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EVALUATION OF THE DORAISWAMY-THOMPSON WINTER WHEAT CROP CALENDAR MODEL INCORPORATING A MODIFIED SPRING RESTART SEQUENCE

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16. Abstract

The Robertson phenology model is used by both EW/CCA and FAS to provide growth stage information to a wheat stress indicator model. The resistance of wheat to a given stress varies with crop phenology.

A stress indicator model demands two accurate predictions from a crop calendar: (1) the date of spring growth initiation and (2) the crop calendar stage at growth initiation. During the LACIE various approaches were studied to predict these two variables.

The EW/CCA project has studied several appraoches for restarting the Robertson Phenology model at spring growth initiation. An approach suggested by D. Smika in 1977 was selected and tested in conjunction with the Doraiswamy-Thompson crop calendar.

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EVALUATION OF THE DORAISWAMY-THOMPSON WINTER WHEAT CROP CALENDAR MODEL INCORPORATING A MODIFIED SPRING RESTART SEQUENCE

The Early Warning/Crop Condition Assessment project of AgRISTARS and the Crop Condition Assessment Division of the Foreign Agriculture Service have employed a version of the Robertson phenology model. The model was improved during the Large Area Crop Inventory Experiment (LACIE) to predict winter wheat growth stages. Model implementation requires an accurate estimation of planting date, the historical normal date are not adequate.

The Robertson phenology model is used by both EW/CCA and FAS to provide growth stage information to a wheat stress indicator model. The resistance of wheat to a given stress varies with crop phenology.

Stress that affects winter wheat prior to growth reduction ("dormancy") are not stage related, therefore accurate phenological data is unnecessary. Following spring growth initiation, phenology information is mandatory.

A stress indicator model demands two accurate predictions from a crop calendar: (1) the date of spring growth initiation and (2) the crop calendar stage at growth initiation. During the LACIE various approaches were studied to predict these two variables.

Baskett, et.al (1976) determined a start and stop dormancy criterion based on many years of Kansas and South Dakota Crop Reporting District data. A stage development rate criterion was incorporated based on daily maximum and minimum temperatures and day length. Their analyses indicated that the Robertson Biometeorological Time Scale (BMT) at spring growth initiation could vary between stages 1.0 and 2.0. This range, while unacceptable, was the best that could be acquired from their data source. The Feyerherm Yield Model used a version of the Robertson Crop Calendar that was reset to BMT 1.85 on Julian day 270. This procedure was used for the LACIE.

The EW/CCA project has studied several approaches for restarting the Robertson Phenology model at spring growth initiation. Best results were obtained with a solar thermal unit method (Caprio, 1971). Solar radiation is, however, not readily available on a global basis. Therefore, an alternate approach suggested by Smika (1977) was selected and tested. Smika indicated soil temperature as the controlling parameter for spring growth initiation; he found that summing the mean soil temperature above $-4^{o}F$ to a total of 25 degree days would predict spring growth initiation as long as the mean daily soil temperature was greater than $-4^{o}F$ for the period. Should the mean soil temperature fall below $-4^{o}F$, the summation is reset to zero and started over. Heuer, et.al (1978) stated that this is the best method to predict spring growth initiation.

Smika's method has soil temperature as the central parameter and it is also not readily available. EW/CCA is evaluating methods to predict soil temperature at the root node (ca. 3cm) for use in the winterkill model. No technique tested thus far has improved the present soil temperature algorithm used in the winterkill model. That algorithm is from a report by

Moiseichik (1966) stating that a $4^{o}C$ mean temperature differential exists between the ambient and root node temperatures. This approximation was selected for use in the wheat crop calendar restart model.

Analyses of ground truth data taken under Smika's direction for 2 years from 7 ARS sites indicate that a BMT of 1.4 rather than 1.85 is a more accurate approximation of the phenology of spring growth initiation.

Model Configuration

The restart model was designed to use the minimum and maximum temperatures provided by either World Meteorological Organization station data or Air Force gridded meteorological data. Coefficients in the Robertson model were modified by Doraiswamy (1981) and the restart model was added. Model structure was configured to accept solar radiation information should it become generally available and STU values can replace the growing degree-day calculations.

Model logic includes:

SOILT: = ((Tmin + Tmax/2) + 4 where SOILT is mean soil temperature
Tmin is the minimum daily temperature, ^{o}C
Tmax is the maximum dialy temperature, ^{o}C

The sum of the degree-days (SDD) is:
SDD + (SOILT $-4^{o}C$) + SDD If the quantity (SDD-$4^{o}C$) is less than zero, then SDD is reset equal to zero, when SCC equals 25^{o}, the phenology model is started with a BMT of 1.4.

Testing

The modified model (Doraiswamy-Thompson) was compared to the LACIE version using Agricultural Research Service (ARS) meteorological and ground truth data. Results are summarized in Table 1.

Conclusion:

An analysis of variance procedure was applied to the data in Table 1. A two-factor ANOV A model with interactions was used with ground truth growth stage information and both D-T and LACIE-Robertson model predictions as factors. Conclusions were:

(1) Neither model tracks phenology perfectly although greater inaccuracies occur with the LACIE-Robertson model (fig. 1).

(2) Overall the D-T model more closely estimates ground-truth than does the LACIE-Robertson (fig. 2).

(3) When compared to ground-truth:

a. Both models performed equally well in growth stages 1 (emergence), 3 (heading), 4.5 (waxy ripe) and 5.0 (harvest).

b. the D-T model is superior at stages 2 (jointing) and 4 (milky ripe).

TABLE 1

MODEL AND GROUND TRUTH RESULTS USING ARS DATA FURNISHED BY DR. DARREL SMIKA

	1 E			2 J			3 H			4 SD			4.5 HD			5 M			TOTAL 2-5		
	LR	DS	GT	LR	DS	GT	LR	DS	GT	LR	DS	GT	LR	DS	GT	LR	DS	GT	HR	DS	GT
77-78 Garden City	271	271	267	98	106	109	146	136	163	169	154	151	173	166	170	180	176	177	82	70	68
Tribune	259	259	258	98	106	136	148	132	151	170	149	164	174	162	177	178	174	184	76	68	48
Albin	246	246	244	113	120	123	163	144	152	185	166	162	190	178	186	196	190	195	83	70	72
Akron	256	256	253	108	117	129	159	141	143	178	162	158	182	174	171	187	184	186	79	67	57
Paxton	263	263	262	113	120	123	157	146	150	176	165	161	180	176	173	184	185	188	71	65	65
78-79 Paxton			270	112	120	124	156	146	162	180	168	170	184	177	183	189	189	192	77	69	68
Medford			270	91	100	112	137	139	143	161	156	151	165	168	–	169	178	172	78	78	60

LR - LACIE Roberts
DS - DORAISWAMY-RESTART MODEL
GT - Ground Truth

E - Emergence
J - Jointing
H - Heading

SD - Soft Dough
HD - Hard Dough
M - Mature

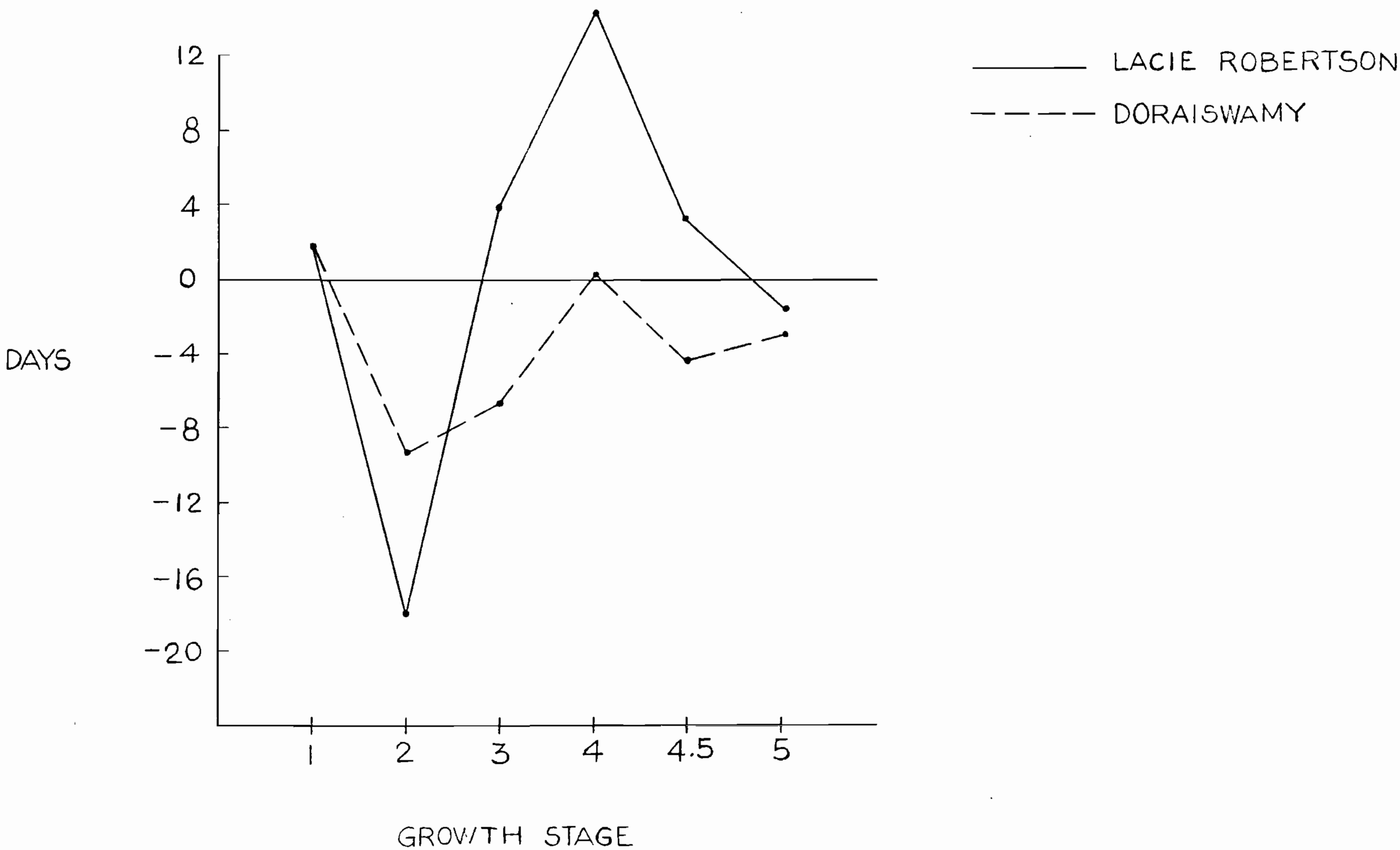

FIGURE I MEAN DIFFERENCE FROM GROUND TRUTH

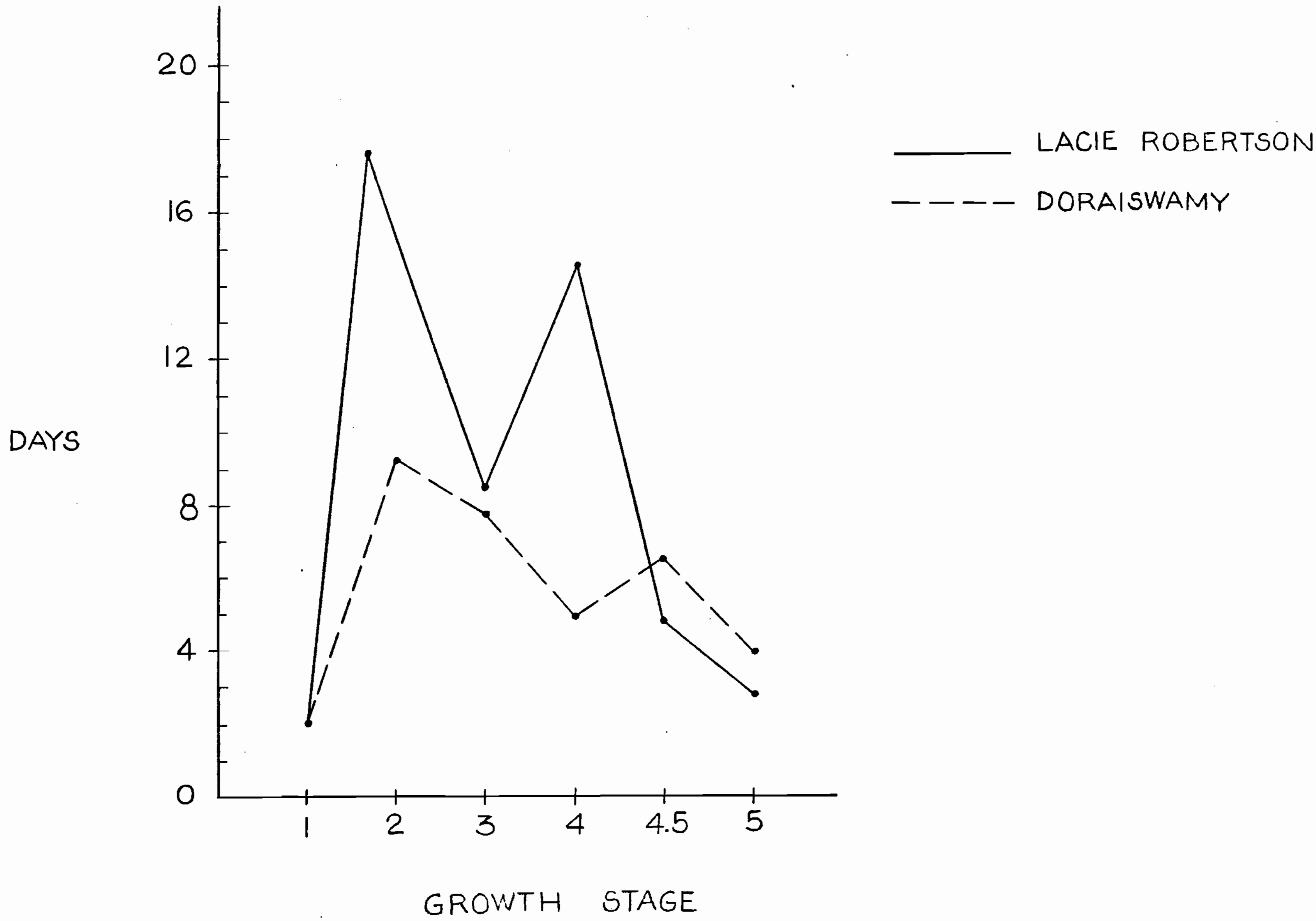

FIGURE 2 MEAN ABSOLUTE DIFFERENCE FROM GROUND TRUTH

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TABLE A1 - REGRESSION COEFFICIENTS FOR THE ORIGINAL ROBERTSON MODEL AND THE DORAISWAMY-THOMPSON IMPROVED COEFFICIENTS

Phenological period[a]	Coefficient							
	a_0	a_1	a_2	b_0	b_1	b_2	c_1	c_2
				Robertson Model				
1	999	0	0	44.37	0.01086	-0.0002230	0.009732	-0.0002267
2	8.413	1.005	0	23.64	-.003512	.00005026	.0003666	-.00000428
3	10.93	.9256	-.06025	42.64	.0002958	0	.00006733	0
4	10.94	1.389	0.08191	42.18	.0002458	0	.00003109	0
5	24.38	-1.140	0	37.67	.0006733	0	.0003442	0
				D/T Improved coefficients				
1	999	0	0	44.37	0.01086	-0.0002230	0.009732	-0.0002267
2	8.413	1.005	0	23.64	-.003512	.00005026	.0003666	-.00000428
3	10.013	.0945	0	.75	.000955	0	.009732	0.0002267
4	7	.9850	-.07050	45.18	.000625	0	.00003109	0
5	999	0	0	-5.50	.00046	0	.009732	0.00022
				LACIE coefficients for Robertson's BMTS				
1	.100E+20	-.14193-19	0	.4437E+02	.7652E-01	-.1571E-02	.6857E-01	-.1597E-02
2	.8413E+01	.5581E-01	0	.2364E+02	-.6324E-01	.9050E-03	.6601E-02	-.7710E-04
3	.1093E+02	.2613E-01	-.1701E-02	.4265E+02	.1047E-01	0	.1396E-01	0
4	.1094E+02	.2021E-01	-.1192E-02	+.4218E+02	.1688E-01	0	.2136E-02	0
5	.2438E+02	0.2165E-01	0	.3767E+02	.3543E-02	0	.1811E-01	0

[a] Periods: 1 = planting to emergence; 2 = emergence to jointing; 3 = jointing to heading; 4 = heading to soft dough; and 5 = soft dough to ripe.

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