

AC Vulcan oriental condiment mustard

G. Rakow and D. Rode

Agriculture and Agri-Food Canada, Saskatoon Research Centre, 107 Science Place, Saskatoon, Saskatchewan, Canada S7N 0X2 (e-mail: rakowg@agr.gc.ca). Received 5 August 2008, accepted 21 November 2008.

Rakow, G. and Rode, D. 2009. AC Vulcan oriental condiment mustard. Can. J. Plant Sci. **89**: 325–329. AC Vulcan oriental condiment mustard [*Brassica juncea* (L.) Czern.] was developed from landraces of oriental mustard grown at Lethbridge, AB, in the 1960s. Lethbridge 22A registered in 1974 was the first true yellow breeding oriental mustard cultivar, followed by Domo in 1977, from which Cutlass was selected. AC Vulcan is a single plant selection from Cutlass. Data on the cultivar Forge (not a check cultivar) are provided for comparison because Forge was the predominant cultivar of oriental mustard in western Canada at the time when Cutlass and AC Vulcan were developed. Forge was developed by Mr. John Hemingway of Colman's Food, Norwich, UK. AC Vulcan yielded 3.0% less grain than the check cultivar Cutlass, on average, over 81 station years in 9 yr of condiment Co-op tests 1999–2007, and was well adapted to the mustard-growing areas of the Canadian prairies. AC Vulcan was one day later in maturity than Cutlass and one day earlier than Forge. It was similar in height to Cutlass. It had 0.5% lower fixed oil than Cutlass and 0.3% greater protein content. Forge had very low fixed oil content at 38.9%. AC Vulcan had increased seed weight (2.82 g per 1000 seed) compared with Cutlass (2.73 g per 1000 seed). Forge had low seed weight (2.49 g) per 1000 seed. AC Vulcan had 12.04 mg g seed⁻¹ of allyl glucosinolate; 0.96 mg g seed⁻¹ greater than Cutlass. Green seed counts varied from 0.65% for Forge to 0.84% for AC Vulcan, statistically not different from each other; this was reflected in seed chlorophyll contents. AC Vulcan and Cutlass were resistant to white rust [*Albugo candida* (Pers.) Kuntze] race 2a, but highly susceptible to race 2v. Forge was highly susceptible to both white rust races. All three oriental mustard cultivars were highly resistant to blackleg disease [*Leptosphaeria maculans* (Desm.) Ces. et de Not.]. Major goals in oriental mustard breeding are further reductions in fixed oil content and increases in grain yield.

Key words: *Brassica juncea* (L.) Czern., cultivar descriptions, grain yield, seed quality

Rakow, G. et Rode, D. 2009. La moutarde orientale AC Vulcan. Can. J. Plant Sci. **89**: 325–329. AC Vulcan est un cultivar de moutarde orientale [*Brassica juncea* (L.) Czern.] issu des races naturelles cultivées à Lethbridge (Alberta) dans les années 1960. Lethbridge 22A, homologué en 1974, était la première variété de moutarde jaune vraiment améliorée; l'a suivie la variété Domo, en 1977, de laquelle a été tiré Cutlass. AC Vulcan vient de la sélection d'un simple plant de Cutlass. Les données sur le cultivar Forge (pas un cultivar témoin) sont fournies à titre de comparaison, Forge étant la principale variété de moutarde jaune cultivée dans l'Ouest canadien lors du développement de Cutlass et d'AC Vulcan. Forge a été créé par M. John Hemingway de Colman's Food, à Norwich (R.-U.). En moyenne, AC Vulcan a produit 3,0 % moins de graines que le cultivar témoin Cutlass à plus de 81 sites-années lors des 9 années d'essais coopératifs sur la moutarde, de 1999 à 2007. La variété est bien adaptée aux zones de culture de la moutarde des Prairies canadiennes. AC Vulcan est plus tardif d'un jour que Cutlass et plus précoce d'un jour que Forge. Sa hauteur est semblable à celle de Cutlass. Ses graines renferment 0,5 % moins d'huile fixe que celles de Cutlass et 0,3 % plus de protéines. Forge se caractérisait par une très faible concentration d'huile fixe (38,9 %). Les graines d'AC Vulcan pèsent plus lourd (2,82 g par 1 000 graines) que celles de Cutlass (2,73 g par 1 000 graines). Celles de Forge étaient plus légères (2,49 g par 1 000 graines). Les semences d'AC Vulcan contiennent 12,04 mg d'allyl glucosinolate par gramme, soit 0,96 mg par gramme de semences de plus que Cutlass. La proportion de graines vertes varie de 0,65 % pour Forge à 0,84 % pour AC Vulcan, un écart statistiquement non significatif; la teneur en chlorophylle des graines le confirme. AC Vulcan et Cutlass résistent à la race 2a de la rouille blanche [*Albugo candida* (Pers.) Kuntze], mais sont très sensibles à la race 2v. Forge était très sensible aux deux races de rouille blanche. Les trois cultivars de moutarde orientale résistent très bien au charbon bactérien [*Leptosphaeria maculans* (Desm.) Ces. et de Not.]. Les principaux objectifs de l'amélioration génétique de la moutarde jaune sont une plus grande diminution de la teneur en huile fixe et une hausse du rendement grainier.

Mots clés: *Brassica juncea* (L.) Czern., description de cultivar, rendement grainier, qualité des semences

AC Vulcan oriental condiment mustard [*Brassica juncea* (L.) Czern.] which is described in detail in this publication, was developed at the Saskatoon Research Centre

(SRC), Agriculture and Agri-Food Canada (AAFC), Saskatoon, SK. It was tested for 3 years in Co-op mustard tests (1991–1993) and received registration

No. 3955 from the Variety Registration Office, Food Production and Inspection Branch, Agriculture Canada on 1994 May 19.

Pedigree and Breeding Methods

Oriental mustard breeding at Saskatoon (or in Canada) and the development of AC Vulcan, began in the early 1960s at Lethbridge, AB, where Mr. Sid Pawlowski developed the cultivar Lethbridge 22A, which had a pure yellow seed while all previous oriental landrace types contained approximately 10% brown seed. Lethbridge 22A was released in 1967 and was grown as a seed of commerce after that time. Lethbridge 22A was selected out of oriental and brown mustard landraces grown in western Canada and, in addition to being true breeding for yellow seed, selections were also made for higher grain yield and increased allyl glucosinolate content. Lethbridge 22A was registered on 1974 Aug. 21, registration no. 1561 (Agriculture Canada 1974).

Domo (line number 23–25) was developed from a single open-pollinated plant "within a broad based *B. juncea* population for yield and high allyl glucosinolate content" according to the plant breeder Mr. S.H. Pawlowski. In 3 yr of Co-op testing (1974 to 1976) it had significantly increased yield and higher allyl glucosinolate content, but had 1.0% higher fixed oil content than Lethbridge 22A. It was registered on 1977 Apr. 19 registration no. 1761 (Agriculture Canada 1977).

Cutlass (line number BJ 08–1418) resulted from a single plant selection from Domo for reduced levels of fixed oil, while maintaining or improving other attributes (Woods 1989). Cutlass had in 5 yr of Co-op testing (1980 to 1984) further increased yield and 0.6% lower fixed oil content compared with Domo, but still had 0.3% higher fixed oil levels compared with Lethbridge 22A. It was registered on 1985 Apr. 19, registration no. 2529, and became the check cultivar in 1988, and is still the check cultivar today (2008).

AC Vulcan was derived through pedigree selection of single plants from the oriental mustard cultivar Cutlass (Woods 1989). In 1988, 500 open-pollinated plants were individually harvested from a breeder plot increase of Cutlass. Seed of the 500 plants was rated for seed colour and 150 best yellow-seeded plants selected and progeny tested in a two-replicate, 3-m single-row nursery at Saskatoon in 1989. Rows were rated for agronomic type, maturity and lodging resistance. All rows were individually harvested with a plot combine and seed yields determined. Seed of each row was analyzed for fixed oil content by nuclear magnetic resonance spectroscopy, seed weight, allyl glucosinolate content by gas chromatography and seed chlorophyll content.

Twenty-four high-yielding lines with low fixed oil content, high seed weight, high allyl glucosinolate content and low seed chlorophyll content were advanced into a six-replicate yield test at Saskatoon in 1990. Line J89–102 was selected from the yield test and tested in

Co-op mustard tests from 1991 to 1993. J89–102 was registered as AC Vulcan.

The check cultivar for AC Vulcan was Cutlass (Table 1). Data on the cultivar Forge are presented for comparison since Forge was the predominant oriental mustard grown in western Canada when the cultivars Cutlass and AC Vulcan were developed. Forge was developed by Mr. John Hemingway of Colman's Food, Norwich, UK. This cultivar description is based on 9 yr of Co-op mustard tests (1999–2007) to provide a solid set of data for a better comparison of cultivar performance. There were totals of 81, 84 and 71 station years of data for grain yield, maturity and plant height, respectively, and 64 station years of data for seed quality (fixed oil, seed protein, seed weight, allyl glucosinolate, seed chlorophyll and distinctly green seed). The tests were randomized complete block designs with four replicates. Statistical analysis of variance was performed using Agrobases™ 21 for Windows (Agronomix Software Inc. Winnipeg, MB) and the SAS® System release 8.2, PROC MIXED model (SAS Institute Inc. Cary, NC). Analysis of variance was performed on a site basis and only locations with less than 16% coefficient of variation for grain yield were included to eliminate locations with questionable data from the data set. Only three locations were lost due to high CV for yield. Years, locations and their interactions with entries were classified as random variables for determination of grand means over all locations in the 9-yr performance table. A one-sided test was used for calculating LSD values at the 5% significance level for comparison of means between AC Vulcan and Forge with the check cultivar Cutlass.

During the 9 yr of testing in Co-op mustard tests, blackleg [*Leptosphaeria maculans* (Desm.) Ces. et de Not.] adult plant stem infection and white rust [*Albugo candida* (Pers.) Kuntze] seedling infection types were assessed at AAFC Saskatoon. Reactions to blackleg were rated in field disease nurseries, while severity of white rust was assessed on cotyledons of seedlings under controlled environmental conditions in growth rooms against *Brassica juncea* races 2a and 2v (Anonymous 1985). These are the two races of white rust found on *B. juncea* in western Canada (Rimmer et al. 2000).

Infection by *Alternaria* species was occasionally observed in breeding nursery, but resistance was sufficient to prevent major damage.

Seed quality was evaluated at several locations each year on sites with acceptable CVs for grain yield representing mustard growing areas across the three prairie provinces. Fixed oil is primarily triglyceride, the oil (or fat) in oilseed such as canola in contrast to "volatile oil" which is the enzymatic (myrosinase) breakdown product of allyl glucosinolate in *B. juncea* seed. A low "fixed oil" content is desirable to improve dry milling of seed and reduce "oiliness" in the final mustard product. Fixed oil content was determined by nuclear magnetic resonance spectroscopy (Prairie Registration Committee Oilseeds). Total nitrogen was measured by

Table 1. Agronomic performance and seed quality of AC Vulcan condiment oriental mustard [*Brassica juncea* (L.) Czern.] compared with the check cultivar Cutlass and the cultivar Forge in Co-op Mustard Tests (1999–2007)^{z,y}

| | Grain yield ^x (kg ha ⁻¹) | Maturity ^w (d) | Height ^v (cm) | Fixed oil ^u (% seed) | Protein ^t (% seed) | Seed weight ^s lpar:g 1000 seed ⁻¹) | Allyl GSL ^r (mg g seed ⁻¹) | Seed chlorophyll ^q (mg kg ⁻¹) | Distinctly green ^p (No. of green in 1000 seed) |
|----------------|--|------------------------------|-----------------------------|------------------------------------|----------------------------------|--|--|---|--|
| Cutlass | 2251 | 90 | 113 | 41.2 | 29.4 | 2.73 | 11.08 | 2.89 | 0.71 |
| Forge | 2178* | 92* | 124* | 38.9* | 30.0* | 2.49* | 11.84* | 2.80 | 0.65 |
| AC Vulcan | 2184* | 91* | 114 | 40.7* | 29.7* | 2.82* | 12.04* | 2.95 | 0.84 |
| Location years | 81 | 84 | 71 | 64 | 64 | 64 | 64 | 64 | 64 |
| LSD (5%) | 50 | <1 | 1 | 0.2 | 0.2 | 0.04 | 0.19 | 0.60 | 0.16 |

^zLocations (grain yield):

1999: Rosebank, Elgin (Manitoba), Watrous, Scott, Swift Current, Saskatoon 1, Saskatoon 2 (Saskatchewan), Irricana, Standard, Bow Island, Oyen (Alberta).

2000: Avonlea, Scott, Swift Current, Saskatoon 1, Saskatoon 2 (Saskatchewan), Irricana, Standard (Alberta).

2001: Rosebank, Neepawa (Manitoba), Mortlach, Watrous, Scott, Swift Current, Saskatoon 1, Saskatoon 2 (Saskatchewan), Irricana, Oyen (Alberta).

2002: Scott, Swift Current, Saskatoon 1, Saskatoon 2 (Saskatchewan), Irricana, Neapolis, Lethbridge (Alberta).

2003: Elgin (Manitoba), Eyebrow, Watrous, Weyburn, Scott, Swift Current, Saskatoon 1, Saskatoon 2 (Saskatchewan), Irricana, Neapolis, Lethbridge (Alberta).

2004: Rosebank, Elgin (Manitoba), Eyebrow, Weyburn, Scott, Swift Current, Saskatoon 1, Saskatoon 2 (Saskatchewan), Irricana, Neapolis, Lethbridge (Alberta).

2005: Rosebank (Manitoba), Eyebrow, Watrous, Weyburn, Swift Current, Saskatoon 1, Saskatoon 2 (Saskatchewan), Irricana, Congress (Alberta).

2006: Rosebank, Elgin (Manitoba), Eyebrow, Scott, Saskatoon 1, Saskatoon 2, Swift Current, Watrous, Weyburn (Saskatchewan) Irricana, Lethbridge, Neapolis (Alberta).

2007: Rosebank, Elgin (Manitoba), Scott, Saskatoon 1, Saskatoon 2, Swift Current (Saskatchewan), Beiseker, Lethbridge, Neapolis (Alberta).

^yLocations (seed quality):

1999, 2000, 2005 and 2007: the same as for grain yield.

2001: Irricana, Rosebank, Saskatoon 1, Swift Current, Watrous.

2002: Irricana, Saskatoon 1, Saskatoon 2, Scott, Swift Current.

2003: Neapolis, Saskatoon 1, Swift Current, Weyburn, Elgin.

2004: Irricana, Neapolis, Eyebrow, Saskatoon 2, Rosebank.

2006: same as for grain yield, except for Scott, Weyburn and Lethbridge locations that were not included.

2001, 2002, 2003 and 2004: Five locations with lowest CV for grain yield were selected for seed quality analysis. Seed quality was determined on seed from at least two replicates at each location.

^xGrain yield: 1.20 m × 6.00 m plots = 7.20 m², 4 replicates.

^wMaturity: at 30% seed colour change of seed in days from seeding.

^vHeight: two measurements per plot in 5 cm increments at swathing maturity.

^uFixed oil: by nuclear magnetic resonance spectroscopy (dry seed).

^tProtein: by Dumas combustion for N × 6.25 (dry seed).

^sSeed weight: by counting and weighing 500 seed.

^rAllyl GSL = allyl glucosinolate by gas chromatography (dry seed).

^qSeed chlorophyll by solvent extraction of chlorophyll and spectrophotometry (dry seed).

^pDistinctly green seed: by counting of distinctly green seed in 1000 crushed seed.

*Significantly different at LSD (5%) from check cultivar Cutlass.

Dumas combustion (Leco PF-528 Model #601-500-100, manufactured by Leco Corporation, St. Joseph, MI) analysis and nitrogen values multiplied by the factor 6.25 for conversion to protein content. Fixed oil and protein data were reported as percent whole seed on a dry weight basis. Seed weight was determined on 500 counted seed and reported as g per 1000 seed. Allyl glucosinolate content was determined by gas chromatography (Prairie Registration Committee Oilseeds).

Seed quality analysis (fixed oil and protein) from the 2007 Co-op test was done by near infrared reflectance spectroscopy after acceptable calibration sets had been developed (2007 Co-op Mustard Report, Prairie Registration Committee Oilseeds).

Performance

Agronomic and seed quality data are summarized in Table 1. On average, grain yield of AC Vulcan was 3.0% lower than Cutlass and equal to Forge at 81 locations. AC Vulcan was 1 d later maturing than Cutlass but was 1 d earlier than Forge at 84 locations. AC Vulcan had similar height to Cutlass (113 cm) but was 10 cm shorter than Forge.

AC Vulcan had 0.5% lower fixed oil content than Cutlass (41.2%), a desirable improvement, but still had 1.8% higher fixed oil than Forge. In contrast, seed protein contents of AC Vulcan were 0.3% higher than Cutlass and 0.3% lower than Forge. AC Vulcan had an average seed weight of 2.82 g per 1000 seed, 0.09 g higher than Cutlass while Forge seed was smaller at 2.49 g per 1000 seed. The allyl glucosinolate content of AC Vulcan was 12.04 mg g seed⁻¹, 0.96 mg higher than Cutlass and 0.20 mg higher than Forge. Forge has the lowest fixed oil content of all oriental mustard cultivars.

The comparison of the performance of AC Vulcan with Forge is of particular significance since Forge represents major improvements in reduced fixed oil content that have not been achieved in other oriental mustard cultivars. The weakness in Forge is low grain yield and significantly smaller seed. The smaller seed might indirectly lower fixed oil content since smaller seed contain relatively more seed coat tissue that contains little oil. However, AC Vulcan is an improvement over Cutlass with greater yield, reduced fixed oil and increased allyl glucosinolate in combination with greater seed weight.

Green seed counts varied from 0.65% for Forge to 0.84% for AC Vulcan, which were statistically non-significant. Seed chlorophyll contents were in agreement with green seed counts ranging from 2.69 mg kg seed⁻¹ for Cutlass to 2.95 mg kg seed⁻¹ for AC Vulcan, statistically also non-significant. Green seed or high chlorophyll contents are less of a problem in oriental mustard than in brown mustard. Seed chlorophyll content of brown mustard cultivars Duchess, Common Brown and Centennial Brown was on average 5.25 mg kg seed⁻¹ compared with average seed chlorophyll content of the three oriental mustard cultivars Cutlass,

Forge and AC Vulcan at 2.81 mg kg seed⁻¹ for the same 9-yr testing period. Seed chlorophyll content of brown mustard was almost double that of oriental mustard. Low seed chlorophyll content is an important grading factor for mustard seed.

Other Characteristics

LODGING. Lodging was observed in tests that had superior growing conditions, but there was no difference among AC Vulcan, Cutlass and Forge.

SEED COLOUR. The objective is a uniform bright yellow seed, either assessed visually or by reflectance using a Hunter Lab colorimeter (whiteness index, method E 313, American Society for Testing and Methods Hunter Lab Mini-Scan XE, Model #450-L, manufactured by Hunter Associates Laboratory Inc., Resto, VA). AC Vulcan had, on average over 9 yr, a whiteness index of -37.2 compared with Cutlass at -36.9. Forge seed had a darker yellow colour (-32.2). A more negative number indicates a brighter yellow seed.

BLACKLEG. Blackleg disease was assessed in field disease nurseries and AC Vulcan, Cutlass and Forge were all highly resistant, with severity ratings of less than 0.5 on a 0 to 5 rating scale.

WHITE RUST: AC Vulcan and Cutlass were both resistant to the *Brassica juncea* white race 2a but were susceptible to race 2v (Prabhu et al. 1998). Forge was highly susceptible to both races. Development of resistant cultivars remains a major breeding objective.

Maintenance and Distribution of Pedigreed Seed

AC Vulcan breeder seed will be produced by AAFC Saskatoon Research Centre, 107 Science Place, Saskatoon, Saskatchewan, Canada S7N 0X2. AC Vulcan has been released for multiplication and distribution to members of the Canadian Mustard Association.

Appreciation is expressed to the following for conducting the Co-op mustard tests over the years: planting, maintaining (weeding) and harvesting plots and providing data and seed samples for quality analysis to the AAFC Saskatoon Research Centre, Saskatoon, SK. Daryl Rex, United Grain Growers, Morden, MB; Tim Ferguson, Jim Dyck, Rod Hayden and Jim Anderson, Agricore Research and Development, Calgary, AB; Ken Vanthyne, Brent Grindheim, Brian Cowan, Anthony and Juanita Allin, and Kathy Hanson, Saskatchewan Wheat Pool, Watrous, SK; Steve Dueck, Scott Research Farm, AAFC Scott, SK; Cal MacDonald and Greg Ford, Swift Current Research Farm, AAFC Swift Current, SK; Greg Lafond and David Larson, Hub and Spoke Demo Sites, AAFC Indian Head, SK; Linda Ost, Crop Diversification Centre, Brooks, AB; Audrey Bamber, Chinook Research Association, Oyen, AB; Brian Beres and Ryan Dyck, AAFC Lethbridge Research Centre, Lethbridge, AB.

Appreciation is also expressed to Dawnne Campbell, Gerald Serblowski, Douglas Hennigan and others and numerous

summer students for seed quality analysis at the AAFC Saskatoon Research Centre, Saskatoon, SK for setting up seed for distribution to collaborators, for cleaning and drying of seed samples from tests, for determining yield, conducting seed chemical analysis and data entry into spread sheets in preparation for annual Co-op mustard reports.

We thank Dr. J. P. Raney for overseeing the seed chemical analyses and Ms. Jo-Anne Relf-Eckstein for summarizing data from Co-op tests and for preparation of the annual Co-op mustard reports.

We further appreciate the financial support from the Canadian Mustard Association Inc. for the Co-op mustard tests and for breeding work.

Agriculture Canada 1974. Description of oriental mustard (*Brassica juncea* (L.) Czern.) variety Lethbridge 22 A. 1974, Aug. 21. Production and Marketing Branch, Plant Products Division Ottawa, Ontario. Recommended for Registration by Research Branch, Agriculture Canada. Supported by Canada Committee on Grain Breeding.

Agriculture Canada 1977. Description of oriental mustard (*Brassica juncea* (L.) Czern.) variety Domo. 1977, April 19. Production and Marketing Branch, Plant Products Division Ottawa, Ontario. Recommended for Registration by Research Branch, Agriculture Canada. Supported by Canada Committee on Grain Breeding.

Anonymous. 1985. Resource book. Crucifer Genetic Cooperative, Department of Plant Pathology, 1630 Linden Drive, University of Wisconsin, Madison, WI.

Co-operative Mustard Reports. 1999–2007. Conducted by Agriculture and Agri-Food Canada, Saskatoon Research Centre for Prairie Registration Recommending Committee for Grain (PRRCG), now called Prairie Recommending Committee for Oilseeds (PRCO). The reports are not for publication, but copies of reports are available by request from Co-op Mustard Test Co-ordinator Dr. Gerhard Rakow, AAFC Saskatoon Research Centre, 107 Science Place, Saskatoon, SK S7N 0X2 (e-mail: rakowg@agr.gc.ca).

Prabhu, K. V., Somers, D. J., Rakow, G. and Gugel, R. K. 1998. Molecular markers linked to white rust resistance in mustard *Brassica juncea*. *Theor. Appl. Genet.* **97**: 865–870.

Prairie Registration Committee Oilseeds. Operating procedures. Procedures for Registration of a Condiment Mustard Cultivar for Production in Western Canada. Copies available from Dr. Ginette Séguin-Swartz, Secretary PRCO, AAFC Saskatoon Research Centre, 107 Science Place, Saskatoon, SK (e-mail: seguing@agr.gc.ca).

Rimmer, S. R., Mathur, S. and Wu, C. R. 2000. Virulence of isolates of *Albugo candida* from western Canada to *Brassica* species. *Can. J. Plant Pathol.* **22**: 229–235.

Woods, D. L. 1989. Cutlass oriental mustard. *Can. J. Plant Sci.* **69**: 249–250.