Kernel tip colour (top of grain)* | Yellowish-white (2) | Yellow (3) | Yellow (3) | Yellow (3) |
| Kernel colour (side opposite germ)* | Yellow-orange (4) | Yellow-orange (4) | Yellow-orange (4) | Yellow-orange (4) |
| Rachis diameter (middle of primary ear) (cm) | 2–2.5 | 2–2.5 | 2–2.5 | 2–2.5 |
| Anthocyanin coloration of glumes of cob* | Strong (7) | Weak (3) | Medium (5) | Strong (7) |
| Stalk characteristics | | | | |
| Anthocyanin coloration of brace roots* | Medium (5) | Medium (5) | Medium (5) | Strong (7) |
| Anthocyanin coloration of node at primary ear | Medium | Weak | Medium | Medium |
| Plant height (including tassel) (cm)* | 200 (5) | 220 (6) | 200 (5) | 170 (5) |
| Primary ear height (cm) | 65–70 | 75 | 65–70 | 60 |
| Ratio height of insertion of peduncle of primary ear to plant height* | Medium (5) | Medium (5) | Medium (5) | Medium (5) |
| Seed parent yield (g) | 72 | 125 | 79 | 85 |
| Parent (seed or male) | Both | Both | Both | Both |

**Note:** *Characteristic is also used by UPOV (International Union for the Protection of New Varieties of Plants) for determining the distinctness, uniformity and stability of maize genotypes (grain). Numbers in brackets refer to UPOV score.

81 d to 50% silking. It has red cob with 14–16 kernel rows and wedge-shaped yellow flint-like kernels. Of the four, CO480 is the shortest in height (1.7 m) and earliest to flower taking only 75 d to 50% anthesis and 78 d to 50% silking. The cobs are red and have 12–14 kernel rows. The inbred lines CO477, CO478, CO479 and CO480 can be used both as male and female parent when developing a hybrid. If used as female parent, seed yield would be 72, 125, 79 and 85 grams per ear, respectively. All inbred lines have moderate to intermediate resistance to common rust, eyespot, northern corn leaf blight and fusarium stalk rot but are susceptible to gibberella ear rot.

## Maintenance and Distribution of Pedigreed Seed Stock

Breeder line seeds of CO477, CO478, CO479 and CO480 are maintained by the Ottawa Research and Development Center, Agriculture and Agri-Food Canada, Ottawa, ON, Canada K1A 0C6. Company and university researchers who wish to receive seed will be required to enter into either a Corn Inbred Release Agreement or a Material Transfer Agreement with AAFC. Agreements can be requested from the Director, Agriculture and Agri-Food Canada, Ottawa Research and Development Centre, KW Neatby Building, 960 Carling Avenue, Ottawa, ON K1A 0C6, Canada. Further information on AAFC seed distribution and inbred lines can be obtained from the website http://www.agr.gc.ca/ScienceandInnovation.

## Acknowledgements

We thank MBS Genetics, L.L.C. and Thurston Genetics L.L.C. for providing the tester inbred line seed. We also thank AgReliant Genetics Inc., Brevant seeds, Maizex Seeds Inc., Pioneer Hi-Bred Limited, and Dekalb (Monsanto Canada Inc.) for providing check hybrid seed. Funding for this project was in part by an AAFC partnership with the Canadian Field Crop Research Alliance (CFCRA) through AAFC's Growing Forward 2 Program.

## References

Brown, D.M., and Bootsma A. 1993. Crop heat units for corn and other warm-season crops in Ontario. Ontario Ministry of Agriculture and Food Factsheet 93–119, Agdex 111/31. Ontario Ministry of Agric. and Food, Toronto, ON.

Cherney, J.H., Cherney, D.J.R., Akin, D.E., and Axtell, J.D. 1991. Potential of brown-midrib, low-lignin mutants for improving forage quality. Adv. Agron. **46**: 157–198.

Gomez-Flores, A., Thiruvengadathan, T.N., Nicol, R., Gilroyed, B., Morrison, M., Reid, L.M., and Margaritis, A. 2018. Bioethanol and biobutanol production from sugarcorn juice. Biomass Bioener. **108**: 455–463.

Reid, L.M., McDiarmid, G., Parker, A.J., Woldemariam, T., and Hamilton, R.I. 2001. CO388 and CO389 corn inbred lines. Can. J. Plant Sci. **81**: 457–459. doi:10.4141/P00-053.

Reid, L.M., McDiarmid, G., and Zhu, X. 2008. CO444 corn inbred line. Can. J. Plant Sci. **88**: 151–155. doi:10.4141/CJPS07027.

Reid, L.M., Morrison, M.J., Zhu, X., Jindal, K.K., and Ma, B.L. 2015. High stalk sugar corn: A potential biofuel crop for Canada. Agron. J. **107**: 475–485. doi:10.2134/agronj14.0271.

Reid, L.M., Zhu, X., Jindal, K.K., Kebede, A.Z., Wu, J., and Morrison, M.J. 2016. Increasing stalk sucrose in sugarcorn (*Zea mays* L.): genetic analysis and preliminary breeding. Euphytica, **209**: 449–460. doi:10.1007/s10681-016-1669-3.

Sims, R., Hastings, A., and Schlamadinger, B. 2006. Energy crops: current status and future prospects. Glob. Change Biol. **12**: 2054–2076. doi:10.1111/j.1365-2486.2006.01163.x.

Singleton, W.R. 1948. Sucrose in the stalks of maize inbreds. Science, **107**: 174. doi:10.1126/science.107.2772.174. PMID:17756610.