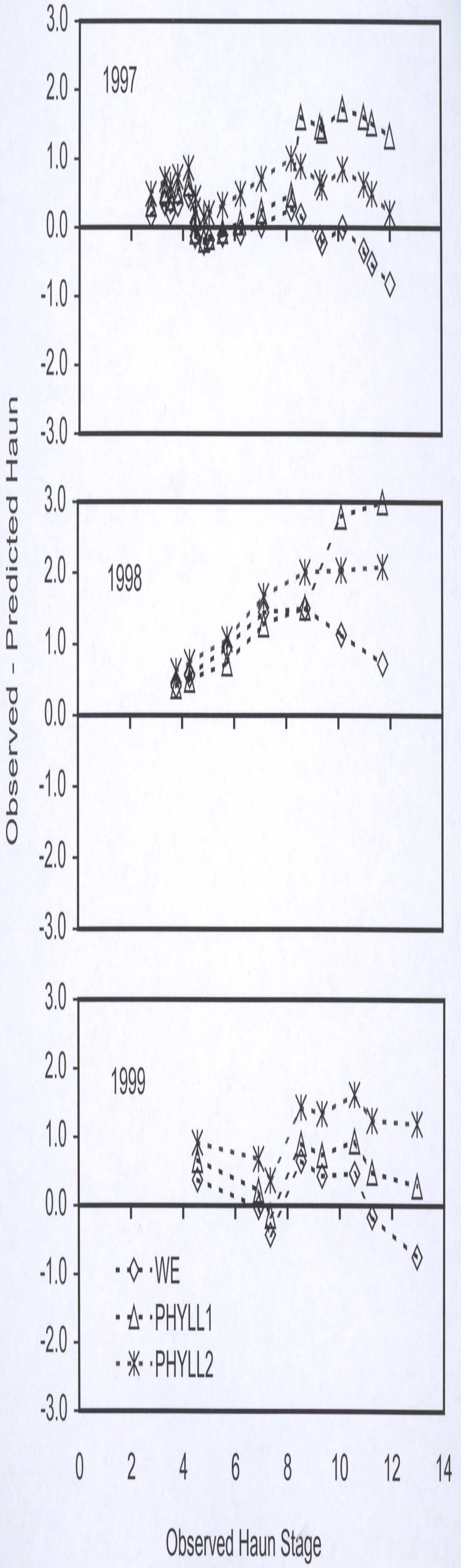
Winter Wheat: Telling Time

A. Weiss, Q. Xue, N.A. Streck
University of Nebraska

LEAF APPEARANCE

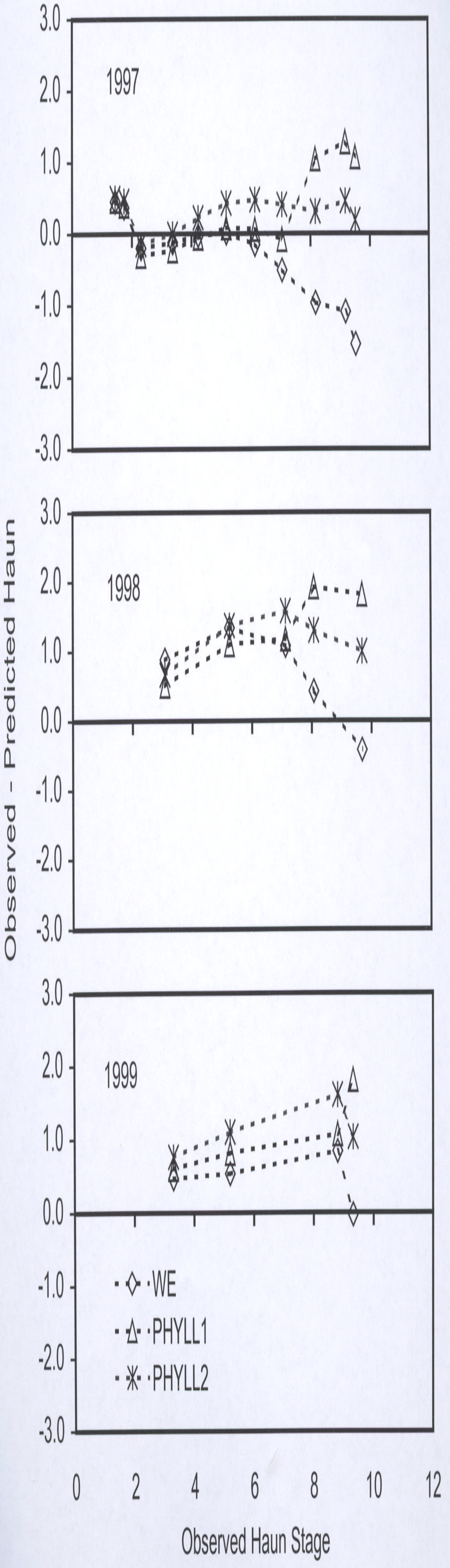
We used a Beta function, with only one unknown – the maximum leaf appearance rate, in conjunction with a photoperiod function to predict leaf appearance based on a paper by Wang and Engel, WE model. We compared predictions using this relationship with those from two phyllochron relationships. The first relationship had a varying phyllochron; 75 ^{o}Cd from Haun stage (i.e. leaf number) 0-2, 100 ^{o}Cd from Haun stage 2-8, and 120 ^{o}Cd thereafter, PHYLL 1. The second phyllochron model assumed a constant value of 108 ^{o}Cd, PHYLL 2. In general, the WE model gave better predictions of the Haun stage than either of the phyllochron models based on statistical comparisons of the RMSE. Figures 1 and 2 illustrate representative results from early and late plantings of the cultivar Arapahoe over three years. We also used 0.05m soil temperatures and hourly air temperatures in these models but there was no improvement in predictions from using mean daily air temperature.

Figure 1



3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
1997
1998
1999
Observed - Predicted Haun
WE
PHYLL1
PHYLL2
0
2
4
6
8
10
12
14
Observed Haun Stage

Figure 2


1997
1998
1999
Observed - Predicted Haun
Observed Haun Stage
WE
PHYLL1
PHYLL2
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
0
2
4
6
8
10
12

PHENOLOGICAL DEVELOPMENT

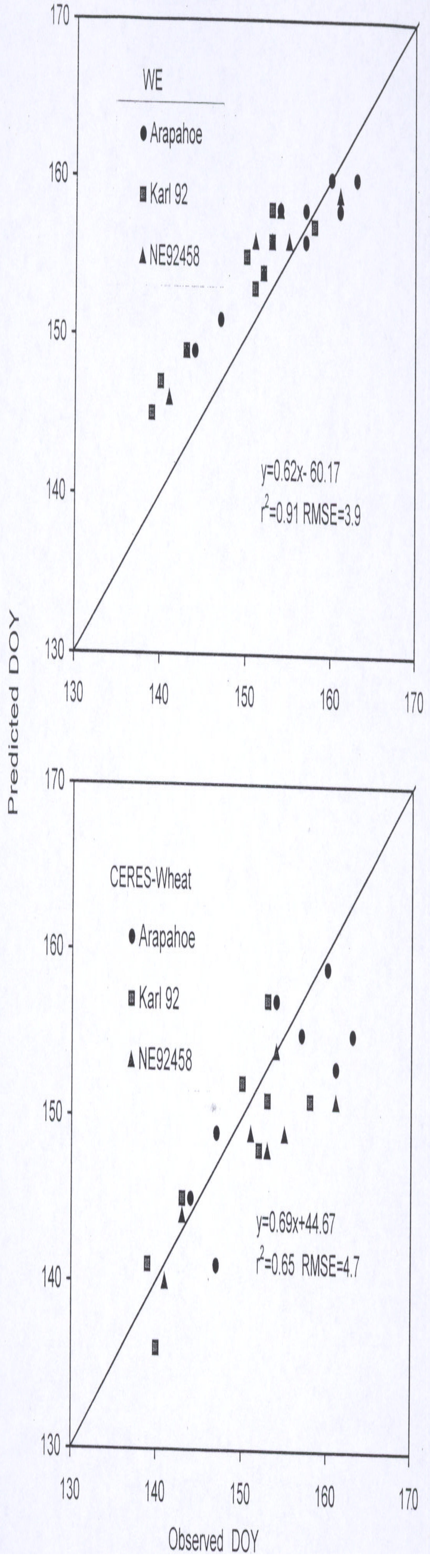
The WE model predicted booting (BT), heading (HD), anthesis (AN), and physiological maturity (MA) better than double ridge (DR) and terminal spikelet (TS), Table 1. As the season progressed, the RMSE decreased. The prediction of MA had a RMSE of 1.1d. The period from AN to MA is solely a function of temperature, while the period from sowing to AN is a function of temperature, photoperiod, and vernalization. Predictions from CERES-Wheat showed a near uniform RMSE throughout the different phenological stages of about 5.4 d. We believe the problem with the WE model is in the vernalization algorithm which assumes a linear response to temperature. Two other independent data sets from the Nebraska Intrastate Wheat Trials (1992 and 1996) for two locations (Mead and Lincoln) were used to predict day of year (DOY) of anthesis for three cultivars, Fig 3. Predictions were better from the WE model than from CERES-Wheat.

Table 1 RMSE for predicting double ridge (DR), terminal spikelet (TS), booting (BT), heading (HD), anthesis(AN), and maturity (MA) using the WE model and CERES-Wheat for the three growing seasons and two planting dates in Lincoln, NE.

Year	PL	DR	TS	BT	HD	AN	MA
WE							
1997	1st	1.2	1.3	2.0	2.6	3.4	0.8
	2nd	19.0	5.1	3.1	4.0	5.7	0.6
1998	1st	10.3	10.7	8.1	6.9	6.8	1.8
	2nd	2.1	5.8	5.0	4.5	5.3	1.2
1999	1st	6.3	11.0	3.8	3.5	2.0	0.7
	2nd	5.0	8.5	2.1	1.6	1.6	1.6
Mean		**7.3**	**7.1**	**4.0**	**3.9**	**4.1**	**1.1**
CERES-Wheat							
1997	1st	†	4.7	4.5	1.8	2.6	2.9
	2nd		7.8	2.7	3.5	3.4	0.6
1999	1st		5.7	7.5	7.0	8.6	7.6
	2nd		6.7	6.5	7.0	9.1	8.6
Mean			**6.2**	**5.3**	**4.8**	**5.9**	**5.0**

†: CERES-Wheat did not prediect double ridge

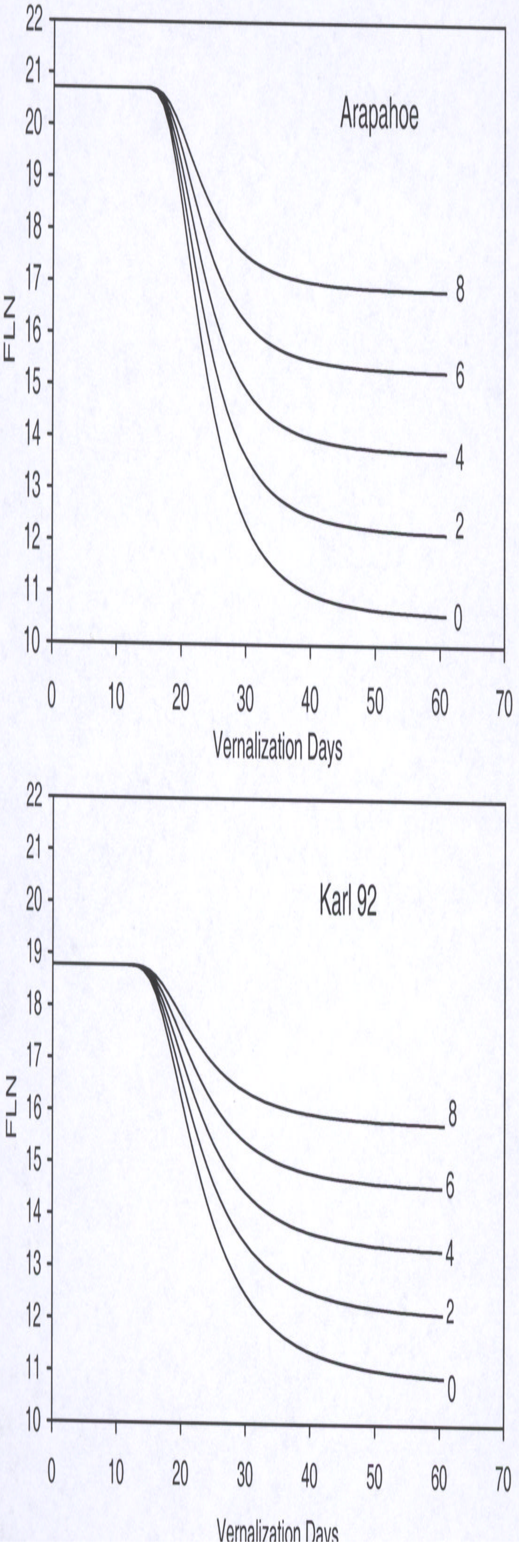
Figure 3


WE
Arapahoe
Karl 92
NE92458
y=0.62x- 60.17
r^2=0.91 RMSE=3.9
CERES-Wheat
Arapahoe
Karl 92
NE92458
y=0.69x+44.67
r^2=0.65 RMSE=4.7
Predicted DOY
Observed DOY
130
140
150
160
170

VERNALIZATION

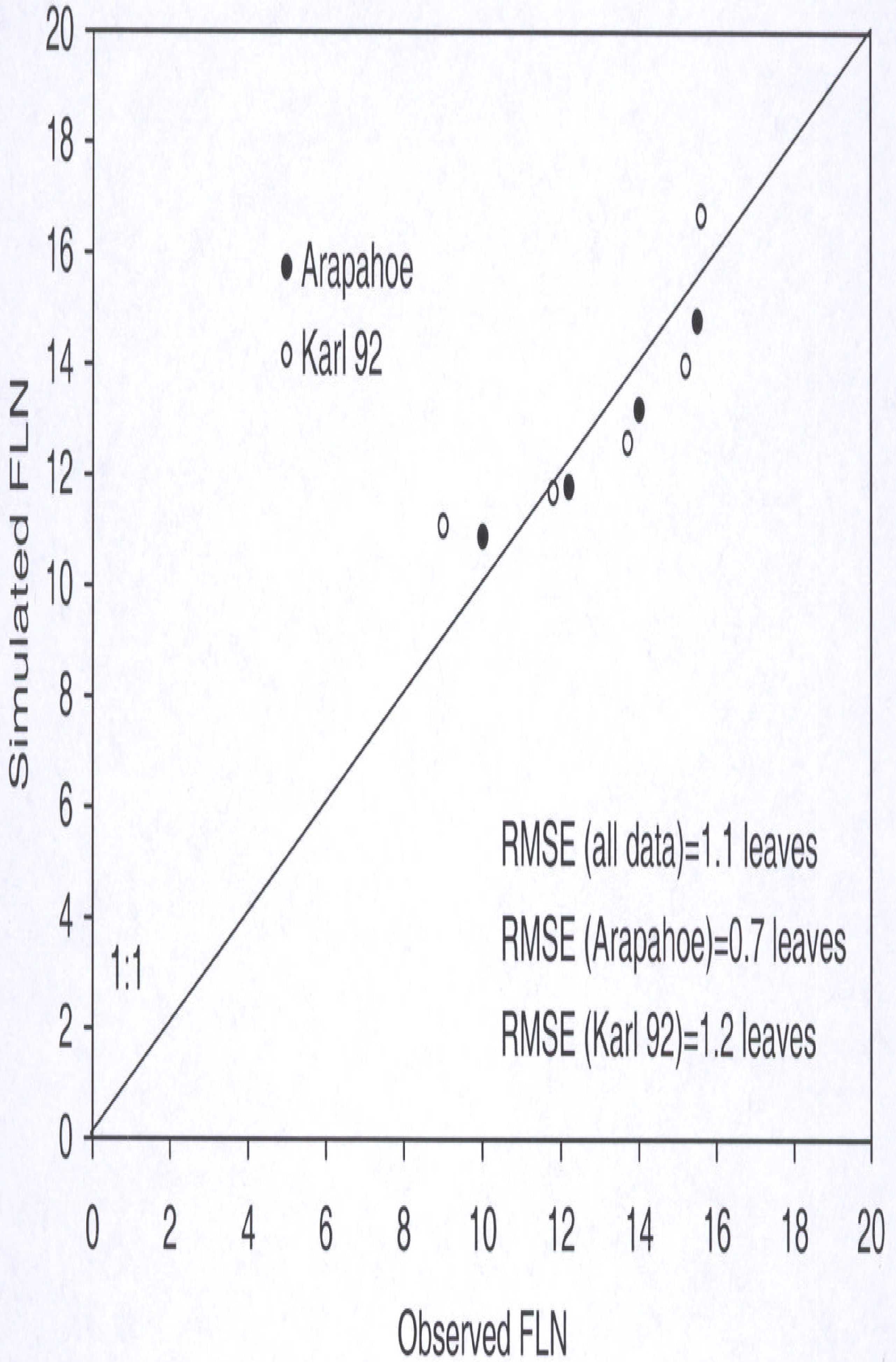
A growth chamber experiment was carried out with two cultivars of winter wheat. One chamber was kept at optimum growth temperatures and the second chamber was used to subject the plants to different vernalization treatments. Results from these experiments fit a Weibull distribution. Figure 4 indicates the final leaf number as a function of the leaf stage at the onset of the vernalization for the two cultivars as a function of vernalization days. The model was verified using an independent data set from five planting dates in 1999, Fig 5. The combined RMSE was 1.1 leaves. We haven't incorporated this algorithm into the WE model yet.

Figure 4



Arapahoe
FLN
22
21
20
19
18
17
16
15
14
13
12
11
10
8
6
4
2
0
0
10
20
30
40
50
60
70
Vernalization Days
Karl 92
FLN
22
21
20
19
18
17
16
15
14
13
12
11
10
8
6
4
2
0
0
10
20
30
40
50
60
70
Vernalization Days

Figure 5



Simulated FLN
Observed FLN
Arapahoe
Karl 92
1:1
RMSE (all data)=1.1 leaves
RMSE (Arapahoe)=0.7 leaves
RMSE (Karl 92)=1.2 leaves
0
2
4
6
8
10
12
14
16
18
20

CLIMATE CHANGE AND GRAIN END-USE QUALITY

A small (2.7x5.5 m) "hobby type" greenhouse was modified to form a supra-ambient temperature chamber to maintain the temperature inside the chamber at a fixed difference above the ambient temperature, Figs 6 and 7. This modification was accomplished by adding a large variable speed fan at the upwind end of the chamber and heaters at upwind and downwind locations. Temperatures at the upwind and downwind locations in the chamber are measured. Fan speed and heaters are manipulated to maintain near uniform conditions in the chamber. When the temperature system is operational, we will add a system to bleed and maintain a near uniform [CO_2] within the chamber. Aside from the agronomic and physiological measurements made on the same cultivar grown inside and outside the chamber, grain end-use quality properties will be determined. Will the resulting grain make a good loaf of bread?

Figure 6

Figure 7