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Research Article

Simulating Winter Canola with a Process-based Model: Crop Parameters for Brassica napus

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Abstract

Canola offers promise in two aspects as a crop in wheat growing regions of the U.S.: as an energy source in the form of hydrotreated renewable jet fuel, and providing positive impacts on wheat in rotation. Efficient analysis of the feasibility of canola as a biofuel can be accomplished through the application of accurate, plant growth and yield process-based models, such as the Agricultural Land Management Alternative with Numerical Assessment Criteria (ALMANAC) simulation model. This study focused on the U.S. National Winter Canola Variety trials, which include seed yields and important management details. Plant parameters for modeling winter Argentine canola were determined from multiple canola varietal field trials conducted on 43 sites across the U.S. Yield data including that of the two most commonly grown cultivars (Safran and Sitro) were used for model parameterization and validation. The ALMANAC model realistically simulated the variability in measured yields of Safran and Sitro, which comparably had intermediate yields. However, ALMANAC over-predicted the low measured yields, and under-predicted the high measured yields. Similar results were found for locations with pooled mean yields of several cultivars. Our overall values of potential LAI of 3.5, harvest index of 0.29, minimum harvest index under drought stress of 0.13, and summed degree days of 1000, showed reasonable model performance in simulating winter Argentine canola across the continental U.S. Causes for errors at high and low measured yields warrant further study.

Keywords: *Simulation Modeling; Brassica; Oilseeds*

Introduction

Canola (*Brassica* sp.) offers promise in two aspects as a crop in wheat growing regions of the U.S.: as an energy source in the form of hydrotreated renewable jet (HRJ) fuel [1-3] and having positive impacts on the wheat it is rotated with, improving disease control, weed control, and soil drainage [4-6]. Large area production of HRJ has not been accomplished due to questions on if it can compete economically with petroleum-based fuels. Eighty percent of the production costs of biofuels from plant-derived oils are in the production of the feed-stock [7]. Efficient analysis of the feasibility of canola as a biofuel can be accomplished through the application of accurate, plant growth and yield process-based models that can predict feedstock supplies, best sites for production, size of different production areas needed to meet demand, and environmental impacts on land converted into canola production.

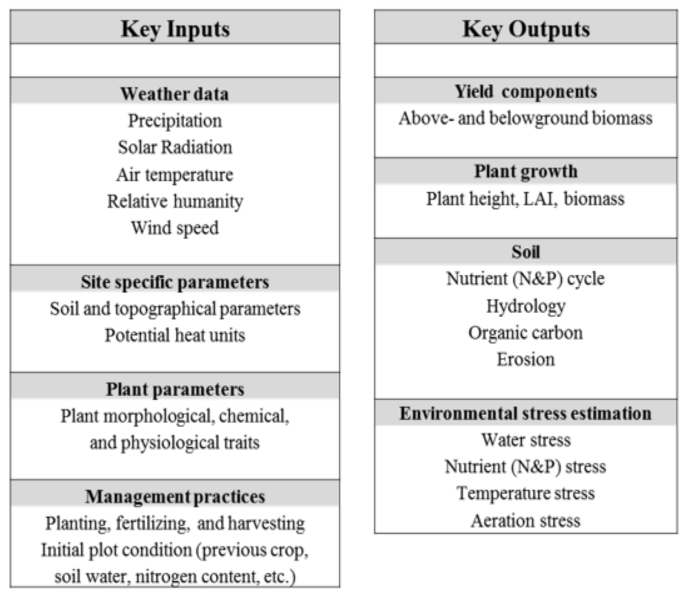
Accurate, realistic crop simulation modeling will help producers establish best practices for growing and rotating canola in winter wheat cropping systems. In addition, modeling can provide critical information about potential soil degradation, nutrient depletion, and wind erosion. Crop modeling can also track weed competition and impacts of climate change during the plants' life cycle. Canola plant parameters for both the Agricultural Land Management Alternative with Numerical Assessment Criteria (ALMANAC) [8] and the Environmental Policy Integrated Climate (EPIC) models [9,10] have been established in the northern Great Plains region for simulation modeling of spring type Argentine canola (*Brassica napus* L.) and spring type Polish canola (*Brassica campestris* L.) [11]. However, modeling parameters for varieties of winter type Argentine canola growing across the U.S. have not yet been established.

In a recent similar project in California [12], the APSIM model [13,14] was applied using yield data from canola variety trials in diverse sites in that state. APSIM is another process-based model for simulating cropping systems [13,14]. This model has simulated canola in Australia in range of conditions [13,15-22]. The National Winter Canola Variety Trial (NWCVT) data sets are a valuable means of charting the success of different cultivars of Argentine canola [23]. This study focused on the trials, which include seed yields and important management details used as we derived the winter Argentine canola plant parameters. The objectives of this study were (i) to use field data from the NWCTs across multiple sites and multiple years to develop values for key plant parameters for two common canola varieties (Safran and Sitro); (ii) if model can accurately simulate the field data, to use the developed parameters to investigate whether the model could realistically simulate high yielding and low yielding sites for Safran and Sitro canola varieties and for other groups of canola varieties in a wide range of conditions. The intended deliverables are a simulation model and associated crop parameters that realistically simulate winter canola yields across a wide range of sites on the continental U.S.

Materials and Methods

Model Descriptions

A more detailed description of the ALMANAC model is given in Kiniry., *et al.* (1992). The ALMANAC model was used to simulate canola yields at different locations in Great Plains, Midwestern, and Southern regions in the U.S. In summary, the model uses a daily time step to simulate the hydrology, erosion, soil organic carbon, nutrient cycling (N&P), canola plant growth and development from daily weather, soil properties, and plant characteristics, and management input data (Figure 1).



Key Inputs

Weather data
Precipitation
Solar Radiation
Air temperature
Relative humanity
Wind speed

Site specific parameters
Soil and topographical parameters
Potential heat units

Plant parameters
Plant morphological, chemical, and physiological traits

Management practices
Planting, fertilizing, and harvesting
Initial plot condition (previous crop, soil water, nitrogen content, etc.)

Key Outputs

Yield components
Above- and belowground biomass

Plant growth
Plant height, LAI, biomass

Soil
Nutrient (N&P) cycle
Hydrology
Organic carbon
Erosion

Environmental stress estimation
Water stress
Nutrient (N&P) stress
Temperature stress
Aeration stress

Figure 1: *Inputs and outputs of ALMANAC model.*

Deriving Model Plant Parameters

Measured yield data for 16 locations (Figure 2 and Table S1) was used to derive ALMANAC model key plant parameters based on two common canola varieties (Safran and Sitro) present in multiple sites and multiple years. The sixteen locations had at least four years of participation in the NWCVTs [23-33]. The average annual dry seed yield for the canola varieties was calculated assuming a standard 9% seed moisture content. This yield data was used to test how well the estimated plant parameters incorporated into the ALMANAC model could be applied to simulate the measured canola yields across the 16 sites. In an earlier study, Kiniry., et al. [11] showed that spring canola frost parameters for both Argentine and Polish canola resulted in a 5% loss in leaf area for each day the minimum temperature reached -5°C, while 10% of the leaf area was lost for each day the minimum temperature reached -15°C. We set the new frost parameters for winter canola similar to those of winter wheat [11], which resulted in winter canola plants losing 1% of their leaf area for each day the minimum temperature reached -15°C, and 10% leaf area loss for each day the minimum temperature reached -30°C.

Sites used to derive Safran and Sitro parameters

1. Clovis, NM
2. Enid, OK
3. Farmington, NM
4. Fruita, CO
5. Garden City, KS
6. Goodwill, OK
7. Hutchinson, KS
8. Griffin, GA
9. Orange, VA
10. Meridianville, AL
11. Vincennes, IN
12. Yellow Jacket, CO
13. Belleville, IL
14. Carbondale, IL
15. East Lansing, MI
16. Fremont, OH

Test locations for Safran and Sitro

17. Petersburg, VA
18. Manhattan, KS
19. Marianna, AR
20. Russellville, KY
21. Torrington, WY
22. Auburn, AL
23. Lubbock, TX
24. Lingle, WY
25. Chillicothe, TX
26. Othello, WA

Test locations for other varieties

27. Akron, CO
28. Bozeman, MT
29. Clearwater, KS
30. Columbia City, IN
31. Custar, OH
32. Etter, TX
33. Kalispell, MT
34. Kibler, AR
35. Lamberton, MN
36. Lincoln, NE
37. Marquette, KS
38. Princeton, KY
39. Reidsville, NC
40. Rocky Ford, CO
41. Spring Hill, TN
42. Suffolk, VA
43. Walsh, CO

Figure 2: *Map of locations used in the study. Green, red, and blue colored number indicate Sites used to derive two canola varieties (Safran and Sitro) plant parameters, test location for two canola varieties (Safran and Sitro), and test location for other canola varieties, respectively.*

Site	County	Soil Type	Soil depth (m)	Plant available water	Runoff curve number	Average annual rainfall	Use of irrigation
Great Plains							
Clovis, NM	Curry	Olton clay loam	2.03	0.21	85	526	Yes
Enid, OK	Garfield	Bethany silt loam	2.03	0.25	85	1011	Yes
Farmington, NM	San Juan	Doak sandy loam	1.52	0.21	85	199	Yes
Fruita, CO	Mesa	Fruita clay loam	1.52	0.19	85	341	Yes
Garden City, KS	Finney	Ulysses silt loam	2	0.28	85	782	Yes
Goodwill, OK	Texas	Gruver clay loam	1.73	0.2	85	493	Yes
Hutchinson, KS	Reno	Ost Clark loam	2.03	0.29	85	1193	No
Lingle, WY	Goshen	Harveson sandy loam	1.52	0.23	78	1386	Yes
Manhattan, KS	Pottawatomie	Smolan silt loam	2	0.24	85	1234	No
Othello, WA	Adams	Neppel sandy loam	1.52	0.07	78	161	Yes
Torrington, WY	Goshen	Harverson and McCook loam	1.52	0.23	78	1331	Yes
Yellow Jacket, CO	Montezuma	Weatherill loam	1.52	0.22	85	348	Yes
Midwestern							
Belleville, IL	St. Clair	Winfield silt loam	2.03	0.3	85	995	No
Carbondale, IL	Jackson	Stoy silt loam	2	0.29	89	1016	No
East Lansing, MI	Ingham	Capac loam	1.52	0.2	89	1949	No
Fremont, OH	Sandusky	Hoytville clay loam	2.03	0.13	89	972	No
Marianna, AR	Lee	Loring silt loam	2.03	0.31	85	1066	No
Orange, VA	Orange	Starr silty loam	1.52	0.2	78	1540	No
Petersburg, VA	Dinwiddie	Ackwater silt loam	1.83	0.17	89	1056	No
Russellville, KY	Logan	Pembroke silt loam	2	0.23	78	1129	No
Vincennes, IN	Knox	Vincennes loam	1.52	0.21	85	1445	No
Southern							
Auburn, AL	Lee	Marvyn loamy sand	1.83	0.16	78	1435	No
Chillicothe, TX	Hardeman	Abeline clay loam	1.52	0.1	85	722	No
Griffin, GA	Spalding	Cecil sandy loam	1.91	0.15	89	10183	No
Lubbock, TX	Lubbock	Amarillo fine sandy loam	2.03	0.16	78	503	Yes
Meridianville, AL	Madison	Decatur silty clay loam	2.03	0.17	78	1222	No
Test							
Akron, CO	Washington	Weld silt loam	1.52	0.22	85	416	No
Bozeman, MT	Gallatin	Amesterdam silt loam	1.52	0.23	85	2756	Yes
Clearwater, KS	Sedgwick	Nalim loam	2	0.2	85	1091	No
Columbia City, IN	Whitley	Blout silt loam	1.63	0.23	78	1375	No
Custar, OH	Wood	Hoytville clay loam	2.03	0.13	89	1049	No
Etter, TX	Moore	Sherm silty clay loam	1.83	0.2	85	663	Yes
Kalispell, MT	Flathead	Mitten gravelly ashy silt loam	1.52	0.1	78	1336	Yes
Kibler, AR	Crawford	Wrightsville silt loam	1.78	0.17	89	937	Yes
Lamberton, MN	Redwood	Amiret loam	2	0.28	67	1932	No
Lincoln, NE	Lancaster	Crete silt loam	1.52	0.19	85	1286	Yes
Marquette, KS	McPherson	Smolan silty clay loam	2	0.24	85	976	No
Princeton, KY	Caldwell	Zainsville silt loam	1.77	0.22	85	1334	No
Reidsville, NC	Rockingham	Clifford sandy clay loam	2.03	0.2	78	1158	No
Rocky Ford, CO	Otero	Rocky ford silty clay loam	2	0.24	85	365	Yes
Spring Hill, TN	Williamson	Mountview silt loam	2	0.38	85	1222	No
Suffolk, VA	Holland	Rains fine sandy loam	1.65	0.16	89	1234	No
Walsh, CO	Baca	Baca clay loam	2	0.26	78	797	Yes

Supplemental Table 1: *County, soil, rainfall, and irriagtion information for each location used in the study.*

Citation: JR Kiniry., *et al.* “Simulating Winter Canola with a Process-based Model: Crop Parameters for *Brassica napus*". *EC Agriculture* 4.2 (2018): 79-89.

We conducted simulations for canola as a cool season annual with a maximum potential leaf area index (DMLA) value of 3.5 [the same as for spring Polish canola of Kiniry., et al. [11] and 1000 potential heat units (PHUs). DMLA values ranging from 3.36 - 3.50 in spring Argentine canola field trials in IA, MN, and ND were reported in unpublished data by Dan Long in 2013, 2104, and 2015. The HI was systematically adjusted until the ALMANAC yields were closest to the reported yields. The HI value used was 0.23 and the minimum harvest index under drought stress (WSYF) was set to 0.22 for both varieties and all locations. Kiniry., et al. [11] used HI values of 0.3 for spring Argentine canola and 0.23 for spring Polish canola, while WSYF was set at 0.17.

Model Simulations Set-up

Model simulation management practices describing the actual field operations, such as, the mean plant and harvest dates were based on practices applied in the NWCVTs. Soils [downloaded from the USDA NRCS Soil Survey Geographic (SSURGO) soils website [34] and weather data [downloaded from the National Oceanic and Atmospheric Administration (NOAA) website [35] for all 16 locations were compiled and input into the model. The soil type, soil depth, runoff curve number, average annual rainfall, and use of irrigation for all locations are listed in table S1. ALMANAC model simulations for Safran and Sitro seed yields were conducted for the 16 locations over multiple years as represented in the NWCVTs.

Given the wide range of canola varieties and site locations in the NWCVTs, we investigated potential genotype by environment interaction in the measured yields by ranking the sites by measured yields, then calculating the ratio of mean Safran yield divided by mean Sitro yield at each site. These ratios were then plotted as a function of mean measured yields and the least-squares regression fit to the data.

Testing parameters over a wider range of measured yields of sitro and safran varieties

In the second part of the study, we included 10 more locations containing Sitro and Safran yields. The additional 10 locations had higher and lower measured yields than in the original dataset. The mean yield was calculated for these additional locations as described previously. Planting date is critical for winter canola survival and varies by location. Planting date can influence vigor and winter survival [36]. ALMANAC simulations were run based on the mean planting and harvest dates for all sites, and the soil and weather data for each location. The same cool season annual crop parameters were applied to further demonstrate the performance of the derived crop parameters.

Testing parameters derived for sitro and safran using data from 17 additional sites with groups of other varieties

These locations were chosen based on region and years of participation in the NWCVTs. The 17 additional sites did not have measured data for Sitro and Safran. The sites had a similar wide range of environmental conditions and latitudes as in the previous set. The ALMANAC simulated yields were compared to the means of all measured yields. This trial was to test how accurately derived parameters performed when simulating mean yields of a group of different canola varieties.

Results

Genotype by environment interaction in the measured yields of safran and sitro

There was no obvious genotype by environment interaction for these two varieties at the 16 original sites. The measured yield ratios of these two varieties showed no trend with increasing mean reported yields (Figure 3). The slope of the regression line was -0.072 and the R^2 was only 0.05. So, there was no apparent G X E for the simulation model to attempt to simulate in this study.

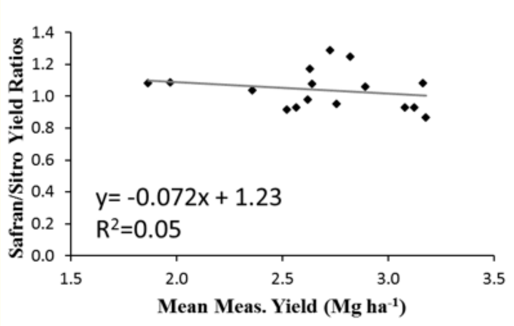


Figure 3: *Genotype by environment interaction for measured yields of two canola varieties, Safran and Sitro. The mean Safran: Sitro measured yield ratio was 1.03.*

Derived simulation parameters for safran and sitro

Because of the similarity in yields of the two varieties, one set of parameters was derived to simulate both varieties. The potential heat units (PHUs) from planting to maturity were 1000 in all cases. The PHUs from planting to maturity were 1000 in all cases. The DMLA was set to 3.5 for all simulations, while the HI was set to 0.29, with the lower limit for HI under drought stress (WSYF) set to 0.13 in all cases. The radiation use efficiency (WA) was set to 3.4g per MJ intercepted photosynthetically active radiation for all runs. Based on the ALMANAC model simulation outputs, the derived parameters could reasonably describe plant growth and yields of canola across multiple locations and years.

Results for parameter derivation of sitro and safran at 16 sites

The ALMANAC model more realistically simulated measured yields greater than 2.5 Mg ha^{-1} than for smaller measured yields of both cultivars (Table 1). For Safran, the mean simulated: measured ratio for Safran was 1.04 for the larger range of measured yields and was 1.31 for the smaller range. For Sitro, these ratios were 1.05 and 1.42, respectively. The mean simulation errors for Safran and Sitro were 0.34 Mg ha^{-1} and 0.33 Mg ha^{-1}, respectively. The RMSE for Safran was 0.80 Mg ha^{-1} and 0.85 Mg ha^{-1} for Sitro.

	Safran canola variety			**Sitro canola variety**		
	Msrd. Yields	**Sim. Yields**	**Sim**	**Msrd. Yields**	**Sim. Yields**	**Sim**
	Mg ha^{-1}	**Mg ha^{-1}**	**/Msrd.**	**Mg ha^{-1}**	**Mg ha^{-1}**	**/Msrd.**
< 2.0 msrd. yields						
Enid OK	1.94	3.33	1.72	1.79	3.23	1.80
East Lansing MI	na	na	na	1.89	2.17	1.15
Means	1.94	3.33	1.72	1.84	2.7	1.47
2.0 to 2.5 msrd. yields						
East Lansing MI	2.05	2.31	1.13	na	na	na
Vincennes IN	2.4	3.34	1.39	2.31	3.34	1.45
Carbondale IL	na	na	na	2.38	3.37	1.42
Goodwell OK	2.41	2.41	1.00	na	na	na
Meridianville AL	na	na	na	2.42	3.05	1.26
Auburn AL	2.47	3.28	1.33	na	na	na
Means	2.33	2.83	1.21	2.37	3.25	1.38
2.51 to 3.0 msrd. yields						
Griffin GA	2.59	2.87	1.11	2.65	2.65	1.00
Chillicothe TX	2.69	2.64	0.98	2.82	2.64	0.94
Garden City KS	2.74	4.26	1.56	2.54	4.34	1.71
Meridianville AL	2.84	3.03	1.06	na	na	na
Auburn AL	na	na	na	2.66	3.28	1.23
Goodwell OK	na	na	na	2.63	2.25	0.86
Fremont OH	2.95	3.29	1.12	na	na	na
Bellville IL	2.97	1.6	0.54	na	na	na
Orange VA	2.97	3.21	1.08	2.81	3.32	1.18
Lingle WY	na	na	na	2.51	3.12	1.24
Means	2.82	2.99	1.06	2.66	3.08	1.17
> 3.0 msrd. yields						
Fruita CO	3.01	2.79	0.93	3.24	3.05	1.01
Carbondale IL	3.07	3.43	1.12	na	na	na
Bellville IL	na	na	na	3.19	1.60	0.50
Fremont OH	na	na	na	3.41	3.11	0.91
Lingle WY	3.13	3.12	1.00	na	na	na
Clovis NM	3.28	2.96	0.90	3.04	2.96	0.97
Means	3.12	3.08	0.99	3.22	2.68	0.85

Table 1: *Sites with data used for deriving crop parameters for Safran and Sitro canola varieties, comparison of measured (msrd.) and simulated (sim.) yields by the ALMANAC model.*
na indicates no data available.

Test results for sitro and safran for 10 sites with a wider range of measured yields

For Safran and Sitro (Table 2) simulation errors showed similar trends as above, with the ALMANAC model simulating more realistically for higher measured yields. For measured yields greater than 2.5 Mg ha^{-1}, the mean ratios of simulated to measured yields were 0.86 for Safran and 0.875 for Sitro. Measured yields less than 2.5 Mg ha^{-1} had mean ratios of 1.17 for Safran and 1.31 for Sitro.

	Safran canola variety			Sitro canola variety		
	Msrd. Yields	**Sim. Yields**	**Sim**	**Msrd. Yields**	**Sim. Yields**	**Sim**
	Mg ha^{-1}	**Mg ha^{-1}**	**/Msrd.**	**Mg ha^{-1}**	**Mg ha^{-1}**	**/Msrd.**
< 2.0 msrd. yields						
Petersburg VA	1.48	0.93	0.63	1.63	0.90	0.55
Hutchinson KS	na	na	Na	1.73	3.37	1.95
Lubbock TX	na	na	Na	1.88	3.14	1.68
Means	1.48	0.93	0.63	1.75	2.47	1.39
2.0 to 2.5 msrd. yields						
Hutchinson KS	2.06	3.19	1.55	na	na	na
Manhattan KS	2.08	3.07	1.48	2.16	3.07	1.42
Yellow Jacket CO	2.16	1.9	0.88	2.08	2.13	1.02
Marianna AR	2.32	2.67	1.15	2.12	2.64	1.24
Lubbock TX	2.33	3.14	1.35	na	na	na
Means	2.19	2.79	1.28	2.12	2.62	1.23
2.51 to 3.0 msrd. yields						
Torrington WY	na	na	Na	2.54	2.73	1.07
Means	na	na	Na	2.54	2.73	1.07
> 3.0 msrd. yields						
Torrington WY	3.05	2.73	0.89	na	na	na
Othello WA	3.98	2.93	0.73	3.98	2.93	0.73
Russellville KY	4.12	3.53	0.85	3.86	3.01	0.78
Farmington NM	4.27	4.07	0.95	4.41	4.07	0.92
Means	3.86	3.31	0.86	4.08	3.34	0.81

Table 2: *Sites with data used for testing derived crop parameters for Safran and Sitro canola varieties, comparison of measured (msrd.) and simulated (sim.) yields by the ALMANAC model.*

na indicates no data available.

For both cultivars, the simulated yields showed significant positive relationships between simulated yields and measured yields (Figure 4). For Safran, the R2 value was 0.48 and for Sitro the R^2 value was 0.28. The regression lines were close to the one: one line.

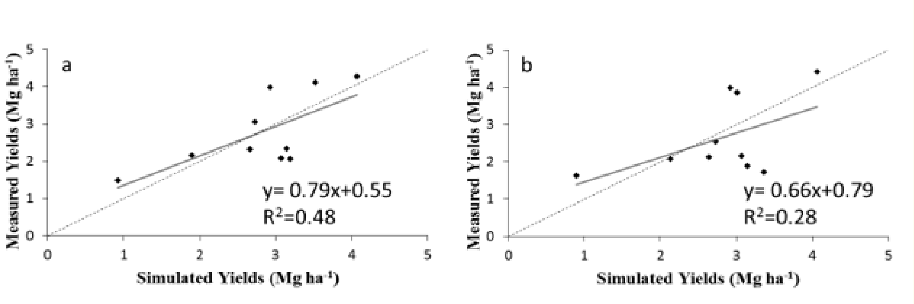


Figure 4: *Plots of simulated and measured yield for Safran (a) and Sitro (b) canola varieties at model testing sites. Solid black line is fitted regression line, and grey dash line is the 1:1 line.*

Test Results for Pooled Variety Yields for 17 Additional Sites with a Wide Range of Measured Yields

For pooled variety yields (Table 3), simulation errors again showed trends similar to above, with sites having larger measured yields showing simulated yields closer to measured yields. Sites with measured yields greater than 2.5 Mg ha^{-1}, had a mean for simulated: measured of 0.91 with sites having smaller measured yields having a mean ratio of 1.66. The mean error (simulated - measured) was 0.69 Mg ha^{-1} and the RMSE was 0.93 Mg ha^{-1}.

Discussion

Our objective to establish standardized crop parameters for winter Argentine canola was met on a national level. Our overall values of DMLA of 3.5, HI of 0.29, WSYF of 0.13, and PHUs of 1000, can be used as reasonable parameters for simulating winter Argentine canola across the continental U.S.

It appears from these results that one set of parameters is adequate to simulate canola over this wide range of locations when the measured average yields are greater than 2.5 Mg ha-1. Causes for the over-estimated simulated yields for the low yielding locations warrant further investigation. There are many possible causes for the low measured yields, some of which are not captured in the model simulations: poor plant establishment, seed shattering, diseases and pests are just but a few of some of the potential problems that can reduce yield. Such processes are not adequately simulated by this model and thus could cause yield over-predictions similar to what we witnessed in this study. There was also a tendency of underestimation of yields that were very high. Causes of under-estimated predictions in the high yielding sites in these data sets are not so easily explained. It would be interesting to further investigate the production of these high yields at these sites by more extensive yield and crop parameter measurements during the growing season.

The derived parameters can be considered as starting points for the simulation of a wide range of varieties that exist for winter Argentine canola. Many independent factors can influence the success or failure of each of these varieties such as soil, fungicides and pesticides use, weather, erosion, and quality of seed. This study tried to encompass many of these factors, despite the fact that each location had successful and unsuccessful varieties due to different seed sources.

Although some of our findings, in particular, the HI and WSYF values for winter Argentine canola, may at first appear to contrast with the previously published spring Argentine and Polish HI and WSYF values [11], once the frost/plant interactions were changed, we found that the HI was similar to Kiniry's spring Polish canola HI of 0.23, but lower than the spring Argentine canola HI of 0.3 [11]. The 1000 PHUs value for our winter Argentine canola also fell within the spring Argentine canola published range of 1000 - 1200 [11].

The results of this project can be viewed by as a failure and a success. The variability in measured yields across locations was poorly accounted for at best. Looking at the simulated yields by group with each measured yield group, for the parameter development datasets, the mean simulated values by group failed to even show consistent increases in parallel with the increased mean measured yields. However, for the two test data set groups for the two cultivars, the model accounted for 28% and 48% of the variability in measured yields and the regressions showed positive slopes and were close to the 1:1 line.

Apparent failure again was evident when we tried to simulate mean yields of several cultivars. The mean simulated values by groups failed to consistently increase with increasing measured yield groups. Thus, the results of this project were a success for researchers wanting reasonable parameters for simulating yields and best practices for growing and rotating canola in winter wheat cropping systems with the ALMANAC model or similar process-based models looking at outputs such as water use, nutrient demands, and soil erosion. Realistic simulation of yields across different stress environments will, however, require better determination of what the yield-limiting stresses are and whether the stresses are adequately accounted for by the applied model.

Conclusion

This study used field data from trials conducted with two canola (*Brassica napus* L.) varieties, Safran and Sitro, to test the ability of a process-based model, ALMANAC, to simulate canola production in multiple sites across U.S. The ALMANAC model was able to moderately simulate yields of Safran and Sitro canola varieties in diverse regions. The developed parameters derived for Safran and Sitro were consequently used to predict the yields of other canola varieties in 17 other sites. The ALMANAC model was able to accurately predict higher mean yields, while the model overestimated for the lower mean yields. To increase accuracy in simulation, the additional soil data such as nutrient, organic matter, and biomass residual content measured from field trial is needed as input data for ALMANAC model. The model, by reasonably simulating canola yields under many conditions, will be useful for evaluating economics of canola production, environmental aspects including soil erosion and associated water quality questions of canola production, and water requirements of this crop. The model will be useful for assessing long term trends in soil erosion and soil quality associated with canola production.

Data Availability

The data used in this study is available from the corresponding author on request.

Conflicts of Interest

The author declares that there is no conflict of interests regarding the publication of this paper.

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