Growing and feeding sugarbeets and safflower to dairy cows in the San Joaquin Valley of California

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Thanks to the dairy operators and farmers in Tulare County for taking the risks to cut new paths in forage production.

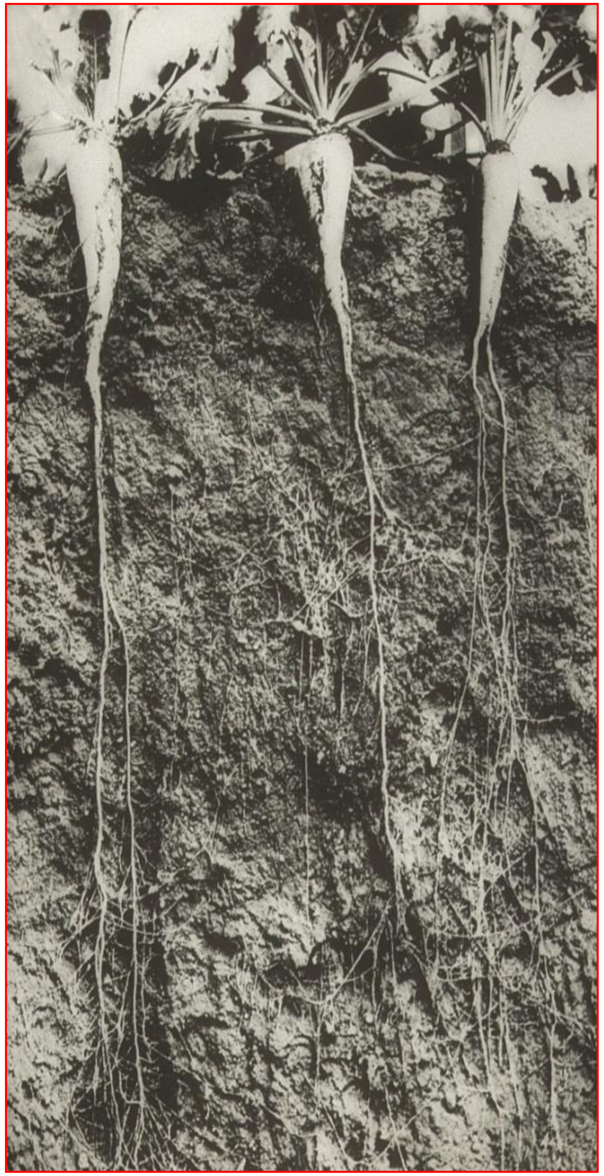
Growing and feeding sugar beets on diary farms in California: Overview

- **Rationale:** Regulatory policies now **restrict groundwater use** for irrigation, alternative supplies are lacking; other policies **restrict nitrate losses** from manure applications on dairies. Together, these policies will force dairy farms in the San Joaquin Valley of California to change crop and nutrient management policies. Previous work on winter water requirements in the SJV for sugarbeets and safflower suggests substantial water savings are possible, coupled with nutrient recovery at depth in the soil profile.
- **Results from on-farm trials to date: water use, yield, silage quality, feed quality and livestock performance.**
- Barriers to adoption and future prospects.

Water use (ETc) by sugar beets in California by location and month (in/month or year)

Location	Month												Total
	J	F	M	A	M	J	J	A	S	O	N	D	
Dates	in/m												(in/yr)
Central Valley													
4-1 to 10-20				1	3.3	8	9.6	8.3	6	3			39
2-1 to 9-15		0.3	0.8	1.6	5.3	8.9	10	8.4	3				38.1
10-1 to 6-30	1.1	1.9	3.6	5.1	6.3	6.1				2	2.5	2.4	22.3
Imperial Valley	3.2	4.3	5.3	8.4	10	8.9	(8.9)			2	2.5	2.4	47.6 (56.5)

Diverse older sources



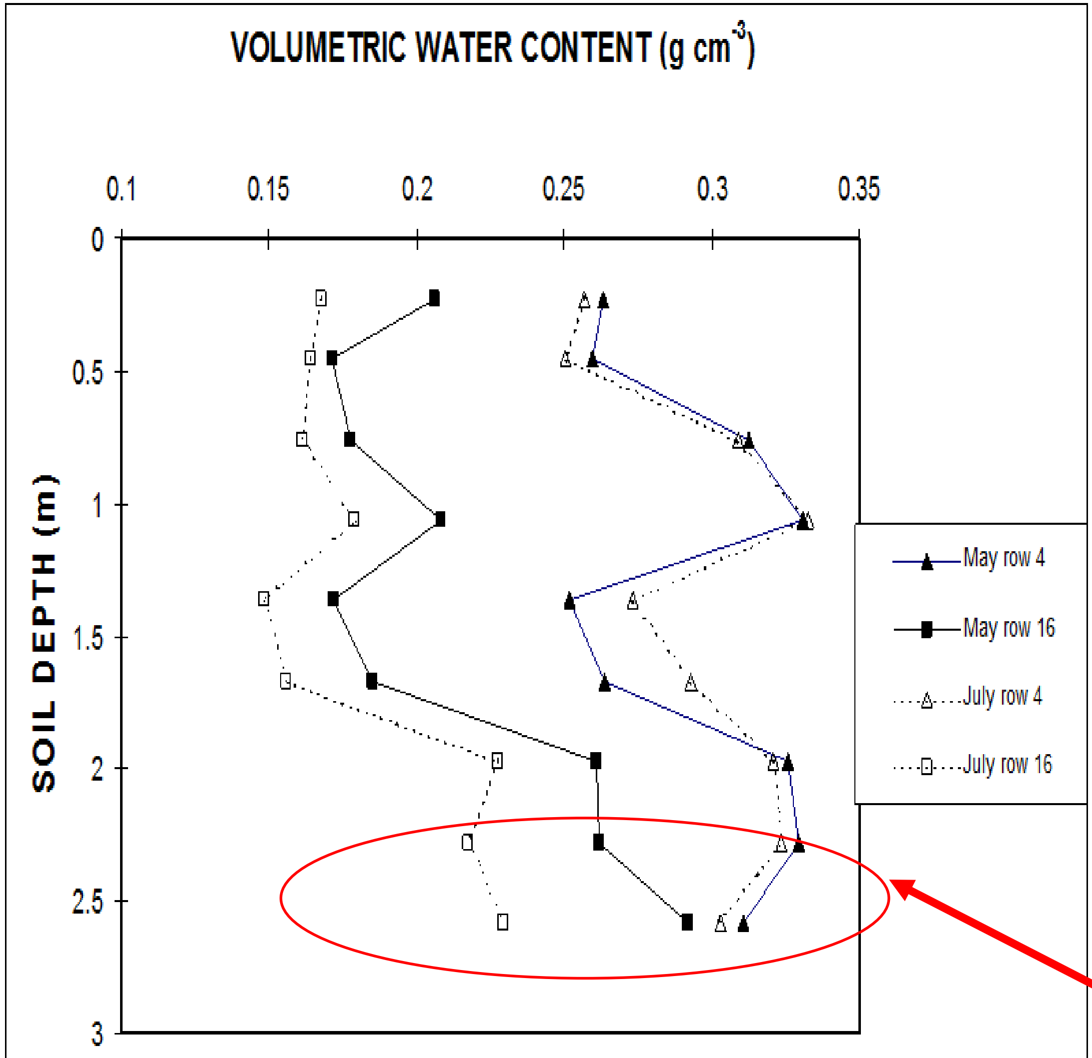
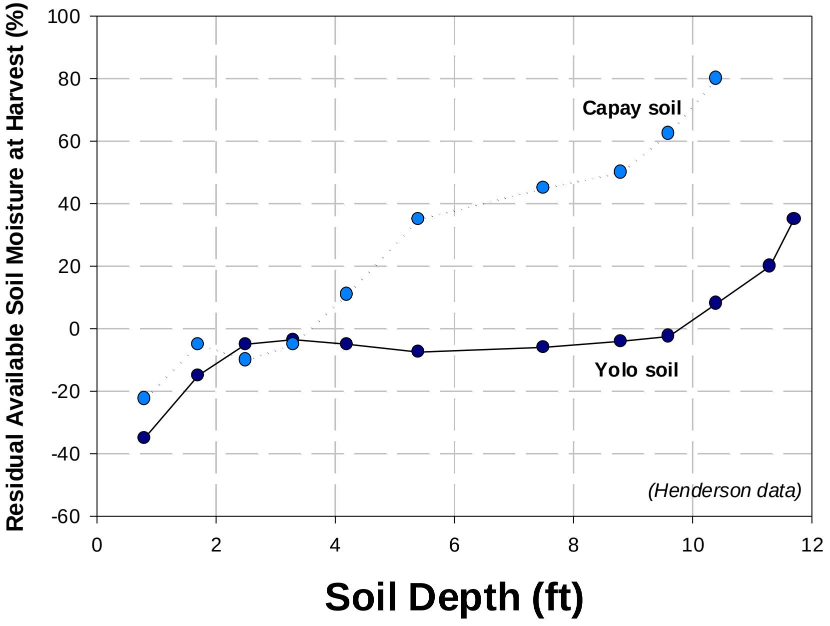


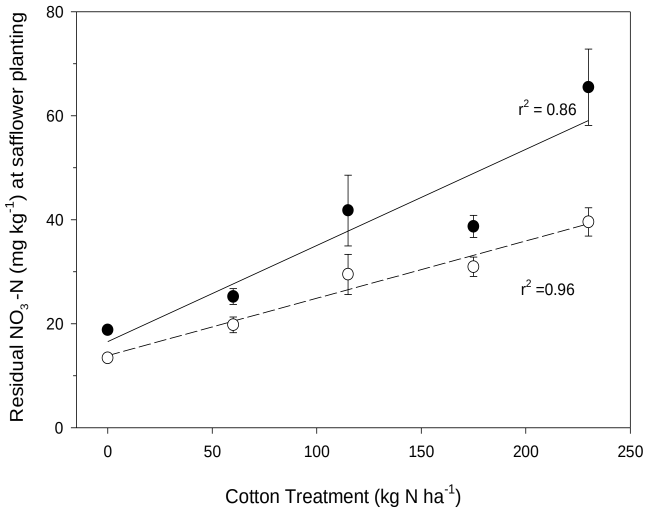
Figure 11 : Volumetric water content by depth (1993-94). Only May and July are presented for visual clarity. The volumetric water content doesn't change between the two months for row 4. Plants in row 16 has already extracted more soil water than row 4 in May and depletes soil water even further in July, especially at depths greater than 2 meters.

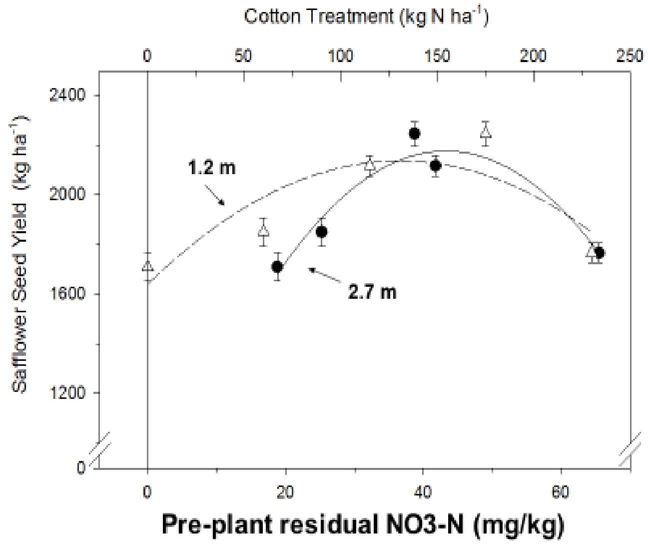
This deep-rooted character makes beets more water use efficient and will help with nitrate management. The figure above was measured changes (depletion) of volumetric soil water content with depth on a Panoche clay loam at the UC WSREC in western Fresno County. Water (and nutrient) recovery were measured at 9 feet deep in the profile. P. Langner, MS thesis.

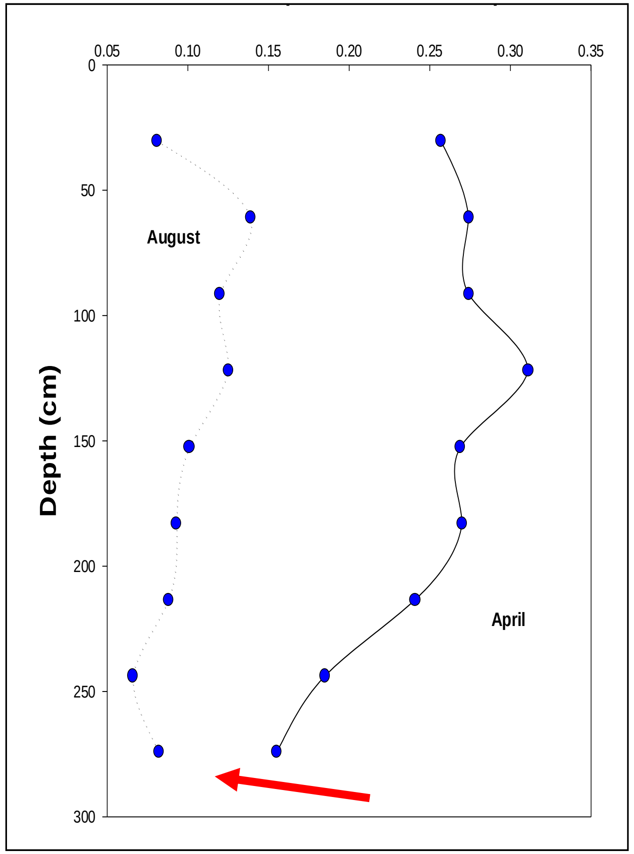
Soil water depletion to 9 + feet in the profile by a fall-planted but water-stressed sugarbeet crop in July

Soil Moisture Use and Soil Depth









Safflower is a very deep-rooted annual crop that can be grown a any time of the year in most years in California. It could help better manage water and nutrients (NO3) on dairy farms if acceptable yields and forage quality are possible.

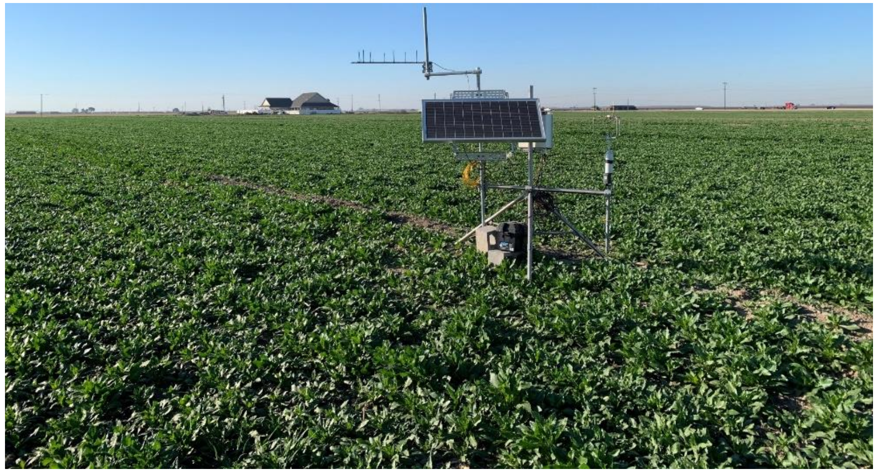
Left above: pre-plant residual NO3-N in experimental plots by depth increased with previous fertilizer treatments. Left below: Unfertilized safflower yield following previous cotton fertilizer treatments. Right: Soil water depletion at depth from spring to summer harvest. Bassil et al. 2002a.

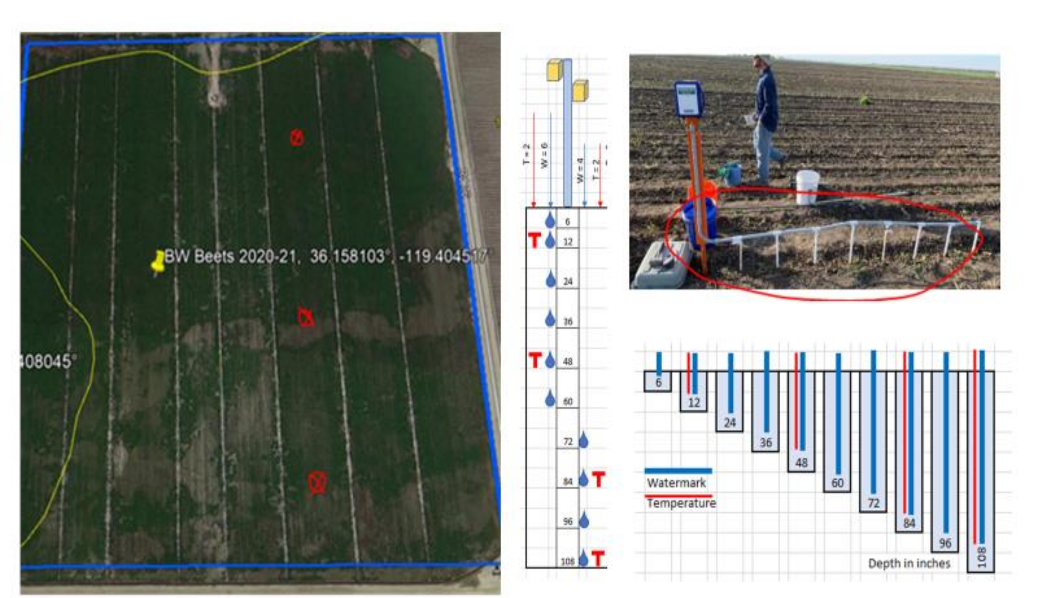
HYP: Crops can be used strategically over a multi-year period to: (1) improve water and nutrient management while also (2) providing high quality feed.

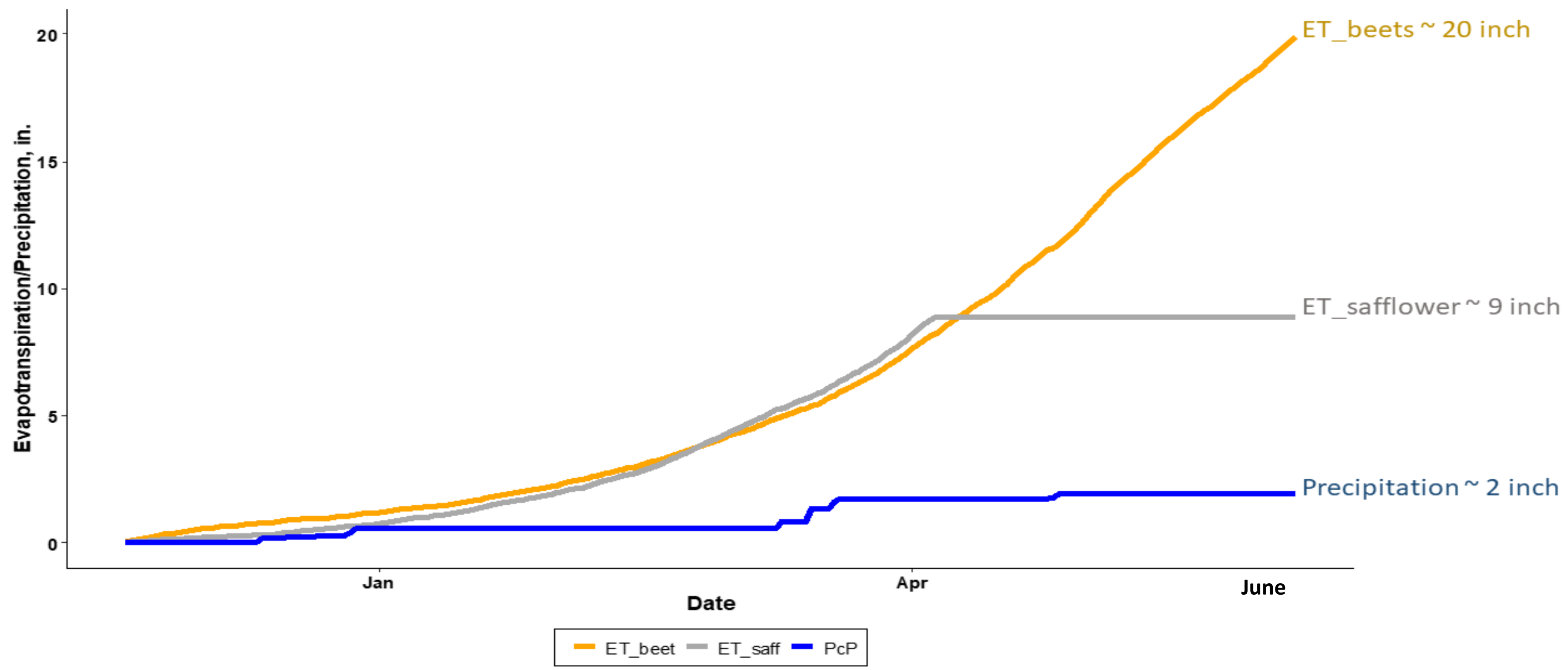
1. **Sugarbeets**: Four trials on dairy farms in the SJV

2. **Safflower**: One trial at UC Davis, three trials on dairy farms in the SJV

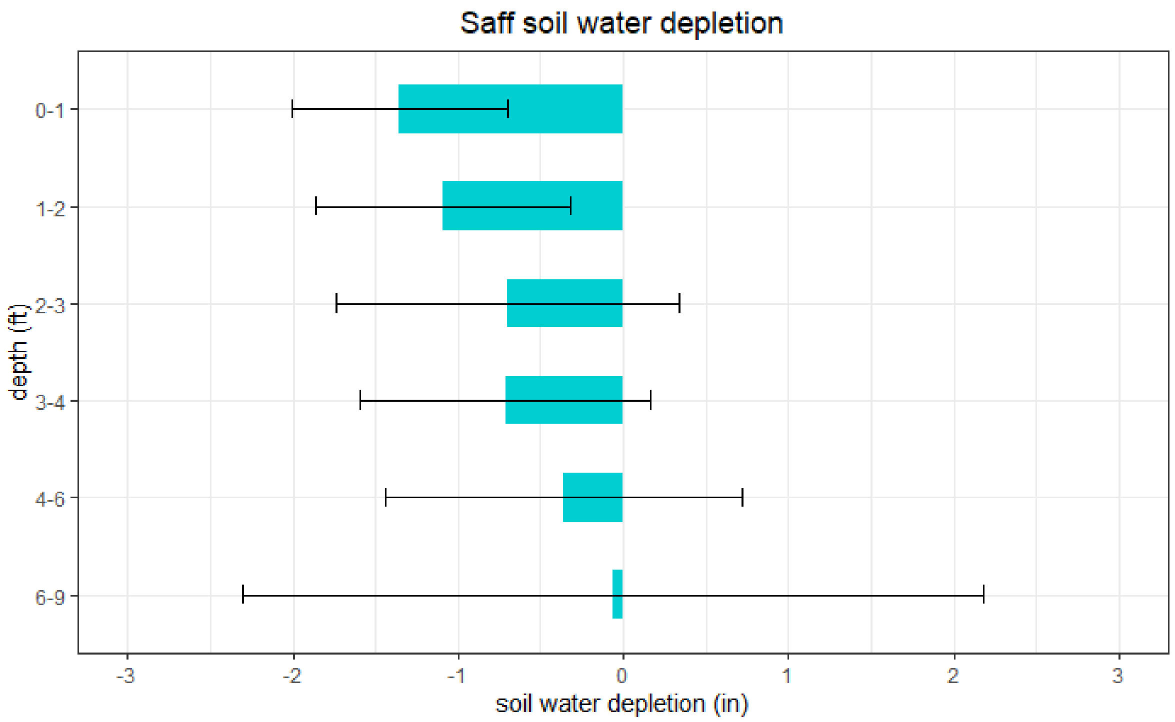
Water Use: Measurements

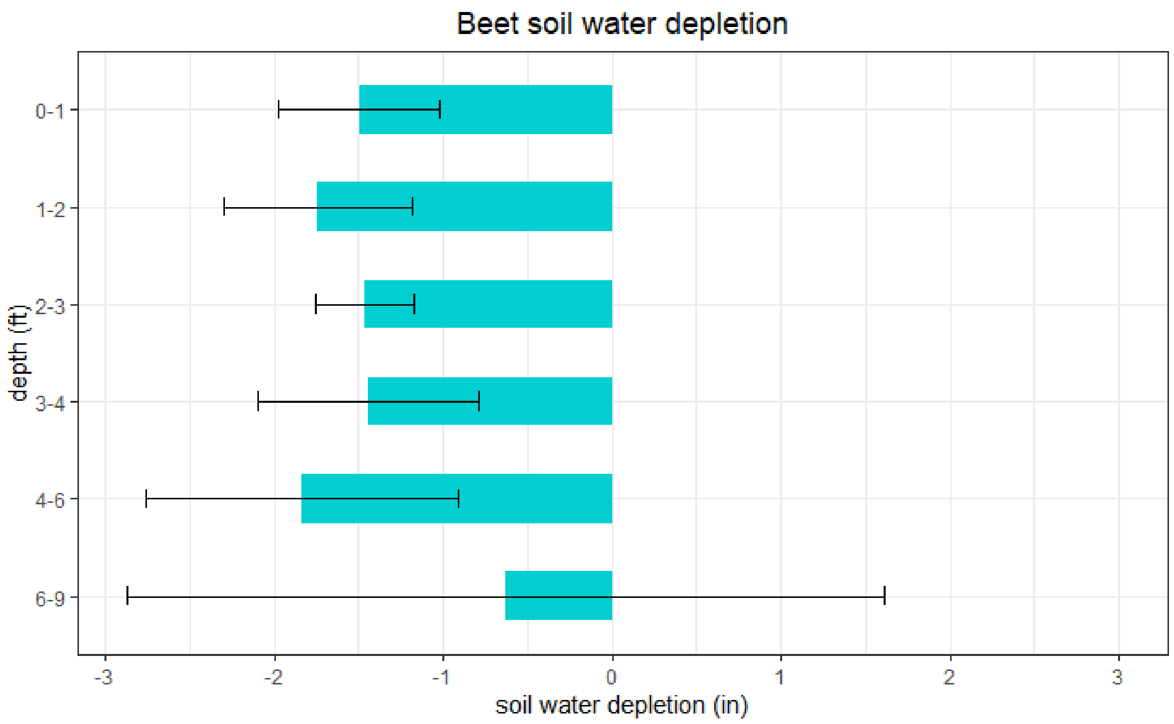




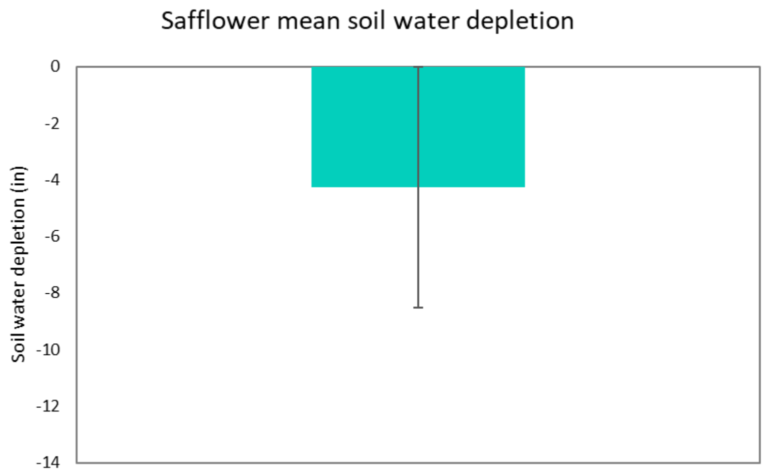


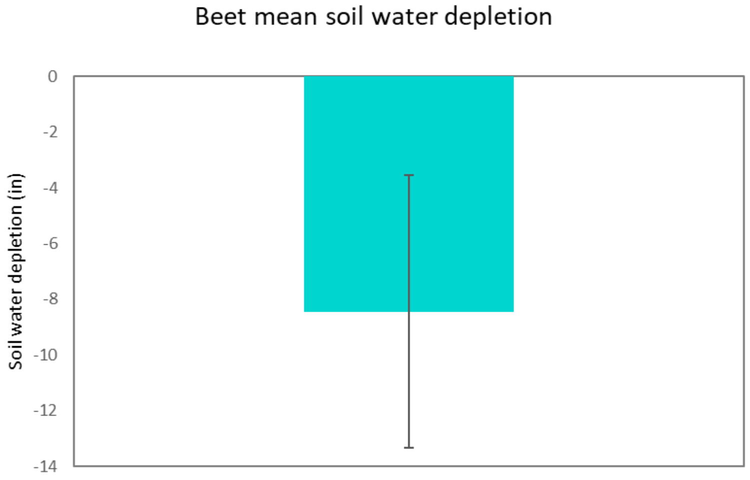
Cumulative evapotranspiration. Data collected November 19th, 2020 to June 10, 2021. This includes all of the safflower season. Beets were harvested on June 12-13. Cumulative seasonal ETc values (Figure 2) show that although safflower developed large amounts of aboveground biomass and used more water for part of the season, sugar beet used more than twice the water due to the longer growing season and higher temperatures later in the growing season than experienced by the safflower crop.





Soil Water Depletion by Depth





Crop Production and Yields:

1. **Sugarbeets**: Four trials on dairy farms in the SJV
2. **Safflower**: One trial at UC Davis, three trials on dairy farms in the SJV

Sugarbeet harvest for silage at dairy in Waukena, June 12, 2021.

Dairy in Pixley, CA, 2018-19		
Root yields		
	average	SD
	t FW/ac	
Field	58.7	10.9
Beta	51.5	6.5
Holly	64.5	10.4

Top and crown yields		
	t FW/ac	
Field	16.5	5.75
Beta	13.2	5
Holly	19.6	6.4

Hand harvests of subplots: Root yields were higher than (conservatively) expected but consistent with current high yields in the IV of California. Tops were not used on the farm but returned to the soil. If fed, care would be needed due to high nitrate levels

Yield – Waukena, CA, 2020

	t/ac (FW)	
Roots	42.8 (33-55)	5.8
Leaves/crowns	35.5	8.7



N uptake		
	leaves	roots
Yield (t/ac)	35	40
lb/t	2000	2000
lb/ac	70000	80000
% DM	0.15	0.22
DM (t/ac)	10500	17600
%N	0.035	0.015
lb/ac	367.5	264

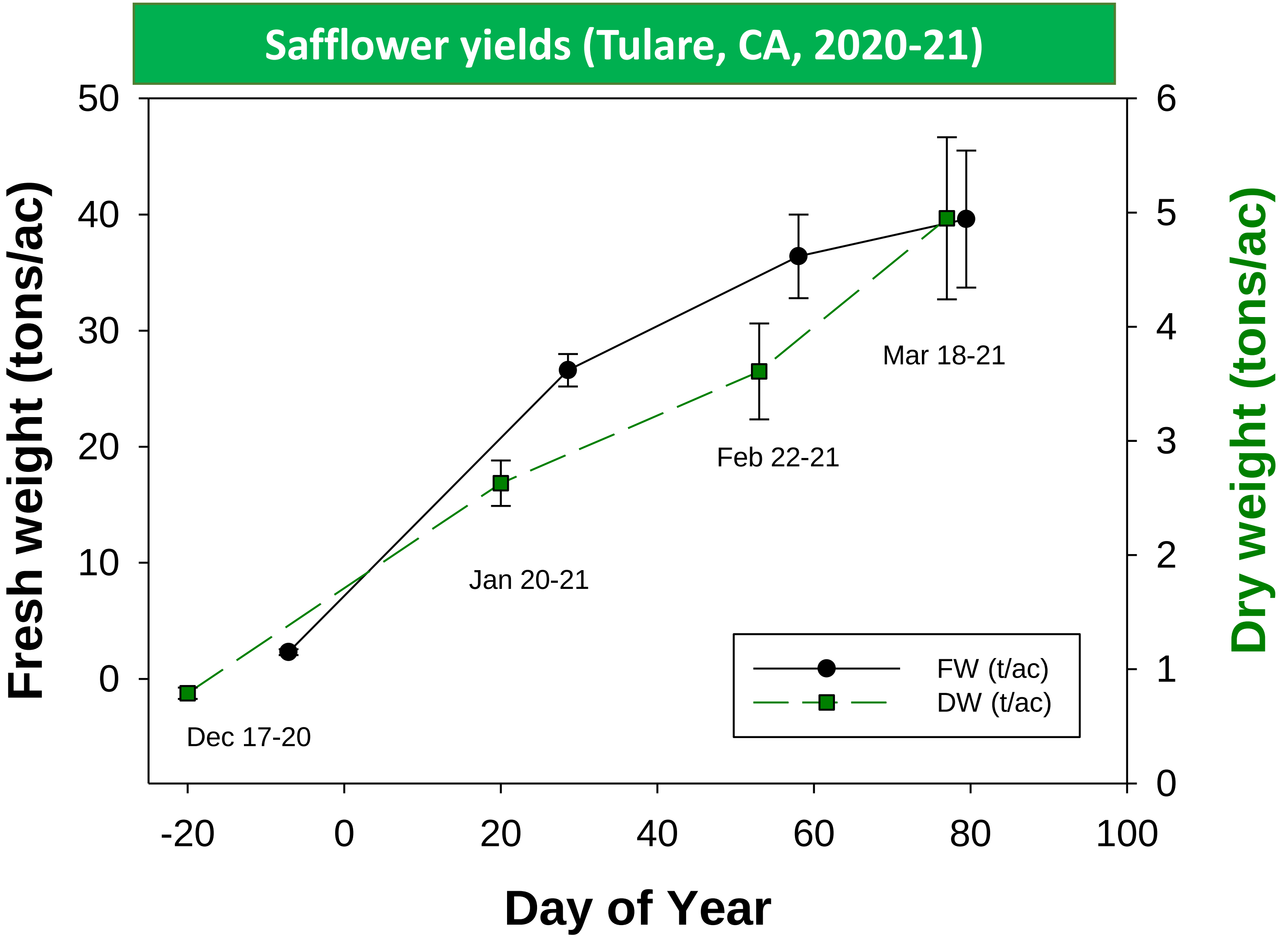
Estimated N uptake at 40 t/ac beets (22% DM) and 30 tons tops per acre (15% DM)= 260 lbs acre in roots and 370 lbs/ac in tops = 630 lbs per acre. Only roots were removed from the field.

Depending on yield, combined roots and tops can remove 600 to > 700 lb N/ac.

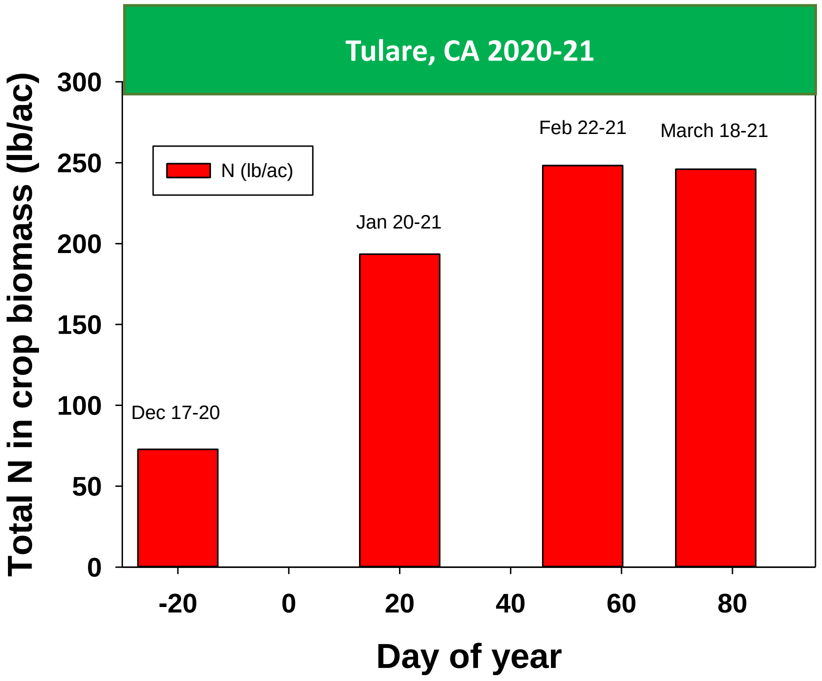
Hand-harvest – Tulare, CA, 6/2 – 6/3/21			
Plot	lb/beet	Ton/ac	beet pop
1	7.5	38.1 ←	11832
1	5.7	47.1	27840
2	3.3	46.3	32016
2	3.8	48.6	28536
3	2.2	52.0	36192
3	5.2	44.7	19488
4	6.9	64.4 ←	20880
4	5.0	53.5	23664
5	3.8	45.0	27144
5	5.7	45.6	18096
6	6.0	48.2	18096
6	3.7	50.2	30624
7	4.6	53.6	22968
7	4.8	52.4	22272
8	4.6	47.0	22272
8	4.7	46.1	20184
9	6.2	60.9	25752
9	5.6	49.9	24360
AVE	4.97	50 ←	24012
SD	1.3	6.1	5814.58
CV	26.5	12.2	24.22

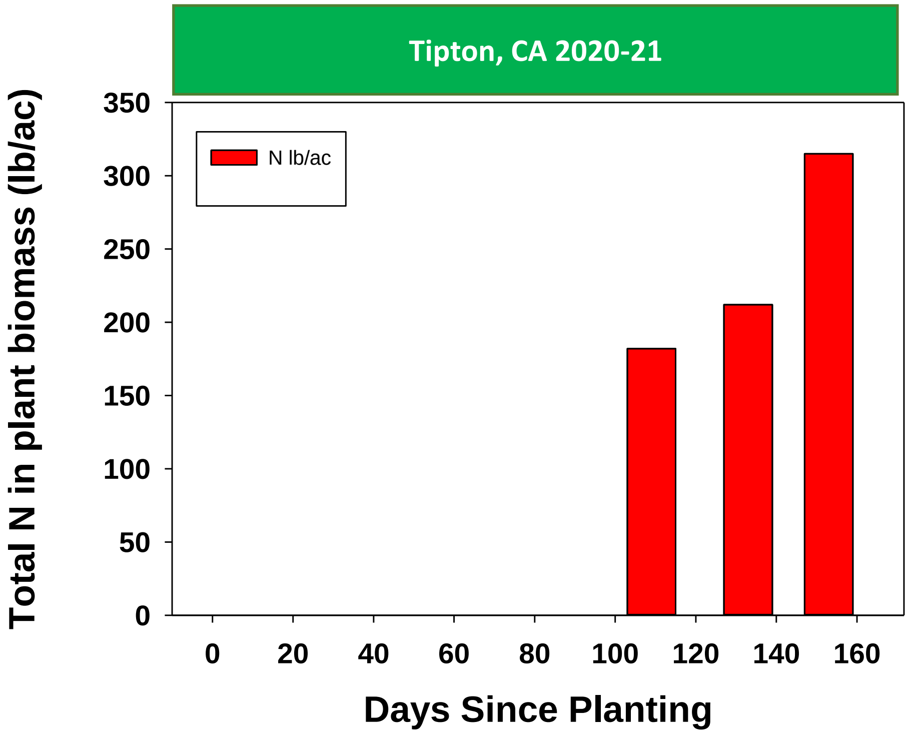
Estimate from truck load weights during harvest: 52.36 t/ac; tonnage of silage including almond hullls: 1866 from 35 acres.

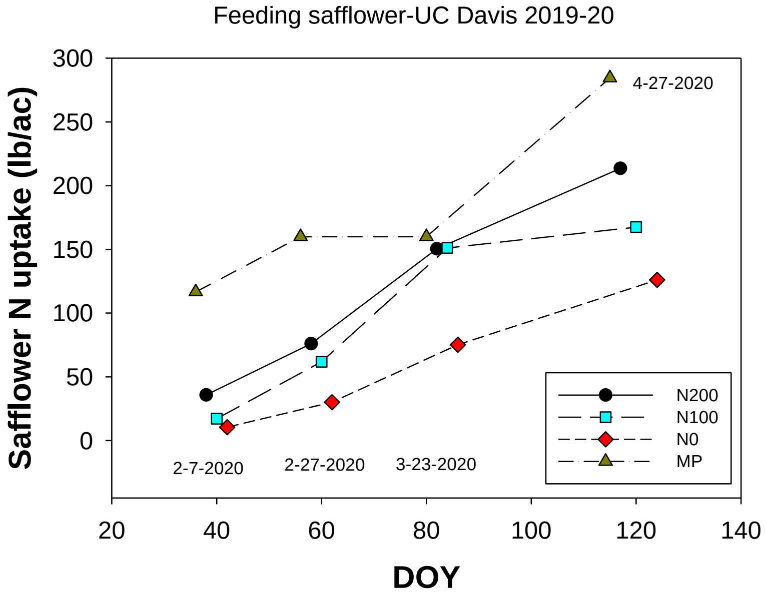
Estimated root yields based on hand harvests of two 25 foot rows in 9 locations. Plots 1 to 3 correspond to areas where soil samples were collected. Plant population, root size, and yield varied across the field (38.2 t/ac to 64.4 t/ac FW). The field had some areas with poor stand establishment, ultimately limiting final yield. Stand establishment estimates in December 2020 estimated 28K roots per acre, however with a large coefficient of variation that led to an estimated limit on upper yields of 75% to 80% of potential. This is approximately similar to the difference in % of between the high yield observed in plots and the field average. More uniform beet populations would have yielded a field average close to the high level observed in hand yield plots, (64 t/ac).



Harvesting plots at Waukena, February 22, 2021; similar methods were used at the Tipton dairy as well.







Based on two on-farm trials and one research station trial, safflower crops recovered from 250 to 300 + lbs N per acre, depending on length of season and soil fertility levels under dairy farm and high fertility conditions.

Forage Quality and Feeding:

1. Sugarbeets
2. Safflower

Ensiling sugarbeet roots with almond hulls (~33 % by weight); Pixley Dairy, June 26, 2019

No seepage and bag integrity was maintained. High strength plastic was used.

Beets ensiled without hulls;
Rovey Farm_Glendale AZ

Beet-Almond hull silage mixture following bagging. June 12-14, 2021 at y. The ratio of beets to almond hulls was 3:1 by weight. Hulls were added to forage trucks prior to beets loads and mixed as they unloaded, simplifying blending. The material was well-mixed.

Tulare Dairy, 2021

Bags one and two (with tires) split after filling (bag one shown) and were covered subsequently with a tarp and tires. The plastic was of insufficient quality to contain the material. Bag three was filled with less pressure and did not split, and bag 4 was filled without hulls, largely with intact beets, to evaluate how beets alone would preserve and feed. That bag is actively leaking fluids. Properly made beet/almond hull silage requires higher strength bags than normally use. Ensiling beets without an absorbent like almond hulls is not recommended.

Heavier-duty plastic bags are needed for beet silage compared to corn or cereal silages.

FEEDING TRIAL TREATMENTS_TULARE DAIRY

CTRL = No beetlage

HIGH = Beetlage @ ~22% ration DM

< 11 lbs./cow/day DM beetlage

LOW = Beetlage @ ~11% ration DM

< 5.5 lbs./cow/day DM beetlage

- Inclusion levels based on:
  - Total beetlage (3:1 ratio) = 1203 tons
  - Assumptions:
    - Beetlage DM = 28.25%
    - Loss during bag unloading = 20%
    - Avg. 50 lbs. DM intake/cow/day
    - 1134 cows to feed (Pens 1-7 + 50)

✓ Average intake of 50 lbs. based on EZFeed data from July 2021 – will be updated

✓ All cows in Pens 1 -7 and 50 are included in order to reduce the mixing and feeding changes required to feed the treatment rations

RESULTS: TMR COMPOSITION

	Treatment			
	No Beets	Lo Beets	Hi Beets	
DM intake (lbs/d)	49.7	50.7	49.9	
TMR Ingredient Composion (% of DM)				
Alfalfa, hay	12.4	12.7	12.5	
Corn, silage	25.8	20.0	14.3	*down*
Beetlage	0.0	9.5	18.8	*up*
Almond, hulls	5.1	5.1	5.1	
Herd premix	16.2	16.1	16.1	
Canola, meal	12.6	13.2	14.0	*up*
Cottonseed, whole fuzzy	5.5	5.5	5.4	
Corn, flaked grain	18.3	16.0	13.8	*down*
Whey, liquid	4.2	2.1	0.0	*down*

RESULTS: PRODUCTIVITY

	Treatment				
	No Beets	Lo Beets	Hi Beets	SEM	Linear *P*
n = 406 cows					
Yield (lbs/day)					
Milk	67.82	68.21	68.75	0.578	0.06
Fat	3.37	3.39	3.41	0.031	0.32
Protein	2.60	2.62	2.63	0.019	0.11
Composition (%)					
Fat	5.03	5.01	5.01	0.038	0.69
Protein	3.88	3.87	3.87	0.016	0.27
SCC (,000)	96	74	95	9.7	0.90
n = 197 cows					
BCS (units)					
Average	3.13	3.10	3.10	0.036	0.33
Change (/28 d)	0.073	0.093	0.080	0.0222	0.83

BEETLAGE BAGS

	Bags			
	1 & 2	3a	3b	4
Length	226 ft each	80 ft	146 ft	180 ft
Pack pressure	Hi	Hi	Lo	Lo
Almond Hulls	+	+	+	-
Bag status	Burst	Intact	Intact/tears	Intact
tons wet	1089	196	266	291
tons dry	297.4	54.9	73.0	63.4
DM%	27.3	28.0	27.5	20.5
Ratio wet	9.3	8.4	9.0	-
% Beets DM	67.8	65.5	67.2	100
wet tons/foot	2.41	2.45	1.82	1.61
dry tons/foot	0.66	0.69	0.50	0.33
Recovery				
Wet	62.7	74.7	not	being
Dry	63.9	74.1	measured	measured

Shrinkage was an issue for beet silage with smaller amounts of almond hulls. It is also an issue for direct ensiled roots without an absorbent. Economic methods to ensile and preserve sugarbeets as silage are not yet developed.

2022 Whole Beet Roots (pre-bagging) Sample Assays at Waukena dairy

Bag Code	**1A/1B**	**2A/2B**	**3,4,5,6,7**	**All**
Date	**14&15-Jun**	**21-Jun**	**5,6,8-Jul**	**All**
Beet Description	**Whole**	**Whole**	**Whole**	**Whole**
Sample #	**1,2**	**3,4**	**5,6,7**	**All**
Dry matter, % (Lab)	**22.1**	**24.6**	**21.3**	**22.5**
(On-site)	**23.8**	**25.8**	**23.0**	**24.0**
CP, % DM	**6.0**	**5.3**	**5.0**	**5.4**
Soluble CP, % CP	**62.8**	**53.7**	**56.9**	**57.7**
ADI CP, % CP	**0.2**	**0.3**	**0.3**	**0.3**
Ammonia-N, % CP	**6.0**	**4.5**	**5.7**	**5.4**
Nitrate-N, ppm DM	**60**	**214**	**99**	**121**
aNDFom, % DM	**12.4**	**12.1**	**12.4**	**12.3**
aNDF, % DM	**14.3**	**15.1**	**13.2**	**14.0**
dNDF30, % aNDF	**57.6**	**58.9**	**33.6**	**47.7**
ADF, % DM	**7.8**	**8.6**	**6.7**	**7.5**
Lignin, % DM	**0.0**	**0.2**	**0.0**	**0.1**
Sugars, % DM	**46.5**	**51.8**	**47.1**	**48.3**
Fat, % DM	**0.3**	**0.6**	**0.4**	**0.4**
Ash, % DM	**5.49**	**7.31**	**4.16**	**5.44**
Ca, % DM	**0.14**	**0.19**	**0.15**	**0.16**
P, % DM	**0.21**	**0.20**	**0.16**	**0.18**
Mg, % DM	**0.16**	**0.18**	**0.17**	**0.17**
K, % DM	**1.13**	**1.13**	**0.90**	**1.03**
Na, % DM	**0.35**	**0.49**	**0.38**	**0.40**
S, % DM	**0.04**	**0.04**	**0.02**	**0.03**
Cl, % DM	**0.28**	**0.39**	**0.26**	**0.30**
Net energy lactation, Mcal/lb DM	**0.90**	**0.88**	**0.88**	**0.88**

Notes:

Samples #: Each sample # represents 4 or 5 beet tubers.

Ash values: Efforts were made <u>not</u> to clean adhering dirt from tubers in order to reflect what would be ensiled. However dirt clods will increase ash values of the ensiled product.

Sugarbeets

Reasons for adoption:

Regulatory pressures limiting irrigation water and restricting nutrient losses

Feeding value (high dietary energy and improved rumen function; increased fat content in milk?, cow health?)

Salinity tolerance

Favorable **Costs of production for a high energy forage**

Barriers to adoption:

Equipment: A beet harvester is needed. Planters need to be adapted to beets. Care needed at stand establishment.

Management: It's a new crop for most dairy producers, and is more difficult to grow well than cereal silage or corn silage.

Preservation: **Preservation problems have not been solved.** Currently, it needs to be ensiled using agbags and likely co-ensiled with another ingredient to manage seepage. Some producers only use bunker silos.

Co-ensiling is more complicated.

Table 1. Characteristics of the safflower silage pile.

Harvest dates	April 25 through April 28, 2022
Total harvest	1681.4 tons as harvested
Average weighted DM	30.4%
Acres harvested	79.58
Tons DM/acre	6.42
Pile volume	80,932 ft^3
Pile density	41.65 lbs/ft^3 as harvested
	12.64 lbs/ft^3 dry matter

Tulare dairy_April 2022

Safflower harvest near Tulare, April 22, 2022

Table 2. Chemical and nutritional characteristics of the fresh cut safflower at ensiling.

	Whole Pile	
	2021	*2022*
Total as harvested tons	413.5	1681.3
Total DM tons	98.0	482.5
Temperature, °F	nd	76.9
Dry matter, %	23.7	30.4
Crude protein (CP), % DM	13.2	11.4
Soluble CP, % CP	51.4	45.6
Acid detergent insoluble, % CP	4.5	3.0
Ammonia N, % Total N	4.5	5.0
Nitrate N, ppm DM	2658	1055
aNDF, % DM	54.8	52.0
aNDFom, % DM	nd	50.9
$dNDF_{30}$, % aNDFom	28.5	41.5
ADF, %DM	47.5	38.9
Lignin(sa), % DM	8.3	7.7
Fat, % DM	1.1	1.2
Water soluble carbohydrate, % DM	6.9	8.9
Starch, % DM	1.3	1.6
Total sugars, % DM	3.8	4.1
Ash, % DM	17.4	10.2
Calcium, % DM	0.96	0.83
Phosphorous, % DM	0.25	0.21
Magnesium, % DM	0.19	0.14
Potassium, % DM	3.63	3.08
Sulfur, % DM	0.15	0.16
Sodium, % DM	0.02	0.03
Chloride, % DM	nd	1.16
Net Energy Lactation, Mcal/lb DM	0.38	0.53

Harvest practices:

Spring 2021. Safflower was harvested at first bud in early April. This presented drying problems and harvest included a significant amount of soil contamination. **Spring 2022**. Harvest strategy was modified to cut later (early flower color at field edges) to avoid overnight dew common in late winter/early spring and to allow additional maturation of the safflower to increase DM at harvest. It was possible to direct-cut the safflower, facilitating harvest and silage making, and soil contamination and reducing ash content.

***Silage Pile**:*
The silage pile was successfully created during the harvest period. No fluid runoff was detected at any time. Little off-gassing occurred. Harvest yield was acceptable and bulk densities are within acceptable ranges as stipulated by CARB.

Safflower silage use at Waukena dairy (2021)

Diet Ingredient Composition (% of DM) of Heifer and Dry Cow Rations Before and After Addition of Safflower Silage Tulare, Tulare County				
	Heifers		Dry Cows	
	w/o Saff	w Saff	w/o Saff	w Saff
Bermuda hay (bought in)	22.1	22.1	15.9	15.9
Triticale silage (farm grown)	71.4	52.1	66.4	49.5
Safflower silage (farm grown)	0	19.3	0	16.9
Whey (bought in)	0	0	10.9	10.9
Canola meal (bought in)	6.5	6.5	6.8	6.8
Water use (L/kg diet DM)	221	187	206	175

Cereal silage feeding was shifted to production groups, and safflower silage used preferentially for heifers and dry cows.

Safflower

Reasons for adoption:

Regulatory pressures limiting irrigation water supplies and restricting nutrient loss.

Feeding value is somewhat less than cereal silage, but suitable for young stock, dry cows, and some producing groups.

Favorable **Costs of production =** Seed costs, planting and harvesting, minimal irrigation, no herbicides or other pesticides, no fertilizer or manure needed.

Barriers to adoption:

Management: It's a new crop for most dairy producers, but is easy to grow. In early spring, drying my be an issue and soil contamination at harvest must be managed to lower silage ash levels. **Timing of harvest is critical**.

Preservation: Care at ensiling not to overpack. Some small amount of off-gassing may occur depending on N content.

HYP: Crops can be used strategically over a multi-year period to: (1) improve water and nutrient management while also (2) providing high quality feed.

Alternative Crop Criteria		
Category	Safflower	Sugarbeets
Water use	***	***
Nutrient uptake	***	***
Yield	***	**(*)
Feed quality	**	***
livestock performance	**	***
Preservation	***	?