Simulating Alfalfa Growth Dynamics of Fall Dormancy Classes across Environments

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OBJECTIVES OF THIS TALK

- Introduce the CROPGRO perennial forage model, and how its read-in species and cultivar files can describe different species and cultivars, including alfalfa (legume).
- Describe physiology, storage organ features, and growth dynamics needed for a perennial forage that allow multiple harvests and re-growth.
- Describe typical outputs: herbage mass, herbage N, crude protein, and percent leaf of herbage per harvest.
- Describe parameterization of Fall Dormancy classes of alfalfa cultivars and resulting performance for three FD class cultivars grown in Arizona, Montana, & Canada.

CROPGRO-Perennial Forage Model

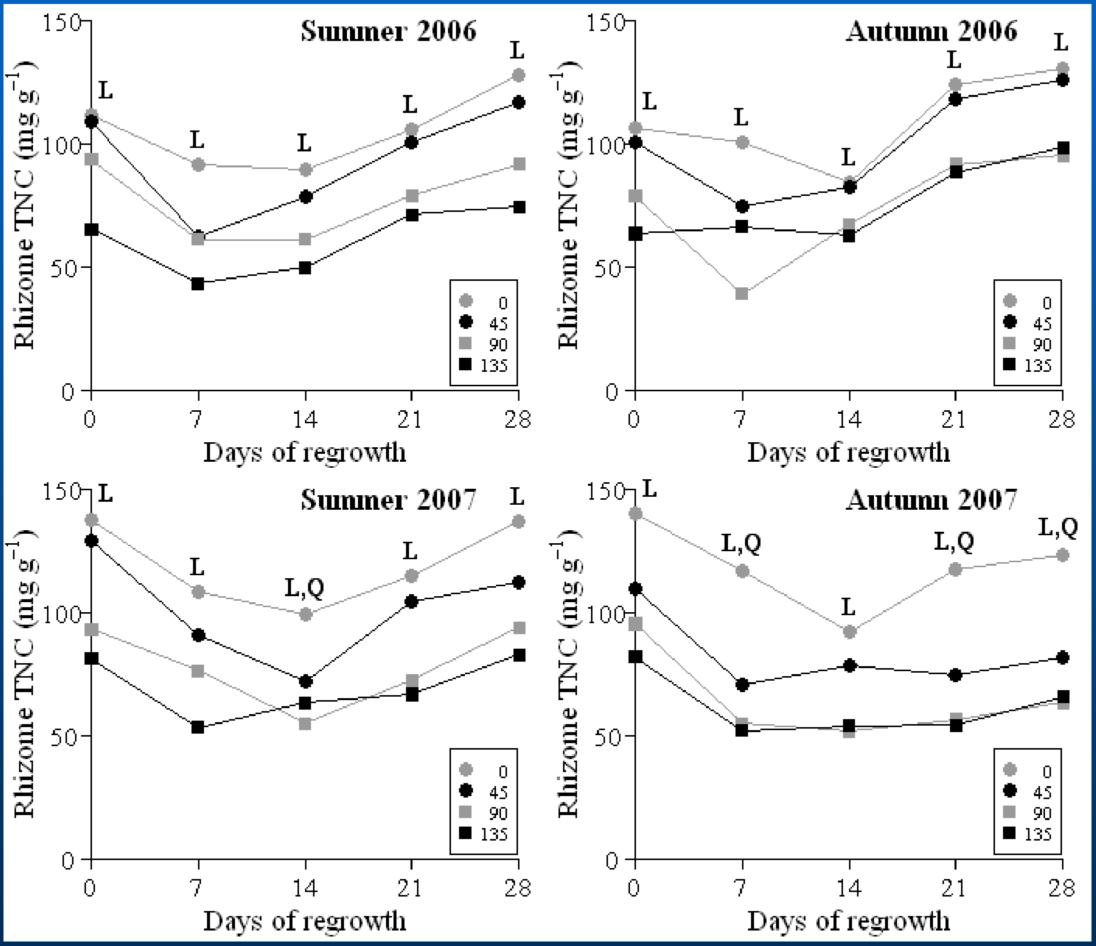
- Derived from CROPGRO model (1992-2004)
- Coded for perennial and storage organ dynamics by Stuart Rymph, UF, 2004, & adapted for *Paspalum notatum.* *(*See Rymph Ph.D. dissertation, UF, 2004)
- Adapted for *Cynodon dactylon* by K. Boote and P. Alderman (M.S. thesis, UF, 2007)
- Adapted for *Brachiaria brizantha* (B. Pedreira, 2011 FCR)
- Adapted for *Panicum maximum* by M. Lara (2012 Agron. J.)
- Initially adapted for alfalfa (Malik et al, 2018 Agron J.).
- Evaluated for alfalfa in Canada (Jing et al., 2020 EJA)
- Released in DSSAT V4.7 and V4.8 for *Brachiaria,* alfalfa

Code Needed for Perennial

- Created: ability to re-grow based on reserves despite zero LAI. Creates memory of poor prior management (low reserves). Winter dormancy.
- Added new state variable (stolon-rhizome-taproot "storage") with TNC and N concentration
- Added rules for partitioning DM, N, and TNC to storage tissue as f(daylength, LAI, Ps, etc.)
- Added rules for mobilization of C and N reserves from storage for re-growth as f(daylength, LAI, Ps, etc.)

Re-growth depends on residual LAI, storage reserves (mass, TNC & N status), time of year

- **Alfalfa** – LAI near zero after harvest
- **Tifton 85 bermudagrass** also has low LAI after defoliation - rhizomes show **cycles of TNC** to **minimum at 7-14 days**, then recovery during re-growth after defoliation (Alderman et al., 2011).
- **5-15% TNC, and 5-6 mt rhizome**
- **Stems** – same dynamics



Additional input requirements: for "MOW" file

- Dates of harvest events:
- MOW: mass of residual living aboveground stubble (kg/ha) after each harvest event. If "missing", interpolate between dates to set stubble mass
- Percent leaf of the "living" stubble. Ignores "dead"
- MVS: leaf # "re-stage" after each harvest

@TRNO	DATE	MOW	RSPLF	MVS
1	18064	800	20	3
1	18094	900	20	3

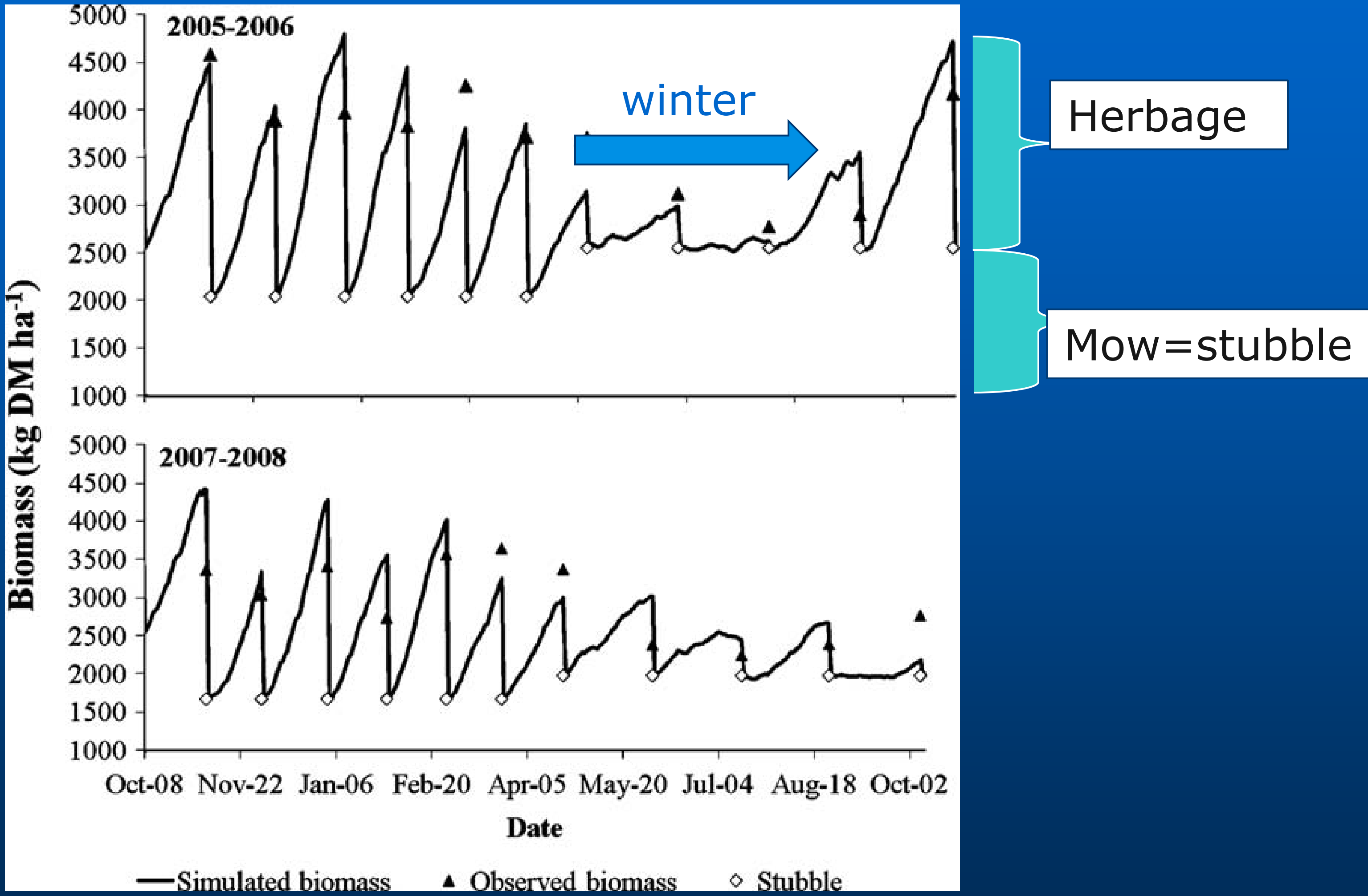
Forage-Related Outputs

In addition to typical LAI, leaf, stem, storage, root, and % N of these organs

Different from typical models

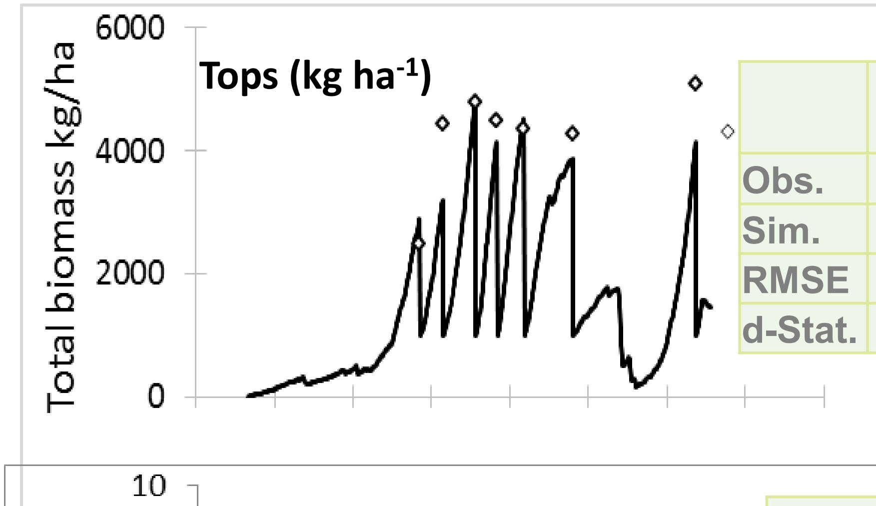
- Herbage = (shoot – stubble)
- Herbage N = (shoot N – stubble N)
- Herbage N conc (~CP) = herbage N / herbage mass
- Herbage %leaf
- Output herbage, herbage N, CP, and herbage % leaf in PLANTGRO.OUT and in a FORAGE.OUT file
- Output abscised dead shoot, leaf, and stem since last harvest in PLANTGRO.OUT

Simulated vs. observed biomass in 2 seasons at Piracicaba, Brazil. *Brachiaria brizantha Xaraes* (Pedreira et al., 2011)

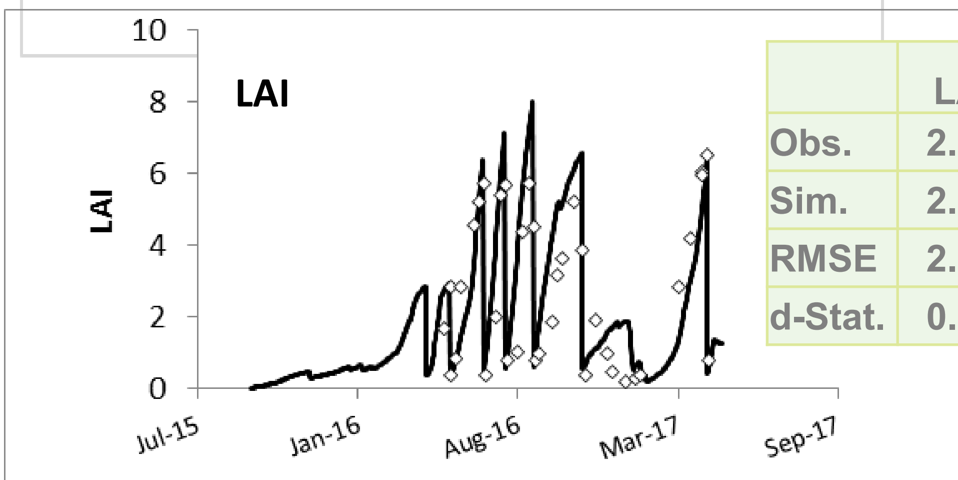


Wafa Malik: Adapting CROPGRO-PFM for Alfalfa

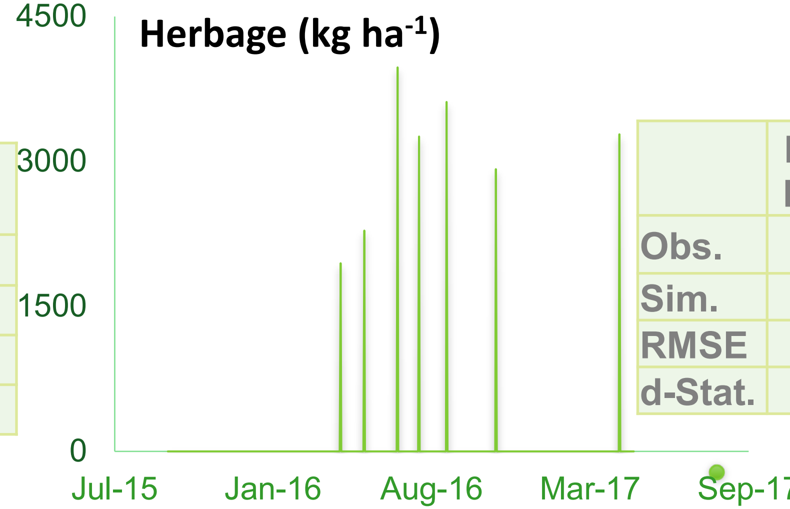
Example Outputs: Aragon, Spain



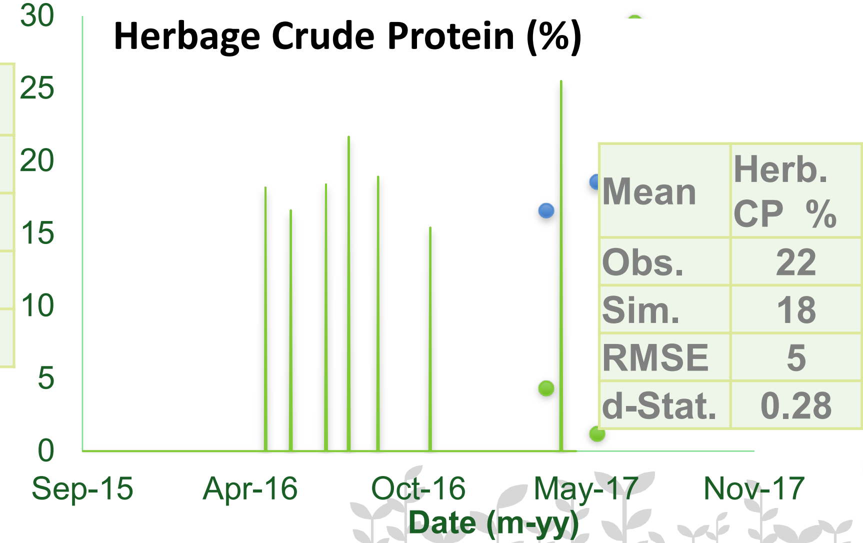
	Tops kg/ha
Obs.	4281
Sim.	3948
RMSE	642
d-Stat.	0.8



	LAI
Obs.	2.83
Sim.	2.49
RMSE	2.13
d-Stat.	0.73



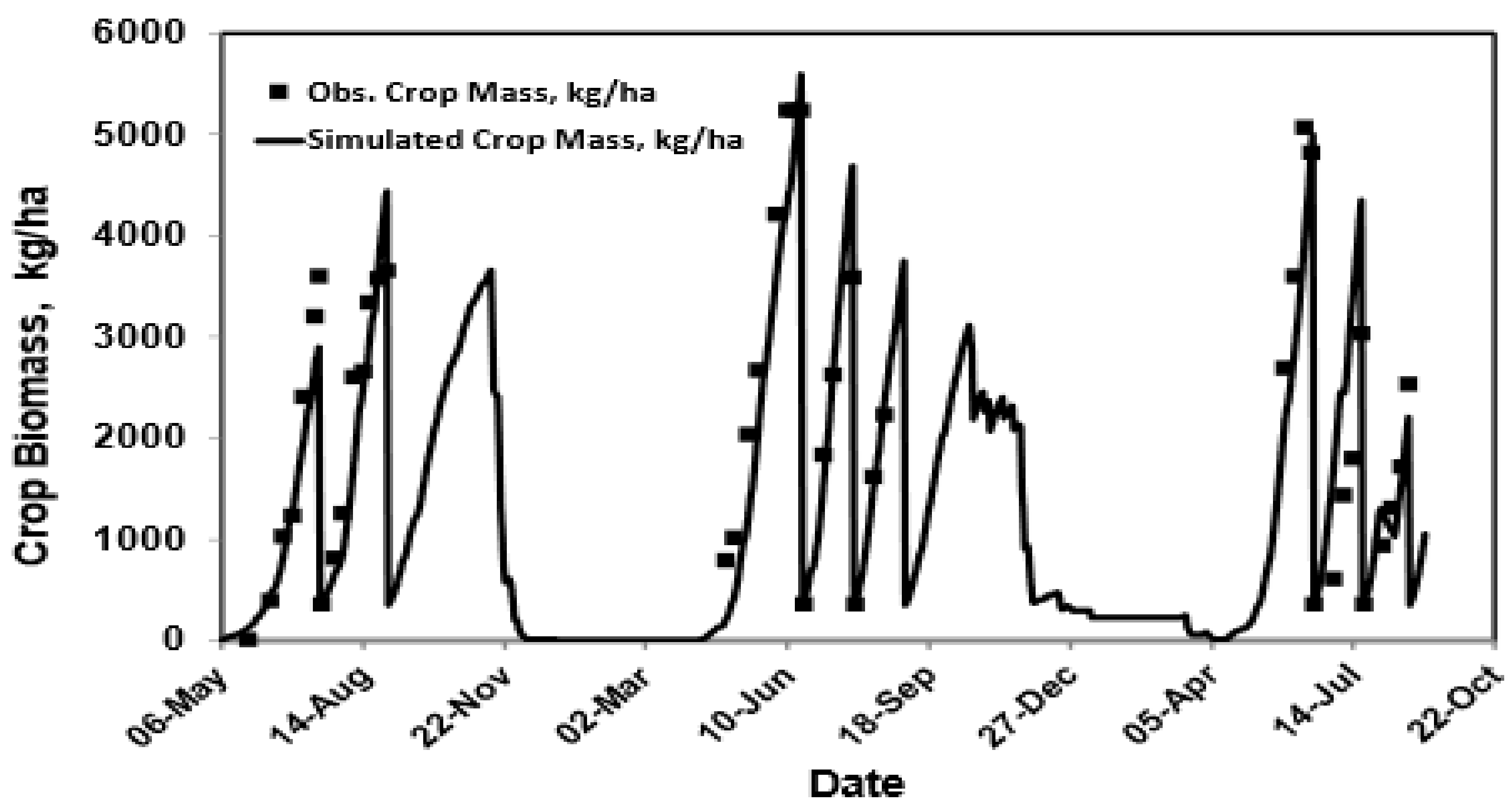
	Herb. kg/ha
Obs.	3281
Sim.	3040
RMSE	594
d-Stat.	0.82



Mean	Herb. CP %
Obs.	22
Sim.	18
RMSE	5
d-Stat.	0.28

Model starts from seed. Has seedling & established partitioning. Uses Tb=1, 3, and 4 C for leaf Ps, time to flower, & node appearance Has nodules & N-fixation. Uses FAO-56 for ET, CENTURY for SOC.

Figure 1. CROPGRO-Alfalfa simulation of CFIA (FD4) during 2014, 2015, 2016 at Ottawa, Canada (Jing et al., 2020)



Modifying ecotype/cultivar to mimic FD classes 1-10

- Daylength effect: partitioning to storage, 9.8 h (max rate) to 14.2 h (min rate). Strength set by RDRMT (strong)
- Daylength on mobilization from storage, 9.9 h min to 13.9 h max. Strength set by RDRMM (minor importance)
- Vary light-saturated Ps, by 0.02 mg CO2/m2/s per FD
- Vary TRIFOL, rate of leaf appearance per ptd, 0.01 per FD

Fall Dormancy	Cultivar	RDRMT	RDRMM	LFMAX	TRIFOL
2	Max Graze, FSG229CR	0.560	0.950	1.30	0.20
3	Oneida*, Rugged* Big Sky Lada	0.500	0.950	1.32	0.21
4	Apica*, Magnum 7	0.440	0.950	1.34	0.22
5	PGI 557	0.380	0.950	1.36	0.23
6	Cisco II*,HI Gest 660	0.320	0.850	1.38	0.24
7	SW 7410	0.260	0.850	1.40	0.25
8	Pacifico	0.200	0.850	1.42	0.26
9	CUF101*	0.140	0.850	1.44	0.27
10	?	0.080	0.850	1.46	0.28

Experiments: FD classes within alfalfa cultivars (NIFA grant)
I. Kisseka, M. Ottman, J. Torrion, K. Boote, G. Hoogenboom

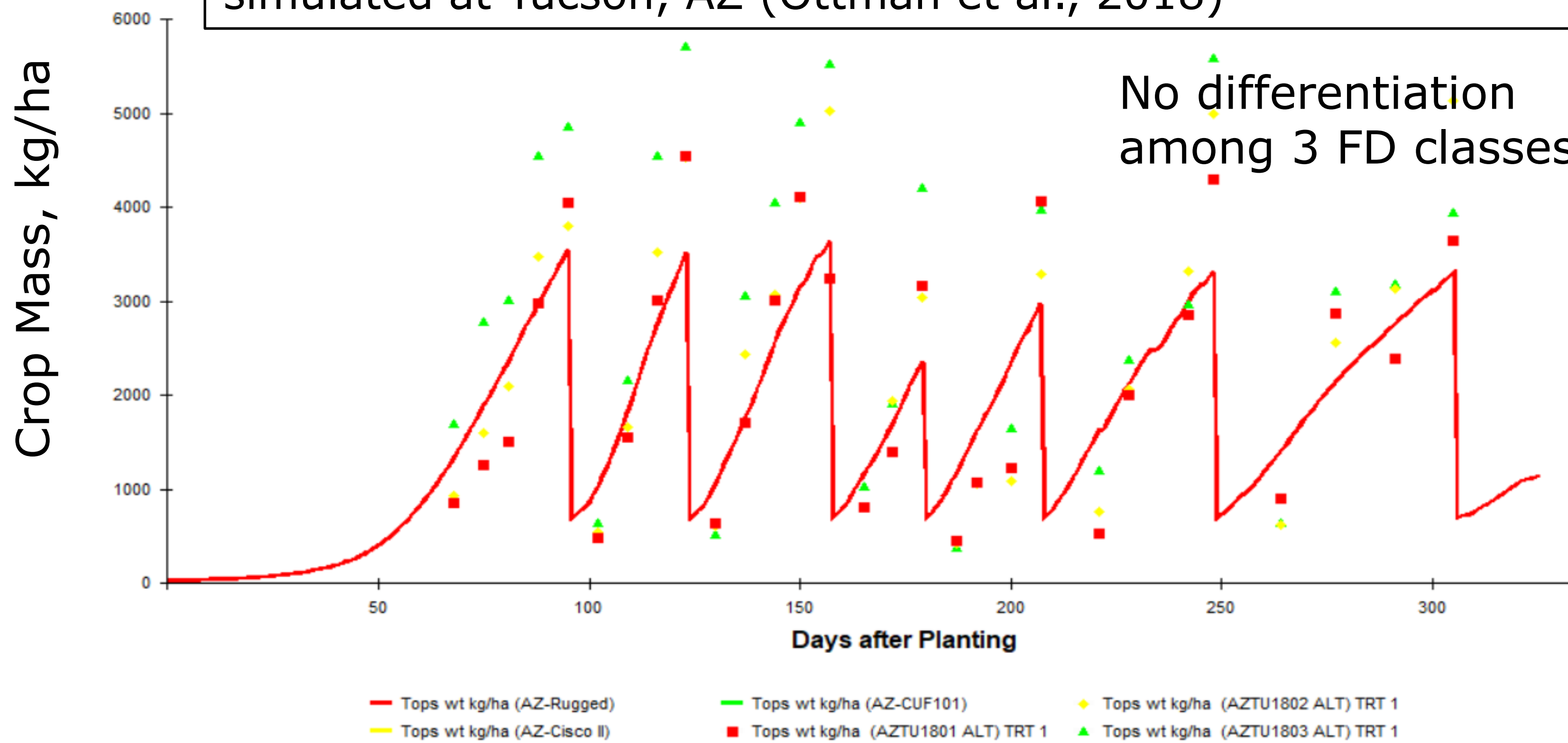
M. Ottman, Tucson,AZ Fall dormancy	Entry	J. Torrion, Montana Fall dormancy	Entry	Jing et al. Canada Fall dormancy	Entry
3	Rugged*	2	Maxi Graze	3	Oneida
4	Magnum 7	2	FSG229CR	4	Apica
5	PGI 557	3	Rugged*		
6	Cisco II*	3	Big Sky Ladak		
7	SW 7410	6	Cisco II*		
8	Pacifico	6	Hi gest 660		
9	CUF 101*				

Weekly samples on LAI, leaf, stem, total biomass between harvests for 7 cuttings in AZ and 2 cuttings in MT, on Rugged, Cisco II, and CUF101 Jing et al. in Canada, 6 sites with multiple harvests and multiple years.

Fall Dormancy classes within alfalfa in AZ (NIFA grant)

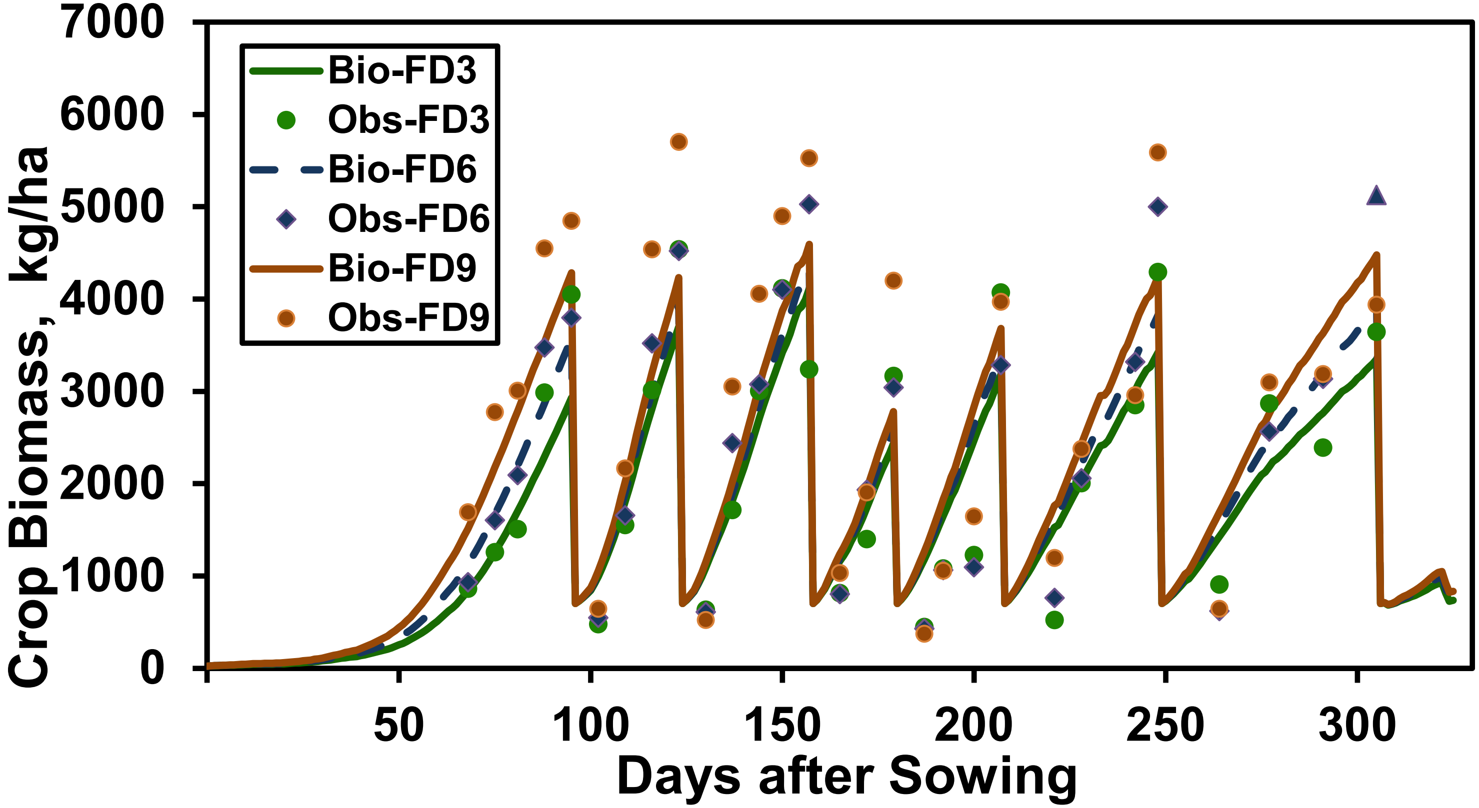
I. Kisseka, M. Ottman, J. Torrion, K. Boote, G. Hoogenboom

Default Model: Prior to setting Fall Dormancy classes: with default daylength 11.1-12.2 h, RDRMT 0.421 of Aragon, simulated at Tucson, AZ (Ottman et al., 2018)



Simulated (lines) and observed crop mass (symbols) after setting fall dormancy (FD) classes for alfalfa cultivars grown in Arizona in 2018 (Ottman et al., 2018).

FD class: Rugged (**green,3**), Cisco II (**blue,6**), CUF101 (**brown 9**), with new daylength FNPTD 9.8 14.2 h, **RDRMT**: **0.500 Rugged**, **0.320 Cisco II**, **0.140 CUF101**



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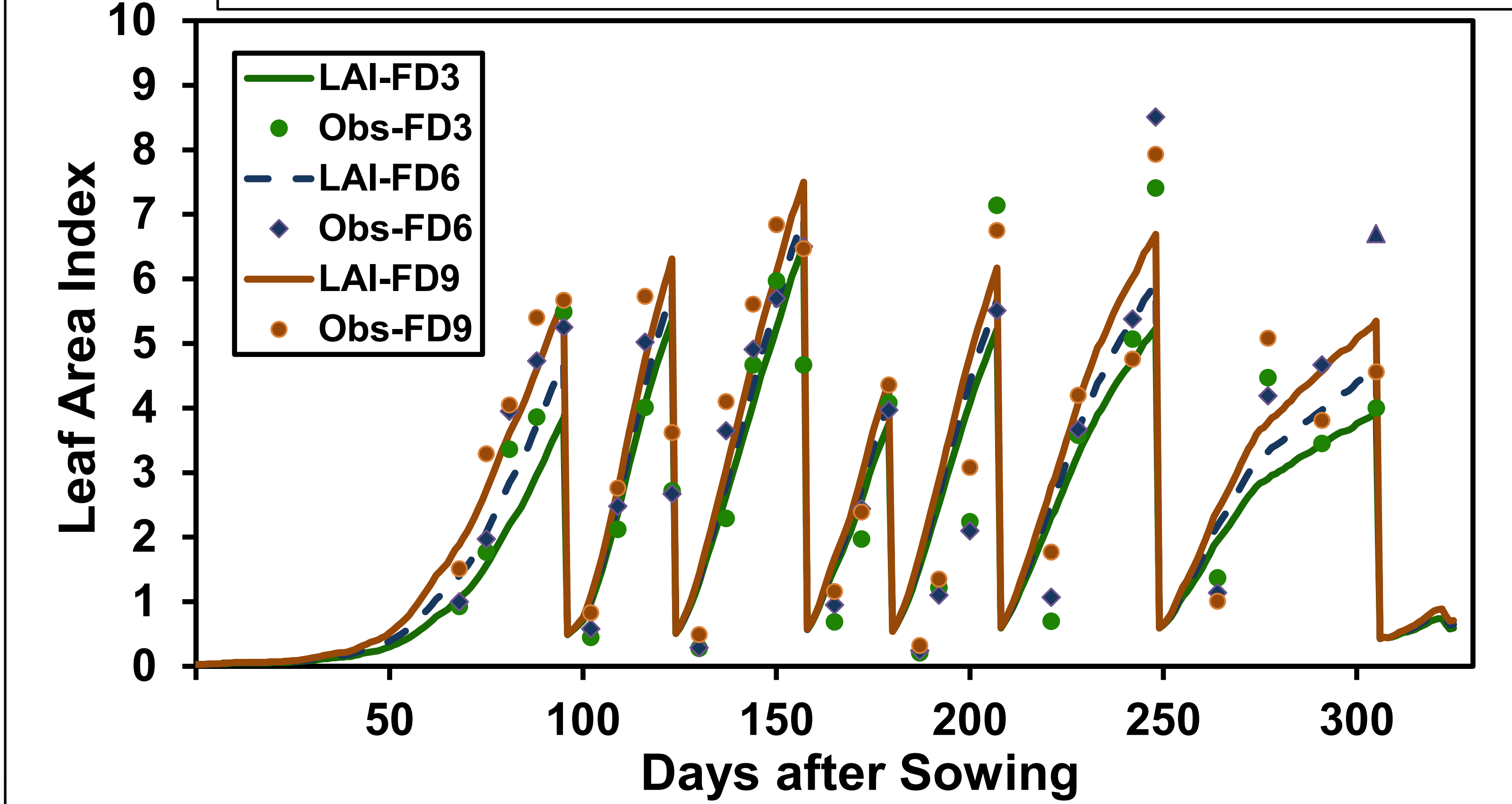
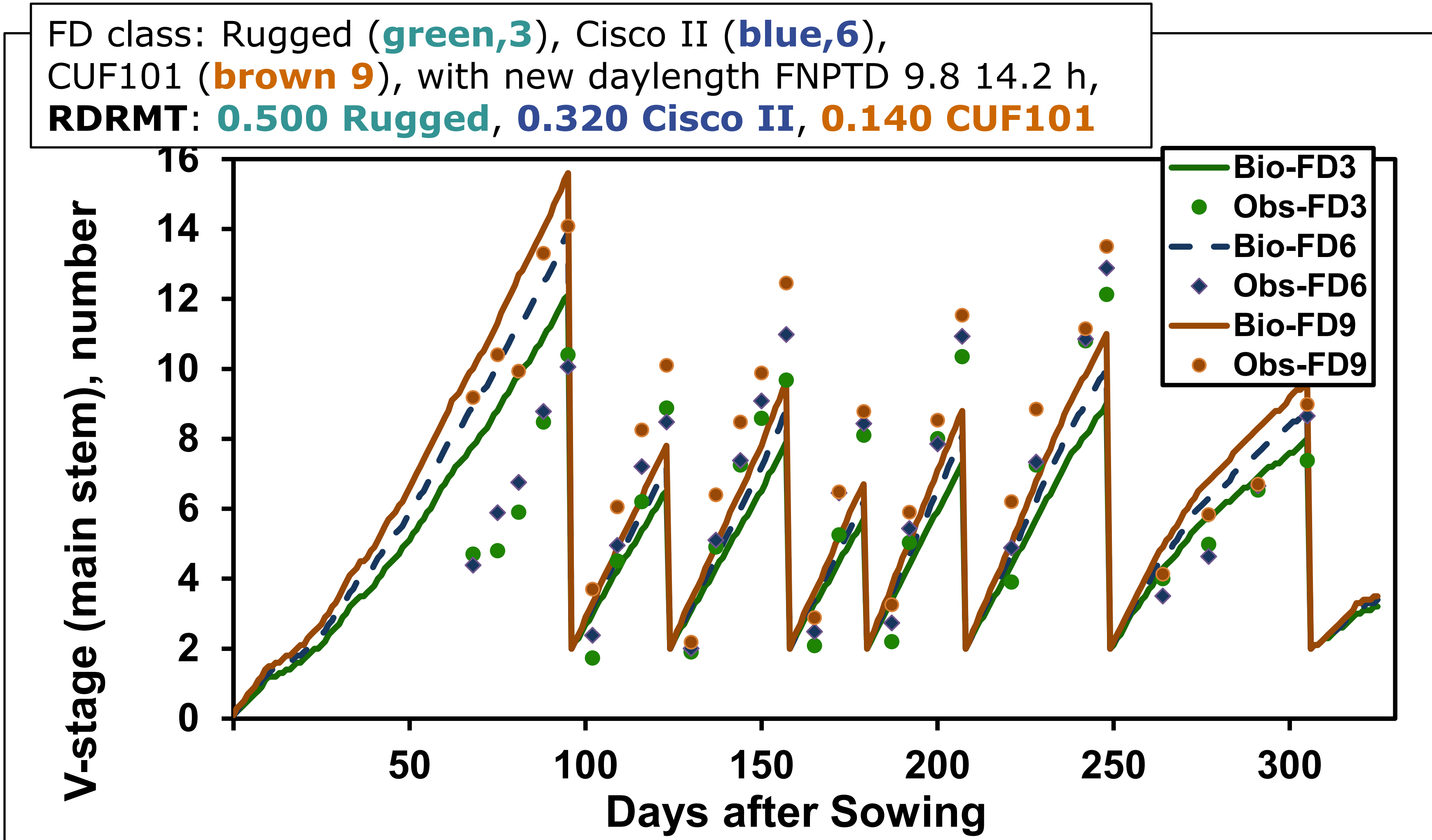
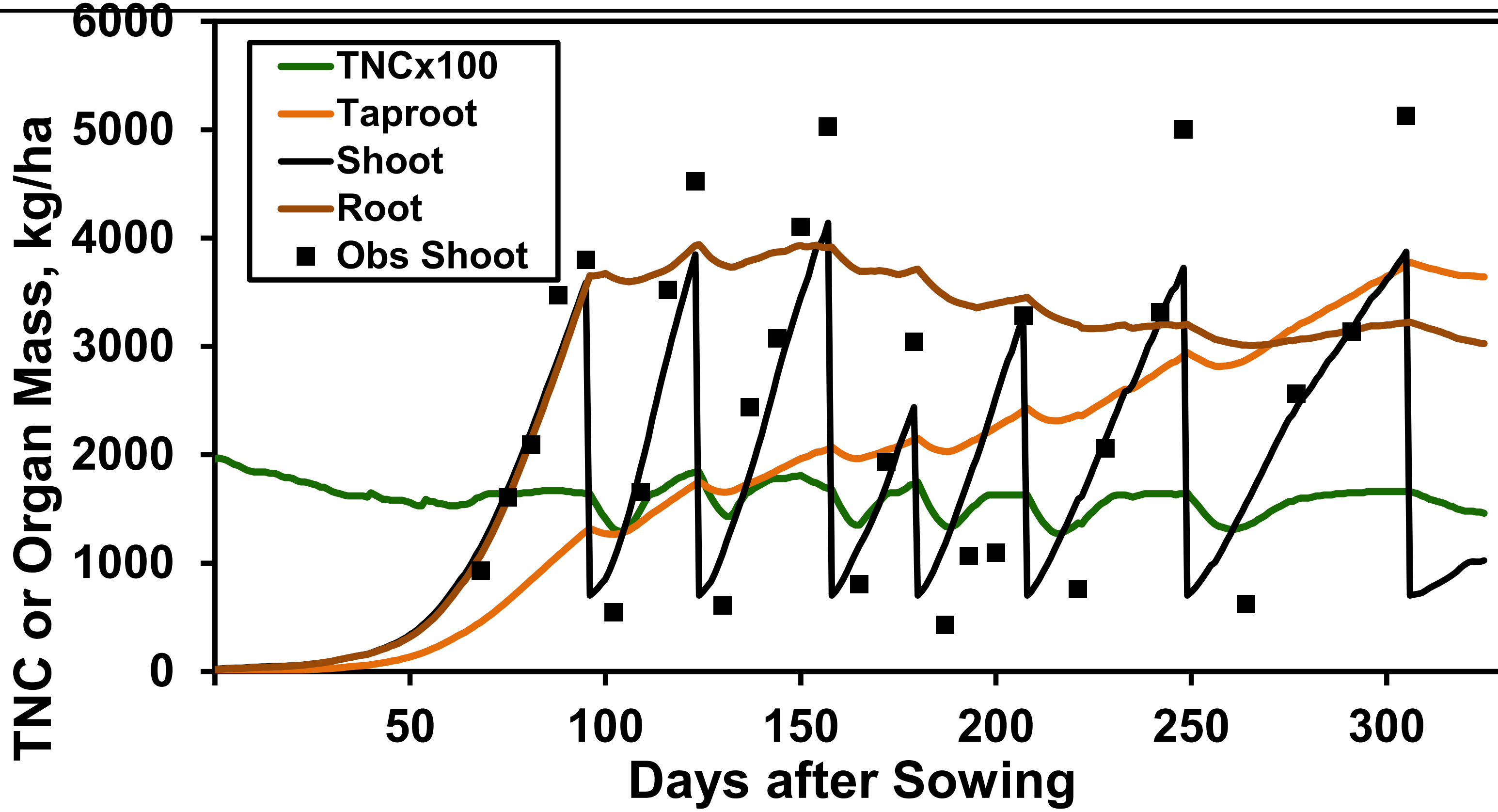


Simulated (lines) and observed main stem leaf number (symbols) for three fall dormancy (FD) cultivars grown in Arizona in 2018 (Ottman et al., 2018).



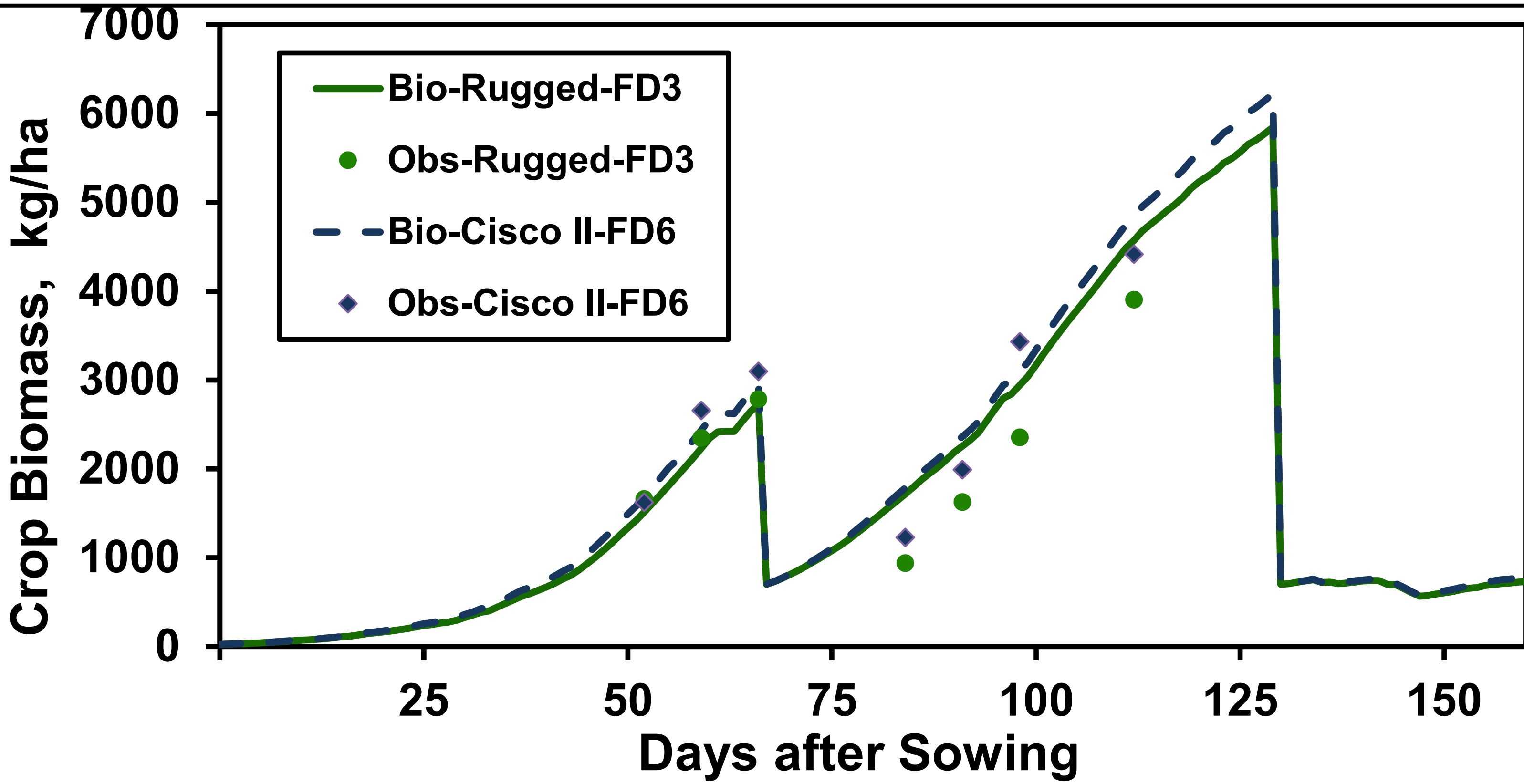
Established from seed. Note the cyclic pattern of TNC depletion of taproot after each cutting. Also cyclic pattern of root & taproot growth

Simulated taproot, root, and shoot mass, taproot TNC, and shoot mass during 7 harvest cycles of FD6 cultivar in Arizona in 2018 (Ottman et al., 2018).



Fall Dormancy classes within alfalfa in AZ (NIFA grant)
I. Kisseka, M. Ottman, J. Torrion, K. Boote, G. Hoogenboom

Simulated crop biomass of Rugged (FD3) and CIsco II (FD6) during two harvest cycles in 2018 establishment season in Montana (Torrion et al, 2018).



CONCLUSIONS

- CROPGRO-Perennial-Forage model simulates alfalfa regrowth and herbage production, and over-wintering behavior in four environments (Spain, Canada, Arizona, and Montana). N-fixation stimulated.
- Re-growth from zero LAI is allowed via carbohydrate pool fill & mobilization dynamics of taproot storage.
- Fall Dormancy classes (1 to 10) created via
  - Daylength sensitivity to enhance partitioning to taproot vs shoot, Strength set by RDRMT
  - Daylength sensitivity affecting mobilization
  - FD class effect on light-saturated Ps (LFMAX)
  - FD class effect on leaf appearance rate (TRIFIL)

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