A Crop Phenology Model for Irrigated New Mexico Chile (*Capsicum annuum* L.) Type Varieties

Roberto Soto-Ortiz and Jeffrey C. Silvertooth
Department of Soil, Water and Environmental Science
University of Arizona

Abstract

Field experiments were conducted with the objective of developing a general New Mexico chile type plant (Capsicum annuum L.*) phenological model as a function of heat units accumulated after planting (HUAP). Field experiments were conducted from 2003 through 2005 in the Sulfur Springs Valley of Arizona, near Sunsites in Cochise County, Arizona (31^o 56" N, 109^o 52" W, about 4,000 feet elevation) on a Borderline fine sandy loam (coarse-loamy, mixed, superactive thermic Typic Calcigypsids) and in the Animas Valley, New Mexico (31^o 57" N, 109^o 48" W, about 4,400 feet elevation), on a Vekol fine sandy clay loam (fine, mixed, thermic, Typic Haplargids). Plant measurements were collected routinely and important phenological stages that corresponded to first bloom, early bloom, peak bloom, physiological maturity, and red harvest were identified and recorded. Results indicate that within locations, all varieties performed similarly in relation to HU accumulation patterns. A general New Mexico chile type plant phenological model as a function of HUAP for all sites and varieties was obtained. First bloom occurred at 954 $\pm$ 254 HUAP, early bloom at 1349 $\pm$ 306 HUAP, peak bloom at 1810 $\pm$ 261 HUAP, physiological maturity at 2393 $\pm$ 215 HUAP, and red chile harvest was identified to occur at 3159 $\pm$ 220 HUAP. The purpose of this phenological baseline or model is to provide a crop management tool for growers for predicting and identifying critical stages of growth. Further development and validation of this model is a continued objective of this research program.*

Key Words: Chile, *Capsicum annuum* L., crop phenology, heat units.

Introduction

Chile (*Capsicum annuum* L.) is a stable and important crop for several crop production areas in the chile belt of the desert Southwest (New Mexico, Arizona, Texas, and northern Chihuahua, Mexico). The latest agricultural statistics (NASS, 2007) showed New Mexico

(NM) to be the leading state in chile production in the U.S.A. where about 15,750 acres were committed to production in 2006 followed by Arizona (AZ) with 5,600 acres. The New Mexico chile type is an integral part of the unique culture of the Southwestern United States. Chile peppers are pungent or non-pungent (which is largely determined by chile type and variety), green or red. In the United States "chili" is the Anglicized form of "chile", but normally refers to pungent types only. Non-pungent forms are collectively called "sweet peppers" (Smith et al., 1987). When harvested green, New Mexico chiles are eaten fresh, canned, or frozen. If allowed to mature on the plant, the chiles turn red and eventually dehydrate (Biles et al., 1993).

In recent years there has been a marked increase in the production of pungent chiles, partly because of the increasing Hispanic population, but also because of the increased use of spices by the non-Hispanic part of population (Smith et al., 1987). As a result, an increase in cultivated chile acreage is needed to meet the market demands for this crop (Johnson and Decoteau, 1996; Johnson and Johnson, 1992). The increase in demand, coupled with more land being committed to chile production has created the need to enhance the basic understanding of chile crop agronomy and general production practices to improve efficiencies.

Accurate prediction of harvest date and developmental stages of a crop has widespread application for improving management of that crop (e.g. fertilization, irrigation, scheduling multiple harvests, pest management activities, labor and machinery, etc.). We can often monitor and predict development based on measuring the thermal conditions in the plant's environment. Various forms of temperature measurements and units commonly referred to as heat units (HU), growing degree units (GDU), or growing degree days (GDD) have been utilized in numerous studies to predict phenological events for both agronomic and horticultural crops (Baker and Reddy, 2001).

Wurr et al. (2002) stated that to describe crop growth and development there is first the need to determine rate functions for various processes. This includes the identification of distinct stages and phases of growth and development, as well as the prediction of the duration of developmental phases for given temperature regimes. The uses of HU accumulation methods are efficient techniques for modeling and predicting growth stages in crops (such as chiles) as compared with the traditional days after planting (DAP) method since variations among seasons and locations can be better normalized by the use of HU calculations rather than DAP.

At present, there is very limited information available concerning basic crop growth and development patterns for irrigated chiles in the desert southwest. Some relevant information does exist in the literature for chiles but it is very limited in scope and the work has dealt primarily with varieties and cultural practices that have changed considerably in recent years (Beese et al. 1982; and Horton et al. 1982). The literature regarding much of the basic agronomic aspects of chile production in Arizona is virtually non-existent. Therefore, there is a distinct need to develop an understanding of basic crop phenology in the desert Southwest. Hence, the objective of this study was to develop a crop phenology model as a function of HUAP that could be used as a crop management tool for New Mexico chile type varieties.

Materials and Methods

Commercial chile fields managed by cooperator-growers were selected from 2003 through 2005 in the Sulfur Springs Valley of Arizona, near Sunsites in Cochise County, Arizona (31^{o} 56” N, 109^{o} 52” W, about 4,000 feet elevation) on a Borderline fine sandy loam (coarse-loamy, mixed, superactive thermic Typic Calcigypsids) and in the Animas Valley, New Mexico (31^{o} 57” N, 109^{o} 48” W, about 4,400 feet elevation), on a Vekol fine sandy clay loam (fine, mixed, thermic, Typic Haplargids), to conduct phenological studies. The general description of the locations and methods are presented in Tables 1 and 2. The study areas were dry planted on 40-inch wide beds in AZ and 30-inch beds in NM. Composite surface 30-cm soil samples were collected from each field prior to any fertilization for complete nutrient analysis (Table 3). Soil nutrient levels were within acceptable ranges based on AZ/NM guidelines (Herrera, 2000 and Doerge et al., 1991). In all cases, all inputs such as fertilizer, water, and pest control were managed throughout the season on an as-needed basis.

Climatic conditions were monitored and recorded on a daily basis throughout the growing season using an Arizona Meteorological Network (AZMET) station sited near Sunsites and a New Mexico Climate Center (NMCC) station for the Animas Valley location. The weather stations near the experimental sites are automated and are used to determine a complete battery of meteorological measurements including the hourly (AZMET) and daily (NMCC) maximum and minimum temperature values. Consequently, the HU accumulations (86/55 ^{o}F thresholds) are calculated by a method presented in Baskerville and Emin (1969) and modified by Brown (1989). The daily HU accumulations are summed up from the time of planting and reported as HUAP.

Plant measurements were made on regular 14-day intervals and the following growth stages were also identified: pre-bloom, early bloom, peak bloom (also corresponded to early pod development), physiological maturity (green chile), and red harvest (complete phenological maturity). The growth stages attained at each sampling date provided an assessment of the full course of vegetative and reproductive development of the chile plants. The mean and standard deviation of every phenological stage for all in-season data were calculated using the PROC TAB procedure of SAS (SAS Institute, 1999a and 1999b).

Results and Discussion

The overall in-season data for all varieties and all sites was collected and tabulated (Tables 4 and 5). In general, the in-season plant measurements provide an indication of the progression of vegetative/reproductive development through the course of the crop fruiting cycle. Results indicate that within locations, all varieties performed similarly in relation to HU accumulation. Based on the analyses of the full data set, a general crop phenology model for New Mexico chile type varieties is presented in Table 4. First bloom occurred at

954 ± 254 HUAP, early bloom at 1349 ± 306 HUAP, peak bloom at 1810 ± 261 HUAP, physiological maturity at 2393 ± 215 HUAP, and red harvest stage was identified to occur at 3159 ± 220 HUAP. The standard deviation for the crop phenology estimation, increased for all sites as the growing season progressed and ranged from 215 to 306 HUAP (11 to 15 calendar days). Further development and validation of this model is a continued objective of this research program.

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Table 1. Chile experimental sites and basic agronomic information, 2003-2005.

Location	Site	Variety	Wet date	Irrigation type	Soil type
		451	3/16/03	Sprinkler	SL
		Esquina	4/03/03	Sprinkler	SL
		AZ 20	3/23/03	Sprinkler	SL
Sunsites, AZ	Curry's Farm	AZ 20	3/23/04	Sprinkler	SL
		AZ 8	3/23/04	Subsurface drip	SL
		AZ 8	4/12/05	Subsurface drip	SL
		AZ 21	4/25/05	Subsurface drip	SL
		AZ 335-270	4/25/05	Subsurface drip	SL
		Esquina	4/01/05	Subsurface drip	SL
		Ancho X Chile	3/14/05	Subsurface drip	SL
		AZ 20	3/25/05	Subsurface drip	SL
Animas Valley, NM	Massey's Farm	B58	4/07/05	Sprinkler	SCL
		300	4/07/05	Sprinkler	SCL
		LB 25	4/07/05	Sprinkler	SCL

SL.- Sandy loam, SCL.- Sandy clay loam.

Table 2. Weather conditions for the chile experimental locations during the growing season (March-October), 2003-2005.

	Sunsites, AZ.			Animas Valley, NM.
Parameters	**2003**	**2004**	**2005**	**2005**
Average air temperature at planting dates (°F).	62.2 ± 0.5	55.9 ± 4.7	53.4 ± 4.7	64
Maximum and minimum mean air temperature (°F).	64 - 59	75 - 57	81 - 50	86 - 63
Maximum and minimum mean relative humidity (%).	51 - 20	56 - 20	62 - 27	54 - 18
Cumulative precipitation (inches).	5.2	10.4	5.4	0.6

Table 3. Soil test results in the two experimental locations, 2003-2005.

Parameters	Arizona Sandy Loam (Calcigypsids)			New Mexico Sandy clay loam (Haplargids)
	2003	2004	2005	2005
†NO_3^--N (ppm)	26	41	41	20
‡ PO_4-P (ppm)	10	23	23	4.9
K* (ppm)	650	200	220	460
Ca* (ppm)	3500	850	3300	3300
Mg* (ppm)	450	150	360	330
Na* (ppm)	430	42	73	450
EC_e (mmhos/cm)	0.69	0.53	0.54	0.56
pH (1:1 H_2O)	7.5	7.2	7.5	7.8
¶CEC (meq/100 g)	24.8	6.2	20.4	22.4
§ESP (%)	7.5	2.9	1.6	8.7
Free lime	None	Low	High	None

† NO_3^--N using Cd-reduction
‡ PO_4-P sodium bicarbonate by Olsen.
*Exchangeable cations using NH_4OAc (pH 8.5).
¶ Computed CEC.
§ Computed exchangeable sodium percentage.

Table 4. Chile phenological stages for all sites as a function of HUAP (86/55°F), 2003-2005.

Location	Site	Variety	First Bloom	Early Bloom	Peak Bloom	Physiological Maturity	Red Harvest
		451	869	1519	2075	2435	3249
		Esquina	832	1481	2038	2398	3211
		AZ 20	859	1508	2065	2425	-----
Sunsites,	Curry's	AZ 20	1051	1440	1782	2416	-----
AZ	Farm	AZ 8	1051	1440	1782	2416	-----
		AZ 8	666	940	1550	2146	-----
		AZ 21	826	1107	1436	2183	-----
		AZ 335-270	826	1107	1436	2183	2765
		Esquina	727	1003	1613	2207	2939
		Ancho X Chile	760	1033	1643	2239	-----
		AZ 20	745	1019	1629	2225	-----
Animas	Massey's	B58	1379	1764	2099	2741	3317
Valley,	Farm	300	1379	1764	2099	2741	3317
NM		LB 25	1379	1764	2099	2741	3317
		Mean	954	1349	1810	2393	3159
		SD	254	306	261	215	220

Table 5. Chile phenological stages by variety (HUAP ± SD), 2003-2005.

Variety	First bloom	Early bloom	Peak bloom	Physiological maturity	Red Harvest
300	1379 ± 0	1764 ± 0	2099 ± 0	2741 ± 0	3317 ± 0
451	870 ± 0	1519 ± 0	2075 ± 0	2435 ± 0	3249 ± 0
AZ 335-270	826 ± 0	1107 ± 0	1436 ± 0	2183 ± 0	2765 ± 0
AZ 20	941 ± 121	1326 ± 215	1773 ± 172	2382 ± 76	------------
AZ 21	826 ± 0	1107 ± 0	1436 ± 0	2030 ± 0	------------
AZ 8	897 ± 211	1190 ± 274	1666 ± 127	2261 ± 144	-------------
Ancho	760 ± 0	1033 ± 0	1643 ± 0	2239 ± 0	--------------
B-58	1379 ± 0	1764 ± 0	2099 ± 0	2741 ± 0	3317 ± 0
Esquina	793 ± 54	1242 ± 262	1795 ± 227	2289 ± 102	3075 ± 145
LB-25	1379 ± 0	1764 ± 0	2099 ± 0	2741 ± 0	3317 ± 0