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Carinata, the Jet Fuel Cover Crop: 2016 Production Recommendations for the Southeastern United States[1]

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Figure 1. From field to flight.
Credits: David Wright, UF/IFAS (field, seed); Thinkstock (plane, oil)

Brassica carinata (carinata) is an oilseed crop with great potential for profitable cultivation in the southeastern US. Its high oil content and favorable fatty acid profile make it suitable for the biofuel industry as a biojet fuel. The UF/IFAS North Florida Research and Education Center (NFREC) in Quincy, Florida has been working to identify advanced carinata genotypes that are high-yielding (seed and oil), disease-resistant, early-maturing, and adapted to the southeastern US. The work at NFREC is being done in conjunction with Agrisoma Biosciences Inc., a company that has the world's largest carinata breeding program and is developing varieties for the southeastern US and the northern prairie states as well as Canada and several other countries. This publication's "Agronomic Management" section provides recommendations based on research conducted at the University of Florida (UF). The recommendations made in this production guide are from preliminary findings from two years of research at

1. This document is SS-AGR-384, one of a series of the Agronomy Department, UF/IFAS Extension. This research is supported by the Florida Department of Agriculture and Consumer Services Office of Energy grant SRD007 and focuses on the development of best management practices, demonstration of commercial potential, and feasibility of the presscake as a feedstuff. Our research partner, Applied Research Associates, FL, USA, was also supported through this grant to develop efficient conversion methods for *B. carinata* oil into "drop-in" bio-jet and bio-diesel fuels. The selection of regionally adaptable carinata genotypes with superior agronomic performance and high oil concentration is done in collaboration with Agrisoma Biosciences Inc. and Mustard 21 Canada Inc. Original publication date December 2014. Revised October 2015. Visit the EDIS website at http://edis.ifas.ufl.edu.

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the West Florida Research and Education Center in Jay, Florida and the North Florida Research and Education Center. The validity of the management recommendations is currently being verified through another year of testing at these two locations. When planted by mid-November and harvested in early May, carinata can be double cropped without lowering yields of subsequent crops. Other key management strategies to maximize yield potential include chisel ploughing followed by rolling to prepare a compact seedbed and planting carinata in 14-inch rows using 5 lb seeds per acre. Elite advanced selections are currently being tested in multiple locations throughout north central, north, and west Florida to identify frost-tolerant, high-yielding varieties that are adaptable to this whole region. Preliminary findings suggest that carinata provides similar ecosystem services as other winter cover crops, including reduction of leaching and soil erosion, suppression of weed populations, improvement of soil fertility through the addition of organic matter, and provision of a food source for pollinators.

Carinata has been grown commercially for several years on the Canadian prairie and more recently in the US northern plains as a summer crop. For the past four years, UF has been conducting research to evaluate various management practices that allow incorporation of carinata into current cropping systems as a winter crop with minimal modification to existing infrastructure in the southeastern US. Carinata, also known as "Ethiopian mustard," is a member of the mustard family, native to the Ethiopian highlands.

Carinata is agronomically superior and frost-tolerant when compared with other oilseed crops and mustards with its high oil content (more than 40%), larger seed size, and lower lodging and shattering rates.

It is also more heat- and drought-tolerant than canola. However, carinata prefers cooler temperatures, making it well-suited as a winter crop in the southeastern US.

The benefits of growing carinata as a winter crop are two-fold: (1) increased revenue for farmers and(2) ecosystem services. Growing carinata following summer row crops and pastures may be a viable option for many producers.

Additionally, carinata as a winter crop may help to reduce soil erosion and nutrient losses to water bodies through leaching, increase soil organic matter, and retain soil moisture. Crop diversification also helps to break disease and pest cycles and control weeds.

Carinata is not an invasive plant in the Southeast US. Volunteer seedling emergence in subsequent crops is not an issue when normal site preparation and herbicides are applied for the summer crops.

Background

Carinata Characteristics

Carinata is high in erucic and linoleic acids and has less than 7% saturated fatty acids. These characteristics make it a desirable oil which can be processed into "drop-in" biofuel. The oil is considered a non-food oil because it is high in erucic acid. Carinata has the potential to help meet the renewable energy demands of the US without displacing feed and food crops.

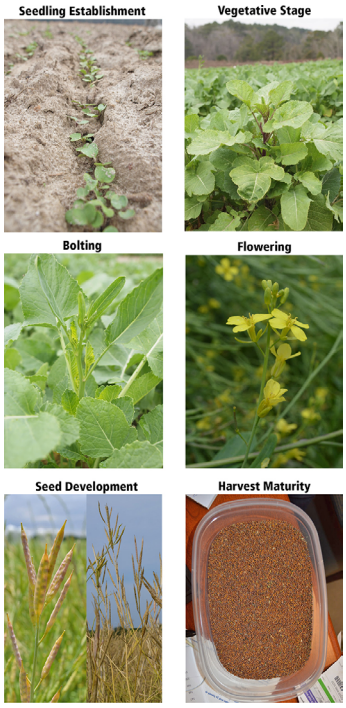

Figure 2. The growth stages of carinata.
Credits: R. Seepaul, UF/IFAS

Carinata Biology

In the early stages of growth, plants resemble turnips or mustard. However, carinata becomes highly branched and can grow as tall as 4 to 5 feet in height. At maturity, it resembles canola. Extensive deep root system, low canopy temperature, and thick, waxy leaves increase the plant's tolerance to heat and drought. The taproots can reach 2 to 3 feet deep with more than 50% of the root system present in the upper 12 inches. In north Florida, the crop cycle ranges from 180 to 200 days (November to May), depending on variety, row spacing, temperature, and rainfall during seed maturation. When planted in early November, seedling emergence and establishment occur between 7 and 20 days after planting (DAP). Fifty percent of the flowering occurs

from 110 to 125 DAP, and pod development and maturation occur between 125 and 200 DAP, depending on variety. Flowering or pod set starts from the bottom and progresses to the upper part of the inflorescence with sequential seed maturation.

Pods are 1.5 to 2 inches long with an average of 10 to 16 seeds per pod and a 1,000-seed weight ranging from 2.9 to 3.2 grams.

Agronomic Management

Nutrient Management

The nutrient requirements of carinata are similar to those of canola; therefore, the production guide to canola in Florida is referenced (Wright 2010). Soil tests are recommended to determine the fertility status and pH of the fields where carinata will be grown. Carinata, like canola, is expected to show a positive response to phosphorus (P) and potassium (K) application if recommended by the soil test results (Silveira 2014). Carinata grows best on well-drained soils with pH between 5.5 and 6.5. Without the benefit of a soil test, the suggested fertilizer application would be (in lb/ac): 80 N, 40 P_2O_5, 80 K_2O, and 25 S for a yield goal of 60 to 75 bu/ac on loamy sands, and between 100 and 120 N on deep sands. Similar to nitrogen (N), sulfur (S) is important in protein synthesis. Unlike N, S is not mobile within the plant, so a continuous supply of S is needed from seedling emergence to crop maturity. A deficiency of S at any growth stage can result in reduced yields. Split application of N and S is recommended to avoid early season deficiencies and/or excessive leaching. For sandy loam soils, apply 20 to 30 lb/ac N and 10 to 15 lb/ac S, all of the P and K fertilizers at planting, and the remaining N and S fertilizer at bolting. For deep, sandy soils, a three-way split of N and S fertilizer is recommended for maximum nutrient uptake and decreased N leaching. At planting or first plant emergence, apply 20 to 30 lb/ac N, 10 to 15 lb/ac S, 50% of the K, and all P fertilizer. Apply 20 to 30 lb/ac N, 10 lb/ac S, and the remaining 50% K at bolting. The remaining N fertilizer should be applied at early flowering. Fertilizer can be broadcast and incorporated at planting followed by topdress, sidedress, or foliar applied through center pivots at bolting and flowering. High N rates at planting or early topdress can cause carinata to have early lush growth, making it more susceptible to freeze damage. Boron deficiency occurs in coarse, sandy soils with pH greater than 7.0, or during prolonged periods of drought. Use 1 lb/ac of boron either as a preplant broadcast or an addition to N applications.

Tillage

Soil type and previous cropping history will influence the type of tillage necessary to prepare the seedbed. Reduced or minimum tillage may increase water conservation, soil organic matter, fuel efficiency, and erosion control. Carinata can be planted into conventionally or minimally tilled soil, or it may be no-till planted in standing stubble. From 2014 to 2015, chiseling to about 8-inch depths produced 8% more yield than disking and 33% more yield than no-tillage. These results were consistent with small grains' response to deep tillage. When carinata is no-till planted into sod or other row crop fields, the previous crop residue should be reduced to minimum stubble height to allow for good seed-to-soil contact.

A fine and firm seedbed allows for good seed-to-soil contact, germination, and uniform emergence. If deep tillage is used (turning plow or chisel plow), the area may need to be firmed with a roller, allowed sufficient time for a rain, or irrigated with enough water to create a firm seedbed.

Variety Selection

NFREC evaluations of advanced genotypes to identify high-yielding (seed and oil), disease-resistant, early-maturing lines adapted to the Southeast US are ongoing. According to evaluations throughout the past three years, yield ranged from 2,100 to 3,600 lb/ac. The current commercial variety, AAC A120, produced approximately 2,900 lb/ac (58 bu/ac at 50 lb/bu), which is higher than yields reported in northern US states and Canada. At 40% extracted oil content and 3,000 lb/ac of seed, carinata will yield 200 gallons of oil per acre with current genotypes having the potential to produce up to 250 gal/ac.

Figure 3. Genotype screening at NFREC, Quincy, Florida.
Credits: David Wright, UF/IFAS

Genotype evaluations in the 2014–2015 season identified promising lines with higher tolerance to cold weather, increased shatter resistance, and higher yield potential than the current commercial variety.

Planting Date

It is recommended that carinata be planted between November 1 and November 30. The best time to plant is in early- to mid-November. Earlier and later plantings may incur high incidence of freeze damage, reduced stand density, and smaller yield. Late plantings may result in increased pest damage and late harvest.

Seeding Depth

Carinata should be planted 0.5 to 0.75 inches deep because of its small seed size. That said, greater planting depths should be considered for sandy soils. Fields may be prepared with a drag attached to a cultivator frame to establish a level seedbed. Seed drills should be calibrated to ensure consistent seeding depth and rate.

Seeding Rate and Row Spacing

Carinata is a relatively large-seeded mustard (140,000 to 160,000 seeds/lb) that should be planted at 5 to 6 lb/ac with a target plant density of 8 to 12 plants per square foot. Increased plant densities may reduce the number of days needed to reach maturity. If seedbed conditions are less than optimum, higher seeding rates should be considered.

Row spacing of 7 to 14 inches is recommended. Row spacing wider than 14 inches lowers the plant's ability to compete with weeds and also results in significant yield reductions.

Weed Management

Carinata is an aggressive crop and will outcompete many winter weeds. That said, wild radish may cause a reduction in harvest value by decreasing oil quality if a significant amount of wild radish seed is included in the harvest. Fields with large amounts of wild radish should be avoided.

There are several products available for weed control (Table 1). Carinata falls into EPA Oilseed Crop Group 20 and Rapeseed Subgroup 20A (Protection to Environment 2016) where permanent tolerances for a number of selective herbicides have been published in the Federal Register, which supports regulatory approvals without additional residue research. Carinata tolerance to commercially available herbicides is still being studied.

Carinata is susceptible to residual herbicides, such as Cadre, commonly used in cotton-peanut rotations, so it is critical to consider the herbicide history of the field before planting. Herbicides used in cotton-peanut rotations may reduce carinata establishment, growth, and yield.

Table 2 provides canola's crop rotation restrictions for some of the commonly used herbicides. This table may be used as a preliminary guide for carinata rotation intervals.

Check label information for restrictions before planting carinata.

Fields meeting the crop rotation restrictions and having a recent history of applications of residual herbicides, such as Prowl (pendimethalin, Group 3), and non-residual herbicides, such as Roundup (glyphosate), Cobra (lactofen), Ultra Blazer (acifluorfen), Butyrac (2,4-DB), and Gramoxone (Paraquat), are less likely to exhibit problems with carinata establishment and growth. These herbicides may be used for preplant weed control. *Check labels before application*.

Disease Management

Carinata disease management is similar to that of canola and other mustards. Scouting for disease is a necessary preventative measure. Like other *Brassica* crops, carinata should not be grown every year on the same field but once every three years to reduce disease problems. Trials and development of recommendations for fungicide use on carinata are ongoing. Table 3 lists approved fungicides for carinata. The following are diseases found during the past three years at NFREC.

Figure 4. Fungicide application, Quincy, Florida.
Credits: David Wright, UF/IFAS

White Mold

White mold is caused by *Sclerotinia sclerotiorum*, which may infect carinata at any stage of development. It grows well in wet environments, especially after prolonged rainfall, and produces white, fuzzy growth as a first symptom. Dark or brown stem lesions may also occur. *Sclerotinia* may cause premature seed ripening, shrunken seeds, and shattering. Currently, it is not considered a serious problem in the Southeast US.

Figure 5. *Sclerotinia* stem and pod infection.
Credits: R. Seepaul, UF/IFAS

Leaf Spot

Leaf spot is caused by *Alternaria* spp., a fungus that damages leaves, stems, and pods. Symptoms begin with small, dark, circular spots that spread outward. Leaves may wilt and drop, stems may turn dark brown, and pod infection may cause seed darkening. Currently, *Alternaria* is not considered a serious problem in Florida.

Figure 6. *Alternaria* infection on leaf, stem, and pod.
Credits: R. Seepaul, UF/IFAS

Fusarium spp.

Fusarium seed rot compromises seed quality by specifically reducing oil content and test weight. Warm temperatures and extended periods of moisture promote infection and disease development at maturity. Plantings done in November seldom have a problem if harvested in a timely manner, as conditions become more favorable for *Fusarium* with June harvests. The crop should be harvested as soon as seeds are 10% moisture or less. Crop rotation is a particularly important part of disease risk reduction, because *Fusarium* survives in crop residue.

Turnip Mosaic Virus

Turnip mosaic virus symptoms include chlorotic lesions in a mosaic or mottled pattern on leaves. It may cause premature leaf drop. This disease is usually spread by aphids, which are normally not as prevalent during periods of frost or cool weather.

Figure 7. Turnip mosaic virus on carinata.
Credits: R. Seepaul, UF/IFAS

Insect Management

Since carinata is in the same family as canola, other mustards, and cabbage, it may share similar insect pests. Scouting for insect pests is a necessary management practice. Potential pests may include aphids (such as root aphid), cabbage seedpod weevil (*Ceutorhynchus obstrictus*), silverleaf whitefly (*Bemisia argentifolii*), and worm complex, which includes diamondback moth (*Plutella xylostella*), cabbage looper (*Trichoplusia ni*), and imported cabbageworm (*Pieris rapae*).

During the 2014–2015 season, the presence of diamondback moths in a few late-planted commercial fields warranted insecticide application (D. Wright, personal communication, July 2015). There is currently no data concerning thresholds, but plans to evaluate have been made. Table 3 provides a list of insecticides registered for use on carinata. *Check label for restrictions.*

Harvest Management

Harvest management practices for carinata are similar to those for canola. Among the mustards, carinata has the highest level of resistance to pod shattering. Nevertheless, timing, proper machine adjustments, and harvest methods are critical for optimum yield and quality. Normal seed desiccation progresses rapidly, indicated by a drop in

moisture content from 25% to 8% in three to four weeks. This may vary depending on the weather conditions. When the moisture content is between 8 and 10%, carinata may be combined. Upper branches and pods will be dry, but the main stem may still be slightly green. Green stems will slow down the harvesting process. Allowing the crop to fully mature first will reduce harvest time and energy expenditure. However, the main stem may still be slightly green at maturity. This will not affect harvest. It is essential to have the proper screens and combine settings to reduce dockage and loss of seed. Use the machine settings for rapeseed outlined in the operator's manual. Ongoing research shows the potential of chemical desiccants to accelerate seed drydown (D. Wright, personal communication, July 2015). Chemical desiccation with Saflufenacil (Table 1) applied when the middle and upper pods are changing color from green to olive green may help hasten carinata harvest and facilitate the timely planting of summer crops.

Economics

Production costs for carinata are very similar to those associated with canola. Preliminary economic analysis for carinata is presented in Table 4. Net returns are calculated assuming an average production cost of $275/acre.

Figure 8. Harvesting carinata using traditional combine harvester in Quincy, Florida.
Credits: David Wright, UF/IFAS

Crop Insurance

To reduce economic risks associated with carinata production, secure a crop insurance policy. Carinata became an insurable crop in the Southeast in the fall of 2015. An XC (unrated practice or type) written agreement is required to insure carinata in counties without a canola program. In counties with a canola program, a TP written agreement is required instead. An XC (county without actuarial documents) written agreement requires three years of similar crop production. Contact your crop insurance agent well before planting to inquire about registration deadlines and the requirements for your area.

Figure 9. Carinata has a production cost similar to that of canola.
Credits: David Wright, UF/IFAS

Summary

We have demonstrated the potential of carinata as an oilseed crop for the Southeast US and identified promising varieties that will be commercialized as quickly as possible. Baseline management and agronomic production practices have been developed.

Establishing carinata as a winter cash crop on underutilized or fallow land will increase diversification, generate revenue, and improve conservation of nitrogen and water, which in turn reduces input costs and increases ecosystem sustainability. Ongoing research at UF in collaboration with Agrisoma Biosciences Inc. is focused on developing region-specific agronomic production recommendations and improved carinata varieties targeted for double crop production in the southeastern US (D. Wright, personal communication, July 2015).

References

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Table 1. Registered herbicides for carinata. Always read and follow label instructions before use.

Herbicide	Weeds		Timing	Rate
Aim (Carfentrazone-ethyl EC)	Broadleaf weeds		Preplant burndown	Up to 2.0 oz/ac
Select Max, Shadow, etc.* (Clethodim)	Grass weeds		According to weed stage	Varies—see label
Roundup (Glyphosate)	Most annual and broadleaf weeds		Preplant burndown	Varies—see label
Sharpen* (Saflufenacil)	Harvest aid/desiccation		Pre-harvest, middle pods starting to turn in color	1.0 to 2.0 oz/ac
Treflan 4D, etc. (Trifluralin)	Broadleaf and grass weeds		Pre-emergence	Varies—see label
*Suppression only.				

Table 2. Crop rotation restrictions of some commonly used herbicides for canola based on product label guidelines. Always read and follow label instructions before use.

Trade name	Active ingredient	Crop rotation restriction (months)
Group 2 (ALS-inhibitors)		
Cadre	Imazapic	40
Classic	Chlorimuron	18
Permit or	Halosulfuron-Methyl	15
Sandea		
Pursuit	Imazethapyr	40
Staple	Pyrithiobac sodium	10*
Strongarm	Diclosulam	30*
Group 14 (PPO-inhibitors)		
Reflex	Fomesafen	18
Valor	Flumioxazin	4 to 18**
*With a successful field bioassay **Depending on quantity applied and tillage.		

Table 3. Registered fungicides and insecticides for carinata on product label guidelines. Always read and follow label instructions before use.

Fungicide	Disease/Pest	Timing	Rate
Aproach (Picoxystrobin)	Alternaria black spot, Sclerotinia stem rot	20 to 50% flowering, or prior to onset of disease	3 to 12 oz/ac
Endura (Boscalid)	Sclerotinia stem rot	20 to 50% flowering, or prior to onset of disease	5 to 6 oz/ac
Quash (Metconazole)	Sclerotinia stem rot	20 to 50% flowering, or prior to onset of disease	2 to 4 oz/ac
Priaxor (Fluxapyroxad + Pyraclostrobin)	Alternaria black spot, Sclerotinia stem rot*	Varies according to target disease—see label	4 to 8 oz/ac
Tilt (Propiconazole)	Alternaria black spot	Prior to bolting	2.6 to 4 oz/ac
Insecticide			
Coragen (Chlorantraniliprole)	Diamondback moth	Apply as required by scouting	Varies —see label
Mustang Maxx, Mustang Maxx EC (Zeta- cypermethrin)	Aphid, cutworm, diamondback moth, stink bug	Apply as required by scouting	Varies —see label
Prevathon (Chlorantraniliprole)	Diamondback moth, cutworm, armyworm	Apply as required by scouting	14 to 20 oz/ac
Intrepid (Methoxyfenozide)	Many insects —see label	Apply as required by scouting	2 to 24 oz/ac
*Suppression only.			

Table 4. Net returns as a function of yield and price.

Net returns per acre			
Price ($/bu)	Yield (bu/ac)		
	50	60	70
8.0	125	205	285
8.5	150	235	320
9.0	175	265	355
Calculated by R. Seepaul (2015).			