

Introduction

Carinata: a unique energy feedstock crop

A new crop offers new opportunities for growers.

Growers in semi-arid regions who want to add a profitable oilseed to their rotation, but have been unable to because of climate limitations, now have an option with *Brassica carinata*.

Carinata, commonly known as Ethiopian mustard, has an oil profile optimized for use in the biofuel industry, specifically for biojet fuel. Agriculture and Agri-Food Canada have developed varieties that offer growers high yields, high oil content and are ideally suited to semi-arid growing conditions commonly found in the southern Prairies of Canada and the Northern Plains of the US.

That's important because biojet fuel produced from plant oils is now approved for up to 50% blend with conventional jet fuel. The US Federal Aviation Administration (FAA) has a stated goal of reaching one billion gallons of biojet fuel use in the commercial and military aviation sectors by 2018.

These initiatives mean fuel suppliers are looking for a sustainable, scalable and economic feedstock to meet this demand – and carinata is that crop. Because it is optimized for industrial use and is not a food crop, carinata offers growers viable, active markets for their production.

It is the best of both worlds: a crop with excellent agronomics that performs well in stressful conditions and has a ready market.

<p>This manual provides agronomic information about carinata, so you can familiarize yourself with the crop, then it goes on to outline the Best Management Practices (BMP) you'll need to know to successfully grow carinata on your farm – from stand establishment through to harvest.</p>

Carinata: Agronomic Profile

Carinata is an industrial oilseed mustard that is particularly suited to production in semi-arid areas. It offers good resistance to biotic stressors, such as insects and disease, as well as abiotic stressors, such as heat and drought.

It is a vigorous crop with a highly branching growth pattern and large seed size relative to other *Brassica* crops. Carinata also has excellent harvestability characteristics such as lodging and pod shatter resistance that make it an excellent candidate for straight cutting.

Two varieties are available for 2013. AAC A100 was released in 2012 while the newest offering, AAC A110, will be available in limited quantities for 2013. AAC A110 has slightly better meal quality however both lines have similar oil profiles and perform equally well in all regions.

Carinata Profile (AAC A100 & AAC A110)

Yield	18% over checks ¹
Oil content	44%
Protein	28%
Maturity Zone	Mid- to long-season ²
Blackleg Resistance	Excellent
Lodging Resistance	Very good to excellent ³
Pod Shatter Resistance	Very good to excellent

¹ Check varieties: AC Vulcan and Cutlass oriental mustards

² 12-14 days later than oriental mustard

³ Depending on moisture conditions

Source: Agriculture and Agri-Food Canada and Agrisoma trials.

Carinata Elite Line Yield Results

Year	AAC A100		AAC A110	
	Yield (kg/ha)	% of Check	Yield (kg/ha)	% of Check
2009	4321	+16%		
2010	2227	+18%		
2011	2843	+14%	3057	+23%
2012	1898	+21%	1906	+21%

Check varieties: 2009-2010 AC Vulcan, 2011-2012 AC Cutlass

Source: Agriculture and Agri-Food Canada and Agrisoma Biosciences Inc. trials.

Stand Establishment

Maximizing crop yield and economic returns starts with stand establishment. Similar to other mustard types, carinata is a small seeded crop that requires special attention to seed quality, seedbed conditions, seeding date, seeding rate, seeding depth and fertility.

- **Seed quality.** Certified carinata seed is produced under strict guidelines for purity, germination and vigor. The seed is typically supplied with a dual-purpose treatment to provide protection from early season disease and insect pressure.

** The seed you purchase should always come from a certified seed dealer to ensure that you are starting with the best possible genetics.*

- **Seedbed.** Emergence is heavily influenced by seedbed conditions. Optimal conditions are a function of soil and crop management. Key soil factors include soil moisture, soil temperature, physical barriers to seedling emergence and erosion. Adequate soil moisture in the top inch is even more important than with larger seeded crops due to the shallow seeding depth. Soils prone to forming a thick surface crust after precipitation can form a physical barrier to seedling emergence and may require additional management. Soil erosion impacts stand establishment by altering seed depth and sandblasting.

Soil and crop beneficial management practices such as direct seeding, minimum tillage, chemical fallow and diverse crop rotations contribute towards providing an ideal seedbed. Minimum tillage practices benefit establishment through conservation of valuable soil moisture and building soil organic matter. Diverse crop rotations provide disease cycle breaks, potential nutrient benefits, weed management opportunities and maintain beneficial soil biology.

- **Seeding date.** Even though carinata is a heat tolerant oilseed, maximum yield is achieved when flowering occurs before the hottest days of summer. Carinata is also a mid to long season crop that requires a slightly longer growing season than other mustard types. Early seeding, from mid-April to early-May typically provide the best results. The ideal seeding date will depend greatly on geography and weather. Consider historic weather patterns for killing frosts and monitor soil temperature. Seeding into soils that are too cool can delay emergence, add to seedling stress and prolong exposure to disease &/or insect pressures. Soils should be at least 5°C or higher before planting.

Relative Effects of Early and Late Seeding

Crop Type	May 10-15 Normal Seeding	Gross Income (\$/ha)	
		Change from normal to Early Seeding	Late Seeding
Argentine canola	370	+ 47	- 20
Polish canola	440	+ 27	- 104
Brown Mustard	570	+ 5	- 113
Yellow Mustard	500	+ 116	- 84

Source: Yantai Gan, Agriculture and Agri-Food Canada

- **Seeding rate.** Carinata is a large seeded mustard however seeding rates should not be based on other large seeded Brassica crop types such as hybrid canola. Research has determined that optimum plant densities for carinata range from 8 to 17 plants per square foot. Higher plant densities (15 to 17 plants per sq. ft.) have been shown to reduce days to maturity by as much as one week. In addition, it has been demonstrated that high plant densities reduce weed competition in oilseed crops. Higher plant densities should also be targeted if seedbed conditions are less than optimum.

Calculating your seed rate

- Seeding rate calculations should start with selecting the desired plant stand density for your growing region. Once you have determined your target planting density, consider seed size and estimated seedling mortality.
- Seed size can vary from one variety to another and even from year to year within the same variety. Because of this variation, the number of seeds per kilogram and therefore the seeding density per kilogram of seed will also vary. Seed size is factored into seeding rate calculations by determining its thousand kernel weight (TKW). If the TKW is not provided, count out 250 seeds and weigh them on a scale. Multiply the value by 4 to get the TKW.
- Seedling mortality is a function of a number of factors such as germination, seedling vigor, seeding depth, soil moisture, in-row fertilizer rates, temperature, disease and insects. Research has shown that seedling mortality for small seeded crops such as carinata can often range from 30 – 60%.

The following table provides calculated seeding rates based on target plant density, TKW and an estimated seedling mortality rate of 45%.

Target Density Plants/sq. m (sq. ft.)		Thousand Kernel Weight (g)			
		4	4.5	5	5.5
		Seeding Rate - kg/ha (lb./ac)			
Min	86 (8)	5.6 (5)	6.72 (6)	7.28 (6.5)	7.84 (7)
Mid	129 (12)	8.96 (8)	10.08 (9)	11.2 (10)	12.32 (11)
High	183 (17)	12.32 (11)	13.44 (12)	15.68 (14)	16.8 (15)

Source: Eric Johnson, Agriculture and Agri-Food Canada

- **Seeding speed.** Excessive seeding speeds can reduce stand density, uniformity and ultimately profitability. Ideal seeding speeds vary with seedbed conditions and equipment type. Leaving a check strip and taking emergence counts is a great way to determine the most suitable speed for your operation.
- **Seeding depth.** Carinata should be seeded at a consistent 1.3 – 2.5 cm (½” to 1”) deep. Planting beyond the recommended depth may result in slower emergence and a reduced plant stand. Be sure to calibrate your drill to ensure even seeding depth.

- **Fertility.** Carinata has fertility requirements similar to other mustards and canola. Adequate availability of nitrogen, phosphorous, potassium and sulfur are required to achieve the true yield potential. Fertilizer rates will vary with growing zone and soil fertility. Fertilize to expected yields and always soil test to make certain that your nutrient program is balanced and appropriate for the crop's needs.

On-farm fertilizer trials are an excellent way to validate optimum rates. If equipped, GPS and yield monitors are efficient ways to mark check strips (high and low rate) and measure yields.

Carinata is sensitive to seed-placed fertilizer. Ensure that there is at least one inch separation between the seed and fertilizer. Slower seeding speeds are recommended in single pass seeding systems to ensure proper seed-to-fertilizer separation.

In-crop Management

Carinata is similar to other mustard types when it comes to in-crop management practices. While carinata is a strong field competitor and offers natural resistance to many pests, proper scouting is essential throughout the season to assess crop health and the need to take any protective action. Regulatory submissions are underway for multiple in-season crop protection tools.

Disease management

- It is highly recommended to practice proper crop rotations to disrupt disease, weed insect cycles that may affect carinata. Crop residue can be a major carrier of disease pathogens, particularly sclerotinia.

Sclerotinia stem rot

- Causes premature ripening, shrunken seeds and shattering.
- Infection occurs two to three weeks before visible symptoms appear.
- Thrives in wet weather; prolonged rainfall before flowering is a risk factor.
- To date, sclerotinia has not been a serious problem in carinata.



Sclerotinia (canola)
(L. Buchwaldt, AAFC)



Sclerotia resting body (canola)
(K. Turkington, AAFC)

Blackleg

- Carinata has excellent resistance to blackleg.
- To date, blackleg is not a problem in carinata.

Aster Yellows

- Caused by phytoplasma bacteria-like pathogen living in the plant phloem and transmitted by phloem-feeder leafhoppers. The main vector is the aster leafhopper (*Macrostelus quadrilineatus*) that arrives in the prairies every spring with winds coming from South USA.
- Causes leaf, stem and/or pods yellowing or reddening, lower seed production (smaller misshapen seeds) and flowers to be transformed into sterile leaf-like structures. The earlier the plant is inoculated, the more severe the symptoms.
- No commercially available products to control the phytoplasma and no economic thresholds are available for the leafhopper vectors.
- Based on field observations, *B. carinata* appears to be less susceptible to Aster Yellows than canola however more research is needed before this can be confirmed.



Aster Yellows
(Daryl Males, Agrisoma)



Aster Leafhopper
(C. Olivier, AAFC)

Club Root

- Caused by *Plasmodiophora brassicae*, a fungus-like pathogen, poses serious threat to carinata production.
- Causes the formation of large galls on the roots which look like clubs; impede nutrient and water uptake and can cause plant death.
- Soil movement seems to be the primary mechanism of pathogen dispersal. Clean all equipment and vehicles that may have come from an infested area.
- Developing resistant cultivars is in progress.



Clubroot (carinata)
(E. Yazdi, AAFC)



Clubroot (canola)
(G. Peng, AAFC)

Insect management

Diamondback moth

- Causes delayed maturity, uneven crop development and reduced yields.
- Damage appears as irregular shot hole feeding damage to leaves; larger larvae will also feed on buds, petals and young pods.
- Windy, wet and humid weather reduces adult moth activity; adult moth population doesn't necessarily predict larvae damage.
- Scout fields in July and August; remove plants from one square foot, beat them on a clean surface to dislodge larvae.
- Economic thresholds: 10 to 15 larvae per square foot at early flowering; or 20 to 30 larvae at the advanced pod stage.



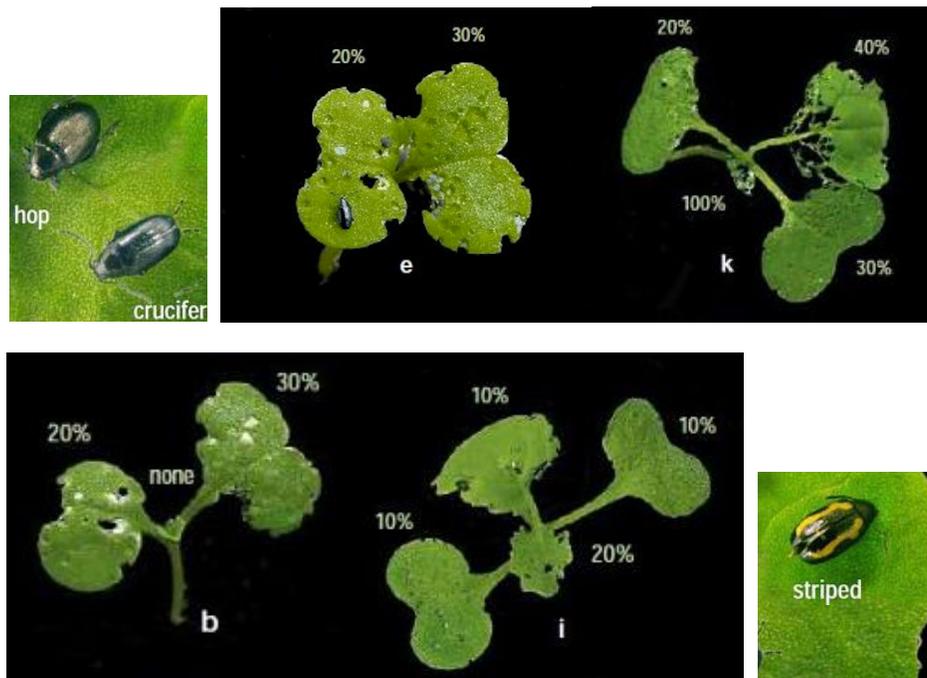
Diamondback Moth larvae
(J. Gavloski, MAFRI)



Diamondback Moth larvae
(Canola Council of Canada)

Flea beetle

- Early-season pest that causes delayed emergence and crop thinning. Feeding occurs on stems, cotyledons and young true leaves.
- Scout fields at early crop emergence beginning at the field edges. Check to determine if flea beetles are actively feeding. Flea beetles are most active when conditions are warm, sunny, dry and calm.
- Consider chemical control when the average seedling defoliation levels reach or exceed the economic threshold of 25%.



Flea beetle species and seedling damage estimates (canola). Upper photos (e & k) show signs of active feeding at or beyond economic thresholds while lower pictures (b & i) may not need chemical control.

(J. Soroka & R. Underwood, AAFC)

Cabbage Seedpod Weevil

- Early season adult feeding on buds can cause bud-blasting and reduce yield potential in dry years. Second generation adults emerge in late summer and feed on immature seeds through the seedpod walls.
- Female adults deposit eggs inside developing seedpods. Larvae feeding damage on immature seeds cause pods to appear distorted and poorly filled.
- Research seems to indicate that *carinata* is relatively less susceptible to cabbage seedpod weevil infestation than canola.
- Monitoring is best conducted at the bud stage through flowering. Chemical control is recommended when sweep counts average three to four adults per

sweep. If required, spraying should be conducted at 10 - 20 percent flowering to prevent adult females from laying eggs inside newly formed pods.



Cabbage Seedpod Weevil
(Dan Johnson, Lethbridge)



Cabbage Seedpod Weevil larvae and adult
(Lloyd Dosdall)

Bertha Armyworm

- Feed on a variety of crops including canola and mustard. Economic crop damage can occur during the last two stages of larvae development (late July and August). These larvae are approximately 1.3 cm (2 in.) in length.
- Early larvae stages chew irregular holes in leaves however they tend not to be economically significant. Later larvae stages can strip the outer seedpod surface, chew holes through pods and eat seeds. In extreme cases whole pods can be consumed.
- Monitor individual fields by evaluating representative square meter areas within the field. Economic thresholds vary with crop value and spraying costs. Research experiments indicate that *carinata* may be relatively resistant to bertha armyworm feeding. Spraying should not be required in most years.
- If the crop requires spraying be aware of pre-harvest intervals. Insecticides require a minimum of seven to twenty one days before straight cutting or swathing. Refer to label directions.



Bertha Armyworm
(Daryl Males, Agrisoma)



Root Maggot

- Found across the prairies with the greatest damage occurring in central and northern Alberta. Recent reports have identified root maggots in Southern Alberta carinata fields.
- Feed on root hairs, secondary roots and tunnel into the taproot leaving a brownish channel. Severe infestations cause plants to appear sick-looking and wilted. Damaged roots are more susceptible to root disease. Extensive tunneling can girdle the root leading to plant lodging and death.
- No chemical control options are available at this time. Increasing the duration between *Brassica* crops, cultivation, vigorous cultivars, increased seeding rates, wider row spacing and adequate soil fertility can minimize root maggot damage.



Root Maggot
(Ed Mazurkewich, AgCall)

* Insect control options for Mustard are listed the 2012 Guide to Crop Protection (Pg. 417-418)

Weed management

Carinata has a highly branching growth habit that allows it to fill in space quickly as it grows and matures. With strong stand establishment, carinata should be able to choke out many weed competitors before they become a problem.

Crop rotation and pre-seed burn-off are important considerations due to limited in-crop herbicide options. The best strategy is to control weeds in the crops leading to carinata.

Herbicides Registered for Weed Control in Brassica carinata

(Source: Eric Johnson, Agriculture and Agri-food Canada)

Herbicide	Timing	Rate	Weeds
Trifluralin (Bonanza, Rival, Treflan)	Pre-emergence applied in fall or spring	Varies according to formulation and soil organic matter	Wild oat ^a , green foxtail, some broadleaf weeds
Glyphosate (Glyphosate, CleanStart)	Pre-seed burndown	Varies according to formulation	Most annual and broadleaf weeds
	Pre-harvest	Varies according to formulation	Perennials (Canada thistle, dandelion, quackgrass)
Muster Toss-N-Go ^b	4-leaf stage of crop but prior to bolting	8 to 12 grams/acre	Stinkweed & wild mustard, primarily
Assure II ^c	According to weed stage	0.15 to 0.30 liters/acre	Grass weeds

^a suppression only

^b add registered non-ionic surfactant. Application at earlier than 4-leaf stage of mustard may result in crop damage

^c add registered surfactant

*** Until further field research is done on surfactants and timing, it is not recommended to apply Assure II and Muster in a tank-mix.**

Ongoing Herbicide Research

Testing confirms that the full suite of selective herbicide options available to other Brassica crops are well tolerated by carinata. Minor Use Pesticide research is underway to investigate the potential to register sulfentrazone for broadleaf weed control in mustards. There may be potential to register ethafluralin (Edge) in Brassica carinata as well. Resistance to other herbicides through conventional plant breeding is underway as part of a long-term strategy.

Harvest management

Prior to complete dry-down, carinata stalks tends to be tougher than canola or other mustard types. Ease of harvest is highly dependent on giving the plant material enough time to dry down. ** Even if the seeds appear ready to combine, allow adequate time for the entire plant to dry down. Harvesting carinata with green stems is slow, requires a lot of power and is prone to plugging the combine.*

Desiccants are one possible way to speed up dry-down. Reglone is a contact herbicide that acts by killing what it contacts. Dry down is rapid and can lock in green seed levels if applied too early. Follow label recommendations regarding application timing.

Glyphosate can even out crop maturity and provide weed control benefits for straight cutting applications. Glyphosate needs to translocate through the plant which results in a more gradual dry down. Due to the mode of action, effects can take up to 3 weeks under cool conditions. Early application can also impact seed quality, yield and seed glyphosate residues.

*** Do not use pre-harvest Glyphosate if you intend to use the crop for seed.**

Straight cutting. Good pod shatter and lodging resistance make carinata an excellent candidate for straight cutting. Eliminating one operation saves a grower time and money. This practice is recommended when the crop is uniformly mature and seed moisture content is less than 9%. The cutter bar should be set just below lowest pods to minimize the amount of material fed through the combine. ***Ensure all crop material is dry before harvesting.**

Swathing. If crop maturity is excessively late or uneven, green seed is high, or weed populations have been significant, swathing may be beneficial.

- Swath when seed moisture content is around 25%. Pod color change is not a good indicator of actual maturity. Seed moisture content is the only reliable measure of harvest readiness.
- Cutting just below the lowest pods should leave sufficient stubble to prevent the swath from blowing away.
- Combine when the majority of seeds have matured and their moisture content has dropped to or below 9%.

Combining. Previous producers have noted that combining carinata can be slow (2-5 mph) and take a lot of power. Harvest challenges are generally a consequence of combining before the straw is dry. If tough conditions are unavoidable, modern type combines tended to out-perform older conventional types. A number of previous growers also noted that an auger header with full length retractable fingers tended to feed better than other header types.

Tip: Be patient and plan on carinata being the last crop off.

Storage. Regularly monitor carinata in the bin to ensure that temperature and moisture are stable. Aerate when necessary to cool grain and prevent storage molds.

The Future of carinata.

On-going research by Agriculture and Agri-Food Canada and Agrisoma is focused on further developing agronomy recommendations and making crop improvements through Crop Breeding efforts.

Carinata is a new crop and, while agronomically similar to other mustard types, the production knowledge pool is still growing. This manual outlines the main BMPs you need to successfully grow Carinata. If you require more detailed information, or have a specific production question, please contact Agrisoma at productioninfo@agrisoma.com.

Interested in Growing carinata.

Industrial carinata varieties are being commercialized by Agrisoma under the Resonance™ Energy Feedstock brand and can be grown under closed-loop production contract with Paterson Grain.

Contact your local Paterson Grain facility for more information.

Links and Reference Material:

Alberta Agriculture and Rural Development: www.agric.ab.ca

Canola Council of Canada: www.canolacouncil.org

Manitoba Agriculture, Food and Rural Initiatives: www.gov.mb.ca/agriculture

Mustard 21: www.mustard21.com

Prairie Soils and Crops Journal: www.prairesoilsandcrops.ca

Saskatchewan Ministry of Agriculture: www.agriculture.gov.sk.ca

Saskatchewan Mustard Development Commission: www.saskmustard.ca

Acknowledgements:

We gratefully acknowledge contributions from the following organizations:

Agriculture and Agri-Food Canada (Saskatoon, Scott & Lethbridge)

Agrisoma Biosciences Ltd.

Alberta Agriculture and Rural Development

Canola Council of Canada

Mustard 21

Saskatchewan Ministry of Agriculture

Saskatchewan Mustard Growers Council

* Please direct any comments or questions regarding this manual to email address: carinata@agr.gc.ca