Conversion of Wright (1981) and Wright (1982) alfalfa-based crop coefficients for use with the ASCE Standardized Penman-Monteith Reference Evapotranspiration Equation

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This technical note describes the conversion of mean crop coefficients of Wright (1981) and basal crop coefficients of Wright (1982), as reported in ASCE Manual 70, for equivalent function with the ASCE Standardized Reference Evapotranspiration equation (EWRI, 2002) for an alfalfa reference (ET_{rs}). The Wright (1981, 1982) coefficients were originally derived for the 1982 Kimberly Penman equation.

The ASCE Standardized Penman-Monteith ET_{rs} method, which is standardized for a 0.5 m tall vegetation reference for all times of the year, has been noted to predict higher than the 1982 Kimberly Penman equation at Kimberly during early spring and fall months (Wright et al., 2000) and to predict slightly below the 1982 Kimberly Penman method during the peak summer period. Conversion of the Wright (1981, 1982) coefficients to the ET_{rs} basis will provide for equivalent prediction of crop ET_c for a southern Idaho type of climate using the ASCE standardized Penman-Monteith method.

Conversion of crop coefficients was made using Kimberly weather data for the same year as used for the original coefficient determination (Table 1). This was done to reproduce the same ET_c values that were created using the smoothed K_c curves of Wright (1981, 1982) used during development of the original K_c and K_{cb} tables and to utilize the same weather patterns as went into the original determinations. The resulting converted K_c curves reproduce the cumulative ET_c vs. time curves for the Kimberly crops as obtained using the original coefficients and the 1982 Kimberly Penman method. It is expected that the converted K_c curves will produce applicable and representative ET_c for other temperate climates similar to Kimberly, Idaho having cold winters with defined dormant periods.

In the conversion work, ET_{rs} was computed daily using Kimberly weather data for air temperature, humidity and wind speed collected by the National Weather Service and solar radiation data collected by the USDA-ARS. The weather data were quality checked and controlled using procedures from ASCE Standardized Report Appendix D, including comparison of measured solar radiation data with a theoretical clear sky curve and comparison of daily dewpoint temperature with daily minimum air temperature. Solar radiation for portions of some years required adjustment.

Crop ET_c for the original crop coefficient data set was computed daily as $ET_{c\ KP} = K_{c\ Wright}$ x $ET_{r\ KP}$ where $ET_{c\ KP}$ represents ET_c as predicted using crop coefficients ($K_{c\ Wright}$) by Wright

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(1981) or Wright (1982), as reported in ASCE Manual 70, Tables 6.6 and 6.9, with some adjustment to some crops by Wright (1995). $ET_{r\ KP}$ represents alfalfa reference ET calculated using the 1982 Kimberly Penman equation and associated equations (Wright, 1982). ET_c for the Standardized Penman-Monteith was computed as $ET_{c\ s} = K_{c\ s}$ x ET_{rs} where $ET_{c\ s}$ represents crop ET computed with the standardized ASCE procedure, and $K_{c\ s}$ represents the crop coefficients of Wright converted for use with ET_{rs}. In the conversion work, cumulative $ET_{c\ s}$ vs. time was set equal to cumulative $ET_{c\ KP}$ vs. time.

The same crop coefficient tabular format as used by Wright (1981) and Wright (1982) is presented for the converted coefficients, where K_c from planting to effective full cover is expressed as a function of percent time from planting to effective full cover, in multiples of 10%, and K_c after effective full cover is expressed as a function of days after full cover in multiples of 10 days. Mean crop coefficients and basal crop coefficients of Wright (1981) and Wright (1982) as reported in ASCE Manual 70 and refined by Wright (1995) are summarized in Tables 2 and 3. The planting, effective full cover and harvest dates summarized in ASCE Manual 70 Table 6.7 are listed in Table 4.

To facilitate the conversion of the K_c tables, computed ET_c was expressed as cumulative ET_c since planting, in mm. This was done by summing ET_c that was computed daily over the growing period using both methods. Each decadal (i.e., 10% or 10 day) K_c entry for the constructed $K_{cm\ s}$ or $K_{cb\ s}$ tables was adjusted for each crop until the cumulative ET_c vs. time curves by the two methods coincided. A root mean square difference, RMSD, was computed for each crop based on the differences in prediction during each decade (10% or 10 day period). The conversions caused the two cumulative ET_c curves to graphically coincide, created a relatively smooth and continuous evolution in K_c vs. time, and minimized the total RMSD for the $K_{cm\ s}$ or $K_{cb\ s}$.

Winter wheat was modeled from the date of planting in fall until estimated dormancy in early winter and then again from greenup in spring until harvest. Alfalfa was modeled and converted for each of the four growth cycles as done by Wright (1981, 1982) and for a mean seasonal curve that smoothed impacts of reduced K_c following cuttings. Three years of weather and lysimeter data had been used by Wright to construct the alfalfa curves (1969, 1970, 1971). Therefore, a combined daily series for ET_r was created by averaging the daily ET_r for these three years. Similarly, two years, 1973 and 1974 were averaged to construct the daily ET_r curve for the snap bean crop since these two years were used in defining the original K_c curves (Wright, 1982).

The clipped ryegrass crop was not reported by Wright (1981) or Wright (1982), but was included in ASCE Manual 70, and was therefore converted here. This crop represented 1983 and 1984, so that the ET_r for these two years was averaged to produce a single daily time series.

Because the second and third growth cycles for alfalfa at Kimberly use the same single curve (Table 2 and 3), this curve was converted so that each of the two growth cycles shared the "error" in the curve conversion.

Converted $K_{cm\ s}$ and $K_{cb\ s}$ coefficient tables are shown in Tables 5 and 6 for use with the ASCE Standardized Penman-Monteith method. Standard errors of estimate between cumulative ET_c by

the two methods vs. percent time to full cover and days after cover were generally less than 1 mm per decadal period. This translates into less than about 0.2 mm/day RMSD in most cases.

Graphs showing daily K_{cm} and K_{cb} vs. time and graphs showing cumulative ET_c vs. time are included at the back of this report.

Table 1. Years of original lysimeter and weather data collection reported by Wright (1981) and Wright (1982) and RMSD of crop coefficient conversion.

Crop	Year of data	RMSD of K_{cm} conversion for use with the ASCE Standardize Penman-Monteith Reference ET method, mm/decadal[1] period
Spring grain	1979	1.1
Peas	1977	1.0
Sugar Beets	1975	0.9
Potatoes	1972	0.7
Field Corn	1976	0.9
Sweet Corn	1976	0.9
Snap Beans	1973, 1974 (ave)	0.3
Winter Wheat	1977-78	1.4
Alfalfa	1969, 1970, 1971 (ave)	0.7 (season) 0.4, 1.3, 1.3, 0.4 for cuttings 1, 2, 3, 4
Ryegrass	1983, 1984	0.7

[1] A decadal period represents 10% of the planting to effective full cover period or each 10 days following effective full cover until harvest.

TABLE 2. Original "Mean" ET Crop Coefficients, K_{cm}, for Normal Irrigation and Precipitation Conditions, for Use with Alfalfa Reference ET_r as computed by the 1982 Kimberly Penman Reference Method (*Original Crop Coefficients* by Wright, 1981; Manual 70 Table 6.9; updated by Wright, 1995))

	Mean ET Crop Coefficients, K_{cm}											
	PCT, time from planting to effective cover (%)											
Crop	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	
Spring grain[1]	0.2[2]	0.2	0.21	0.26	0.39	0.55	0.66	0.78	0.92	1	1	
Peas	0.2	0.2	0.21	0.26	0.36	0.43	0.51	0.62	0.73	0.85	0.93	
Sugar Beets	0.26	0.26	0.26	0.26	0.26	0.27	0.29	0.38	0.5	0.75	1	
Potatoes	0.2	0.2	0.2	0.22	0.31	0.41	0.51	0.62	0.7	0.76	0.78	
Corn	0.2	0.2	0.2	0.2	0.23	0.32	0.42	0.55	0.7	0.85	0.95	
Beans	0.2	0.2	0.2	0.26	0.35	0.45	0.55	0.66	0.8	0.9	0.95	
Winter Wheat	0.3	0.3	0.3	0.5	0.75	0.9	0.98	1	1	1	1	
	DT, days after effective cover											
	0	10	20	30	40	50	60	70	80	90	100	
Spring grain[1]	1	1	1	1	0.9	0.5	0.3	0.15	0.1			
Peas	0.93	0.93	0.7	0.53	0.35	0.2	0.12	0.1				
Sugar Beets	1	1	1	1	0.99	0.94	0.88	0.83	0.78	0.73	0.68	
Potatoes	0.78	0.78	0.76	0.74	0.71	0.67	0.63	0.59	0.36	0.25	0.2	
Field Corn	0.95	0.96	0.95	0.94	0.9	0.85	0.79	0.74	0.35	0.25		
Sweet Corn	0.95	0.94	0.93	0.9	0.85	0.75	0.58	0.4	0.2	0.1		
Beans	0.95	0.95	0.9	0.67	0.33	0.15	0.1	0.05				
Winter Wheat	1	1	1	1	0.95	0.55	0.25	0.15	0.1			
	Time from new growth or harvest to harvest (%)											
Crop	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	
Alfalfa (1st cycle)[3]	0.55	0.7	0.82	0.91	0.96	0.99	1	1	0.98	0.96	0.94	
(Intermediate cycles)	0.3	0.4	0.5	0.8	0.96	0.99	1	1	0.98	0.96	0.94	
(Last cycle)	0.3	0.4	0.5	0.6	0.65	0.63	0.61	0.59	0.57	0.55	0.5	
	Total Season (days from beginning of spring growth)											
	0	**20**	**40**	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	
Alfalfa	0.45	69	0.87	0.88	0.7	0.75	0.88	0.81	0.88	0.71	0.65	
(seasonal)	0.5	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.75	0.6	
(overall seasonal mean)						0.85						
perennial rye grass	0.6	0.7	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.76	0.75	(8-15 cm)

[1]Spring grain includes wheat and barley.

[2]The value 0.2 is appropriate for relatively dry surface soil conditions from planting until significant crop development. For moderately wet surface soil, as with preemergence irrigation(s) or some precipitation, use 0.35, and for very wet conditions use 0.50.

[3]1st denotes first harvest, intermediate harvests may be 1 or more depending on length of season. The last harvest is when crop becomes dormant in cool weather. See text for further discussion. Cultivar used was Ranger.

Minor changes from Wright (1982) reflect additional data for some crops (Wright, 1984, personal communication).

TABLE 3. Original Basal ET Crop Coefficients, K_{cb}, for Use with Alfalfa Reference ET_r as computed by the 1982 Kimberly Penman Reference Method (*Original Crop Coefficients* by Wright, 1982; Manual 70 Table 6.6; updated by Wright, 1995))

	Basal ET Crop Coefficients, K_{cb}											
	PCT, time from planting to effective cover (%)											
Crop	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	
Spring grain[1]	0.15	0.15	0.16	0.2	0.25	0.4	0.52	0.65	0.81	0.96	1	
Peas	0.15	0.15	0.16	0.18	0.2	0.29	0.38	0.47	0.65	0.8	0.9	
Sugar Beets	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.21	0.35	0.69	1	
Potatoes	0.15	0.15	0.15	0.15	0.15	0.2	0.32	0.47	0.62	0.7	0.75	
Corn	0.15	0.15	0.15	0.16	0.17	0.18	0.25	0.38	0.55	0.74	0.93	
Beans	0.15	0.15	0.16	0.18	0.22	0.34	0.45	0.6	0.75	0.88	0.92	
Winter Wheat	0.15	0.15	0.15	0.3	0.55	0.8	0.95	1	1	1	1	
	DT, days after effective cover											
	0	10	20	30	40	50	60	70	80	90	100	
Spring grain[1]	1	1	1	1	0.9	0.4	0.15	0.07	0.05			
Peas	0.9	0.9	0.72	0.5	0.32	0.15	0.07	0.05				
Sugar Beets	1	1	1	0.98	0.94	0.89	0.84	0.79	0.74	0.69	0.64	
Potatoes	0.75	0.75	0.73	0.7	0.66	0.63	0.59	0.52	0.2	0.1	0.1	
Field Corn	0.93	0.93	0.93	0.9	0.87	0.83	0.77	0.7	0.3	0.2	0.15	
Sweet Corn	0.93	0.91	0.9	0.88	0.8	0.7	0.5	0.25	0.15			
Beans	0.92	0.92	0.86	0.65	0.3	0.1	0.05					
Winter Wheat	1	1	1	1	0.95	0.5	0.2	0.1	0.05			
	Time from new growth or harvest to harvest (%)											
Crop	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	
Alfalfa (1st cycle)[2]	0.4	0.5	0.62	0.8	0.9	0.95	1	1	0.98	0.96	0.94	
(Intermediate cycles)	0.25	0.3	0.4	0.7	0.9	0.95	1	1	0.98	0.96	0.94	
(Last cycle)	0.25	0.3	0.4	0.5	0.55	0.5	0.4	0.35	0.3	0.27	0.25	
	Total Season (days from beginning of spring growth) (These are Kcmeans)											
	0	**20**	**40**	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	
Alfalfa	0.45	69	0.87	0.88	0.7	0.75	0.88	0.81	0.88	0.71	0.65	
(seasonal)	0.5	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.75	0.6	
(overall seasonal mean)						0.85						
perennial rye grass	0.6	0.7	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.76	0.75	
(8-15 cm)												

[1]Spring grain includes wheat and barley.

[2]1st denotes first harvest, intermediate harvests may be 1 or more depending on length of season. The last harvest is when crop becomes dormant in cool weather. See text for further discussion. Cultivar used was Ranger.

Minor changes from Wright (1982) reflect additional data for some crops (Wright, 1984, personal communication).

TABLE 4. Dates of Various Crop Growth Stages Identifiable for Crops Studied at Kimberly, Idaho 1968-1979 (after Wright, 1982, and Table 6.7 of ASCE Manual 70)

	Date of Occurrence (Month/Day)							Days		
Crop	Planting	Emer-gence	Rapid Growth	Full Cover	Heading or Bloom	Ripening	Harvest	Planting to Full Cover	Full Cover to Harvest	Growing Period Length, Days
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	
Spring grain[1]	04/01	04/15	05/10	06/10	06/10	07/20	08/10	70	61	131
Peas	04/05	04/25	05/10	06/05	06/15	07/05	07/25	61	50	111
Sugar Beets	04/15	05/10	06/01	07/10			10/15	86	97	183
Potatoes	04/25	05/25	06/10	07/10	07/01	09/20	10/10	76	92	168
Field Corn	05/05	05/25	06/10	07/15	07/30	09/10	09/20	71	67	138
Sweet Corn	05/05	05/25	06/10	07/15	07/20		08/15	71	31	102
Beans	05/22	06/05	06/15	07/15	07/05	08/15	08/30	54	46	100
Winter Wheat[2]	(2/15)	(3/1)	03/20	06/05	06/05	07/15	08/10	(110)	66	304
Alfalfa (1st)[3]	04/01		04/20				06/15			75
Alfalfa (2nd)[3]	06/15		06/25				07/31			46
Alfalfa (3rd)[3]	07/31		08/10				09/15			46
Alfalfa (4th)[3]	09/15		10/01				10/30			45

[1]Spring grain includes barley and wheat.
[2]Effective dates in parentheses, Crop was planted on 10/10 and emerged 10/25 the previous season.
[3]Effective planting date for established alfalfa is date growth begins in spring or harvest of preceding crop dates for these cuttings are indicated. Final harvest is date crop becomes dormant.
Minor changes from Wright (1982) reflect additional data for some crops (Wright, 1984, personal communication).

TABLE 5. "Mean" ET Crop Coefficients, K_{cm}, for Normal Irrigation and Precipitation Conditions, for Use with Alfalfa Reference ET_r as computed by the *ASCE Standardized Penman-Monteith Reference Method* (Converted from Original Crop Coefficients of Wright, 1981; Manual 70 Table 6.9; and updates by Wright, 1995))

	Mean ET Crop Coefficients, K_{cm}											
	PCT, time from planting to effective cover (%)											
Crop	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	
Spring grain[1]	0.2[2]	0.2	0.2	0.25	0.37	0.5	0.63	0.76	1	1.03	1.03	
Peas	0.15	0.17	0.19	0.21	0.32	0.42	0.52	0.63	0.73	0.83	0.93	
Sugar Beets	0.26	0.26	0.26	0.26	0.26	0.28	0.3	0.38	0.55	0.74	1.03	
Potatoes	0.2	0.2	0.2	0.22	0.3	0.41	0.53	0.67	0.73	0.77	0.8	
Corn	0.2	0.2	0.2	0.2	0.24	0.34	0.44	0.58	0.72	0.9	1	
Beans	0.2	0.2	0.22	0.26	0.35	0.45	0.55	0.68	0.83	0.95	0.97	
Winter Wheat	0.25	0.25	0.27	0.38	0.6	0.8	0.9	0.96	1	1.03	1.03	
	DT, days after effective cover											
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	
Spring grain[1]	1.03	1.03	1.03	1.03	0.94	0.5	0.3	0.15	0.1			
Peas	0.93	0.93	0.7	0.54	0.38	0.22	0.12	0.1				
Sugar Beets	1.03	1.03	1.03	1	0.97	0.92	0.82	0.74	0.65	0.61	0.56	
Potatoes	0.8	0.8	0.76	0.72	0.68	0.63	0.58	0.5	0.38	0.2	0.15	
Field Corn	1	0.99	0.98	0.95	0.88	0.8	0.72	0.63	0.35	0.18		
Sweet Corn	1	0.97	0.94	0.9	0.84	0.7	0.55	0.35	0.2	0.1		
Beans	0.97	0.97	0.94	0.64	0.32	0.15	0.1	0.05				
Winter Wheat	1.03	1.03	1.03	1.03	1	0.55	0.25	0.15	0.1			
	Time from new growth or harvest to harvest (%)											
Crop	0	10	20	30	40	50	60	70	80	90	100	
Alfalfa (1st cycle)[3]	0.5	0.62	0.73	0.83	0.88	0.94	1	1	1	0.98	0.95	
(Intermediate cycles)	0.3	0.4	0.55	0.8	0.94	0.97	1	1	1	0.97	0.94	
(Last cycle)	0.3	0.35	0.45	0.53	0.58	0.58	0.54	0.48	0.46	0.44	0.44	
	Total Season (days from beginning of spring growth)											
	0	20	40	60	80	100	120	140	160	180	200	
Alfalfa	0.45	69	0.87	0.88	0.7	0.75	0.88	0.81	0.88	0.71	0.65	
(seasonal)	0.44	0.77	0.82	0.86	0.9	0.88	0.85	0.82	0.78	0.66	0.5	
(overall seasonal mean)						0.85						
perennial rye grass	0.55	0.66	0.77	0.8	0.8	0.8	0.78	0.76	0.72	0.68	0.55	(8-15 cm)

[1]Spring grain includes wheat and barley.
[2]The values 0.15 to 0.26 for all crops are appropriate for relatively dry surface soil conditions from planting until significant crop development.
[3]For moderately wet surface soil, as with preemergence irrigation(s) or some precipitation, use 0.35, and for very wet conditions use 0.50.
1st denotes first harvest, intermediate harvests may be 1 or more depending on length of season. The last harvest is when crop becomes dormant in cool weather. Cultivar used was Ranger.

TABLE 6. Basal ET Crop Coefficients, K_{cb}, for Use with Alfalfa Reference ET_r as computed by the *ASCE Standardized Penman-Monteith Reference Method* (Converted from Original Crop Coefficients by Wright, 1982; Manual 70 Table 6.6; updated by Wright, 1995))

	Basal ET Crop Coefficients, K_{cb}											
	PCT, time from planting to effective cover (%)											
Crop	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	
Spring grain[1]	0.15	0.15	0.15	0.19	0.24	0.36	0.48	0.62	0.92	0.98	1.03	
Peas	0.12	0.13	0.14	0.15	0.18	0.27	0.36	0.5	0.65	0.78	0.92	
Sugar Beets	0.15	0.15	0.15	0.15	0.15	0.16	0.17	0.21	0.4	0.66	1.03	
Potatoes	0.15	0.15	0.15	0.15	0.15	0.2	0.34	0.49	0.64	0.72	0.77	
Corn	0.15	0.15	0.15	0.16	0.17	0.2	0.27	0.41	0.55	0.8	0.96	
Beans	0.15	0.15	0.17	0.19	0.23	0.35	0.46	0.6	0.78	0.93	0.95	
Winter Wheat	0.12	0.12	0.14	0.22	0.45	0.7	0.84	0.96	1	1.03	1.03	
	DT, days after effective cover											
	0	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	
Spring grain[1]	1.03	1.03	1.03	1.03	0.94	0.4	0.15	0.07	0.05			
Peas	0.92	0.92	0.72	0.52	0.32	0.16	0.07	0.05				
Sugar Beets	1.03	1.03	1.02	0.98	0.93	0.86	0.78	0.72	0.66	0.6	0.54	
Potatoes	0.77	0.77	0.73	0.68	0.64	0.59	0.54	0.47	0.2	0.08	0.08	
Field Corn	0.96	0.96	0.96	0.92	0.85	0.79	0.72	0.62	0.28	0.16	0.12	
Sweet Corn	0.96	0.95	0.93	0.88	0.8	0.65	0.47	0.23	0.12			
Beans	0.95	0.95	0.88	0.64	0.3	0.09	0.05					
Winter Wheat	1.03	1.03	1.03	1.03	1	0.5	0.2	0.1	0.05			
	Time from new growth or harvest to harvest (%)											
Crop	0	10	20	30	40	50	60	70	80	90	100	
Alfalfa (1st cycle)[2]	0.35	0.45	0.56	0.72	0.82	0.9	1	1	1	0.98	0.96	
(Intermediate cycles)	0.25	0.3	0.42	0.72	0.9	0.95	1	1	0.98	0.96	0.94	
(Last cycle)	0.25	0.27	0.36	0.42	0.5	0.45	0.35	0.3	0.25	0.22	0.22	
	Total Season (days from beginning of spring growth) (These are K_{cmeans})											
	0	20	40	60	80	100	120	140	160	180	200	
Alfalfa	0.45	69	0.87	0.88	0.7	0.75	0.88	0.81	0.88	0.71	0.65	
(seasonal)	0.5	0.74	0.82	0.86	0.88	0.88	0.86	0.84	0.78	0.7	0.5	
(overall seasonal mean)						0.85						
perennial rye grass	0.6	0.68	0.76	0.78	0.8	0.8	0.79	0.76	0.73	0.68	0.6	
(8-15 cm)												

[1]Spring grain includes wheat and barley.
[2]1st denotes first harvest, intermediate harvests may be 1 or more depending on length of season. The last harvest is when crop becomes dormant in cool weather. Cultivar used was Ranger.

References

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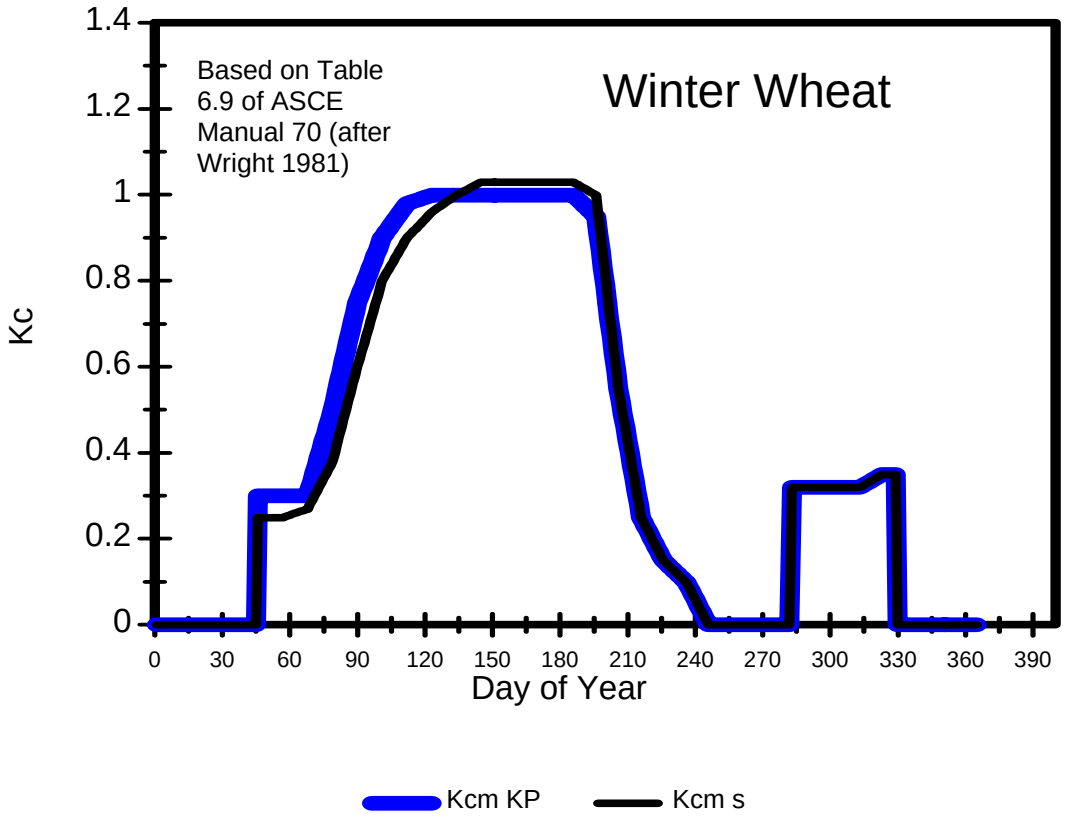
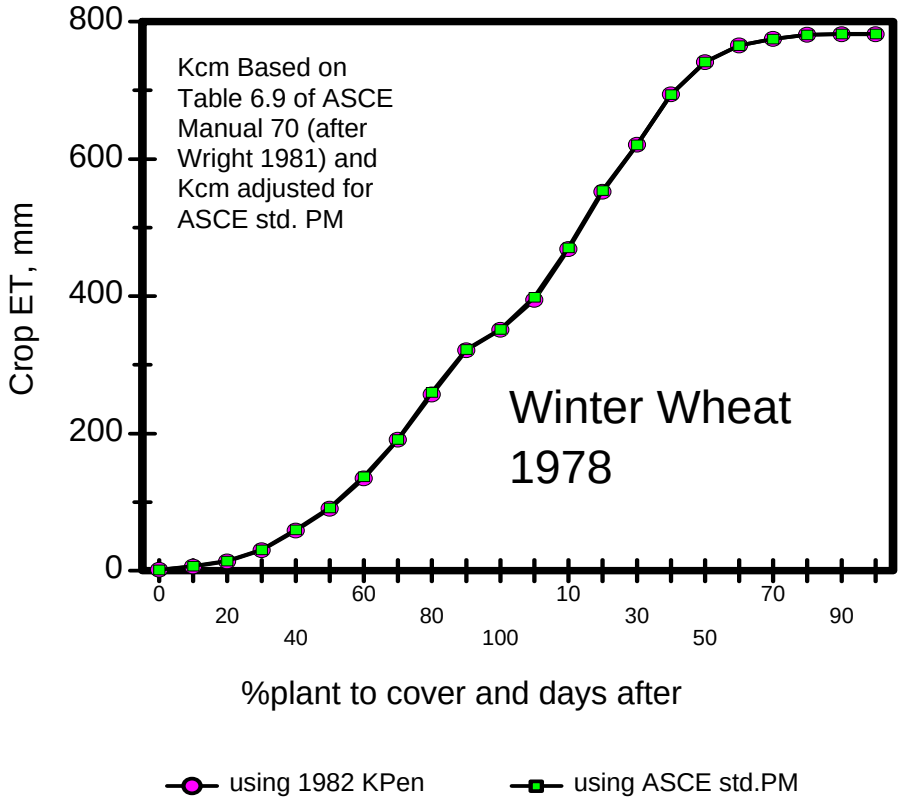
Wright, J.L., R.G. Allen, T.A. Howell. 2000. Comparison Between Evapotranspiration References and Methods. pages 251-259 in Evans, R.G., B.L. Benham, and T.P. Trooien (ed.) Proceedings of the National Irrigation Symposium, ASAE, Nov. 14-16, 2000, Phoenix, AZ.

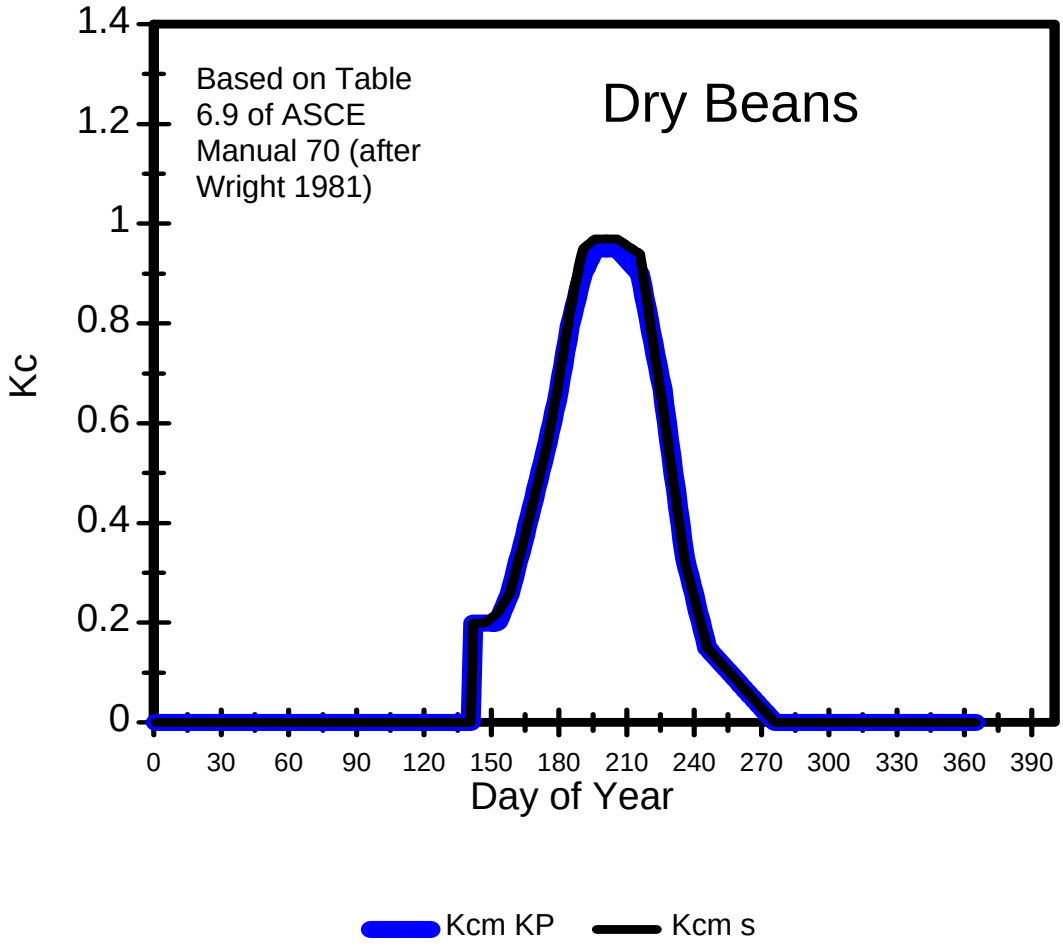
Mean Crop Coefficients

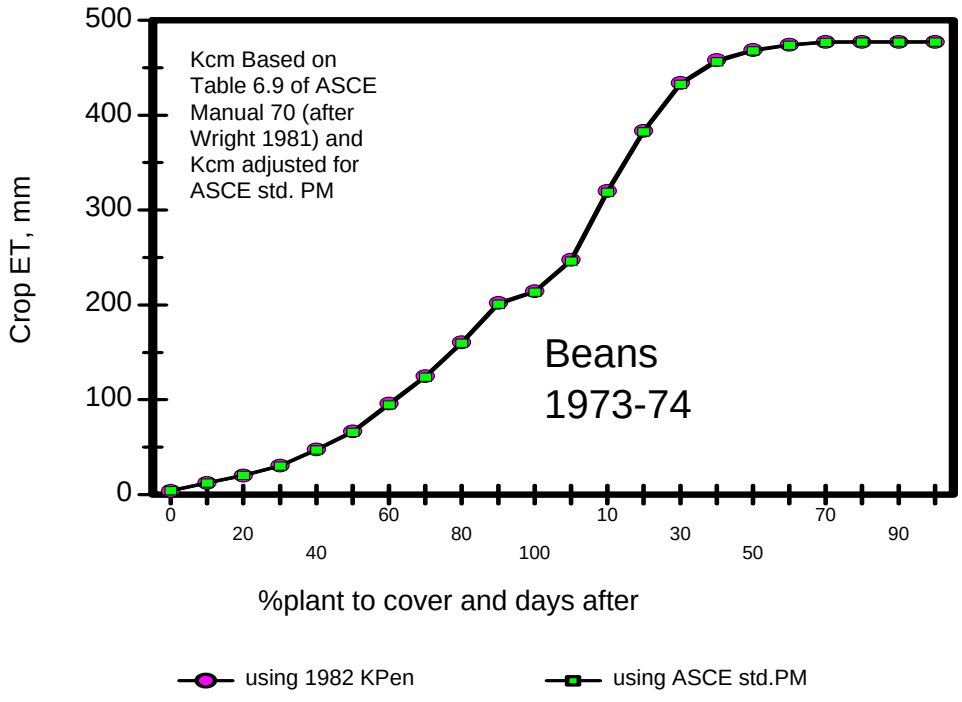
$K_{cm\ KP}$ = original mean crop coefficient curves for use with the 1982 Kimberly Penman

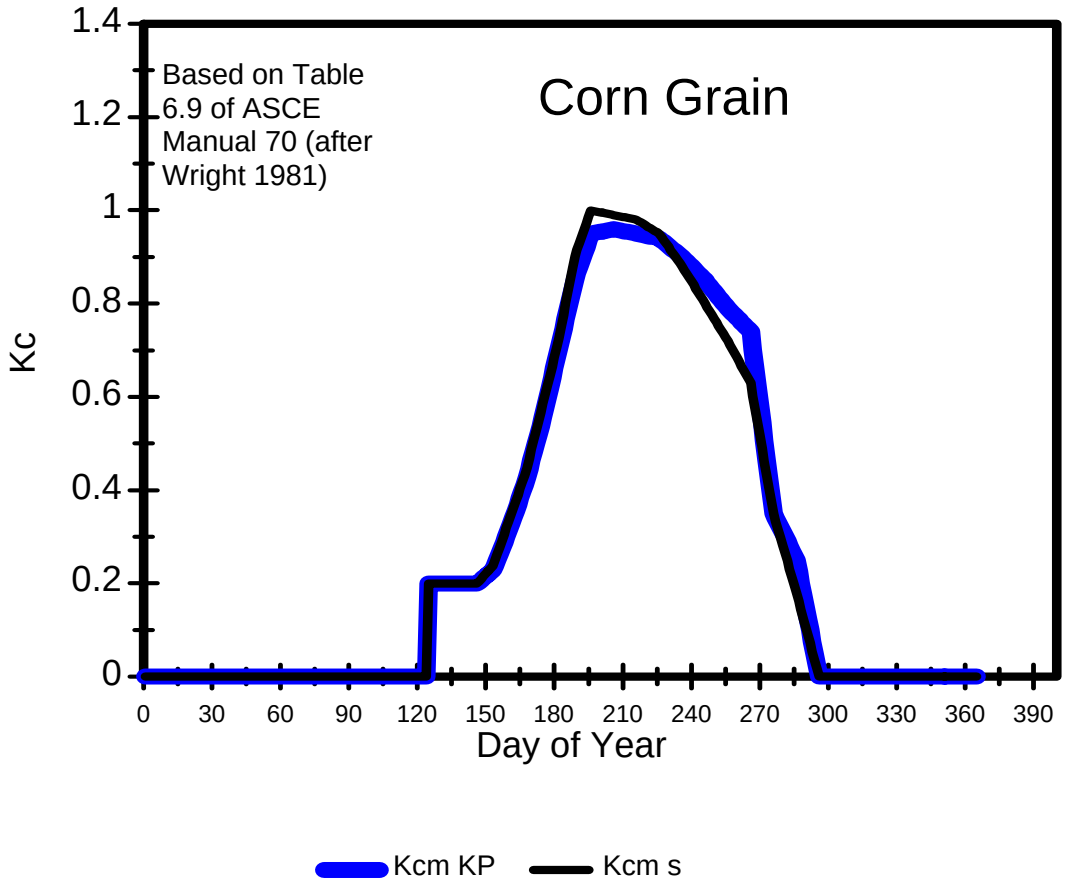
$K_{cm\ s}$ = converted mean crop coefficient curves for use with the ASCE Standardized Penman-Monteith method

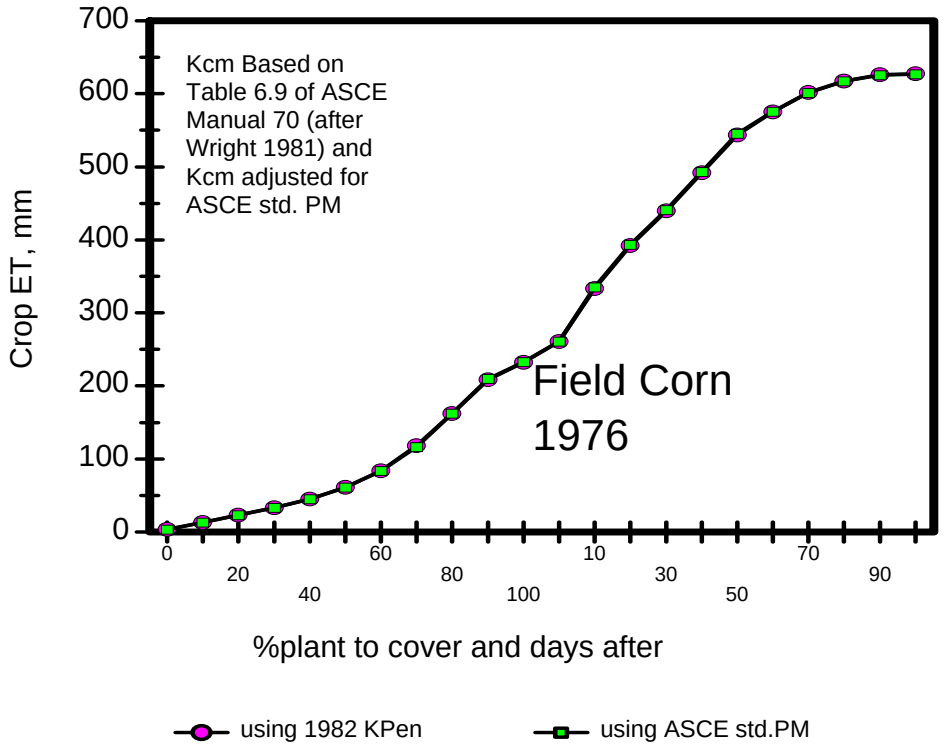

Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Winter Wheat
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcm KP
Kcm s

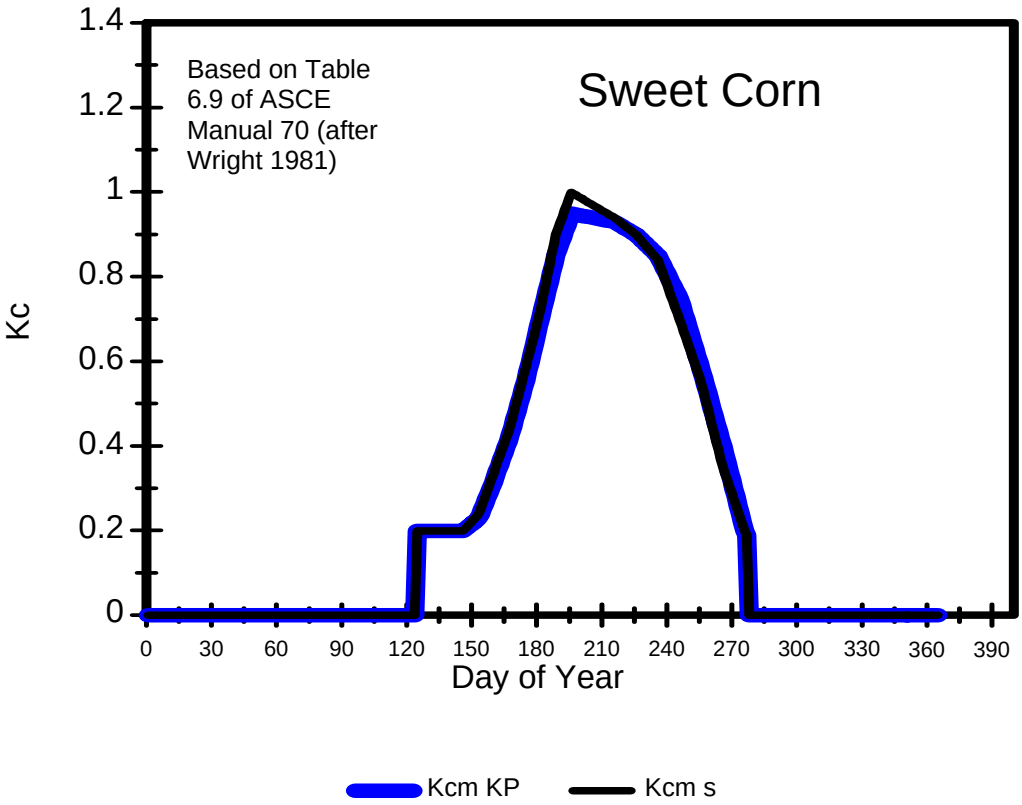

Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981) and Kcm adjusted for ASCE std. PM
Winter Wheat 1978
Crop ET, mm
800
600
400
200
0
0 20 40 60 80 100 10 30 50 70 90
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

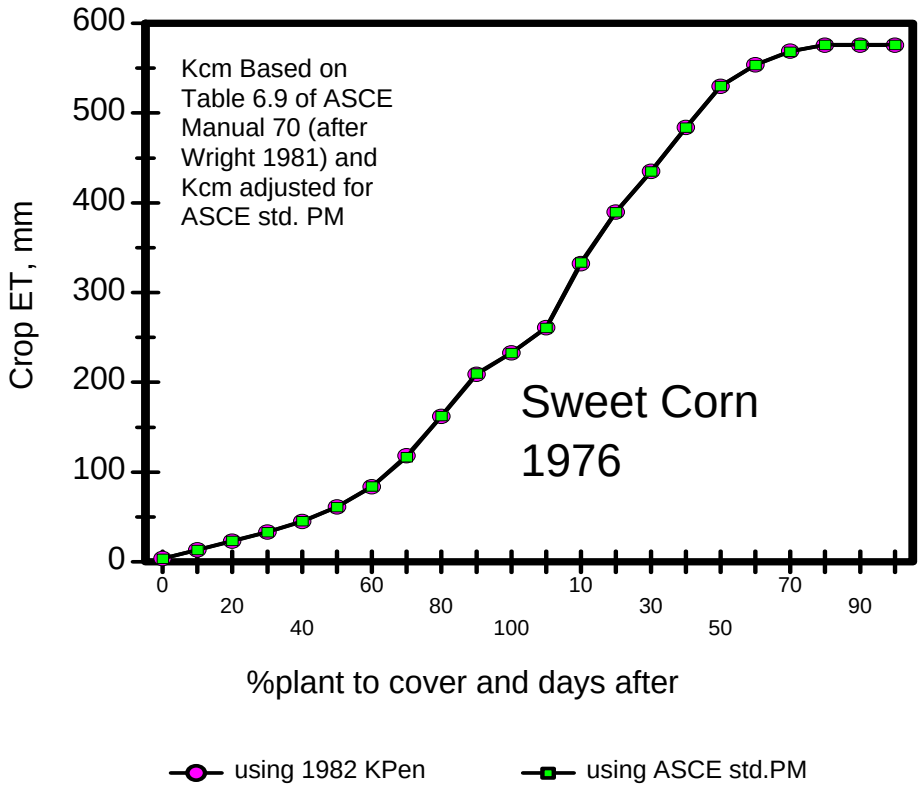

Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Dry Beans
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcm KP
Kcm s

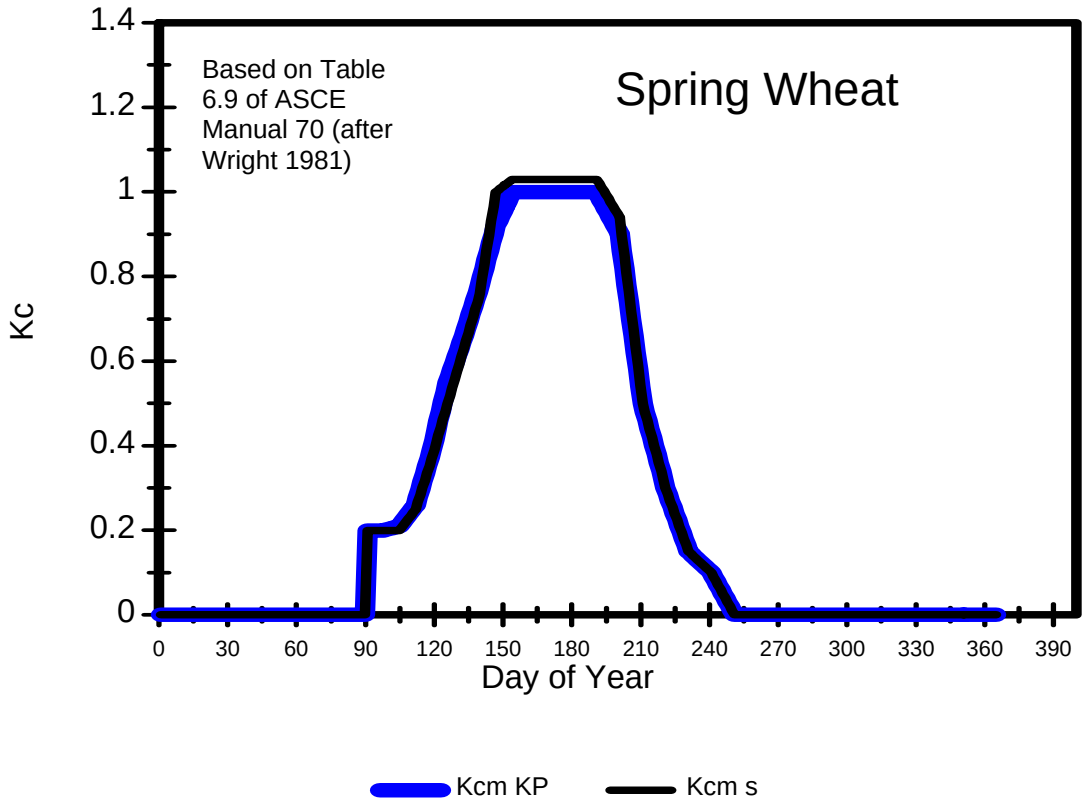

Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981) and Kcm adjusted for ASCE std. PM
Beans
1973-74
Crop ET, mm
500
400
300
200
100
0
0 20 40 60 80 100 10 30 50 70 90
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

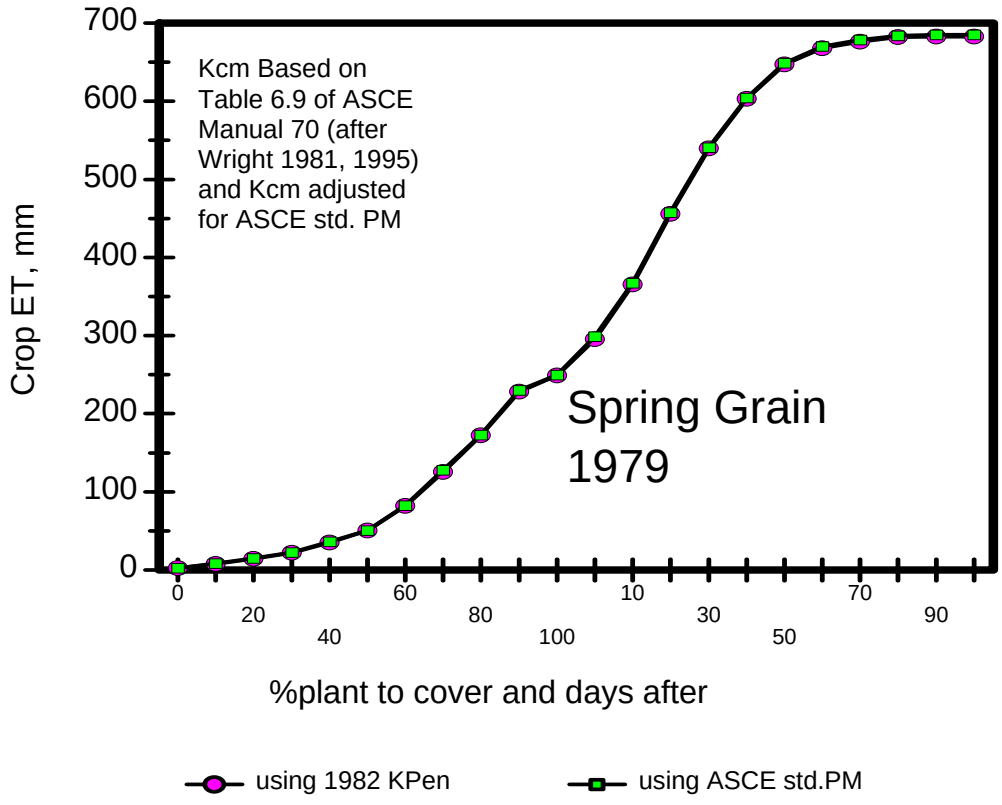

Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Corn Grain
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcm KP
Kcm s

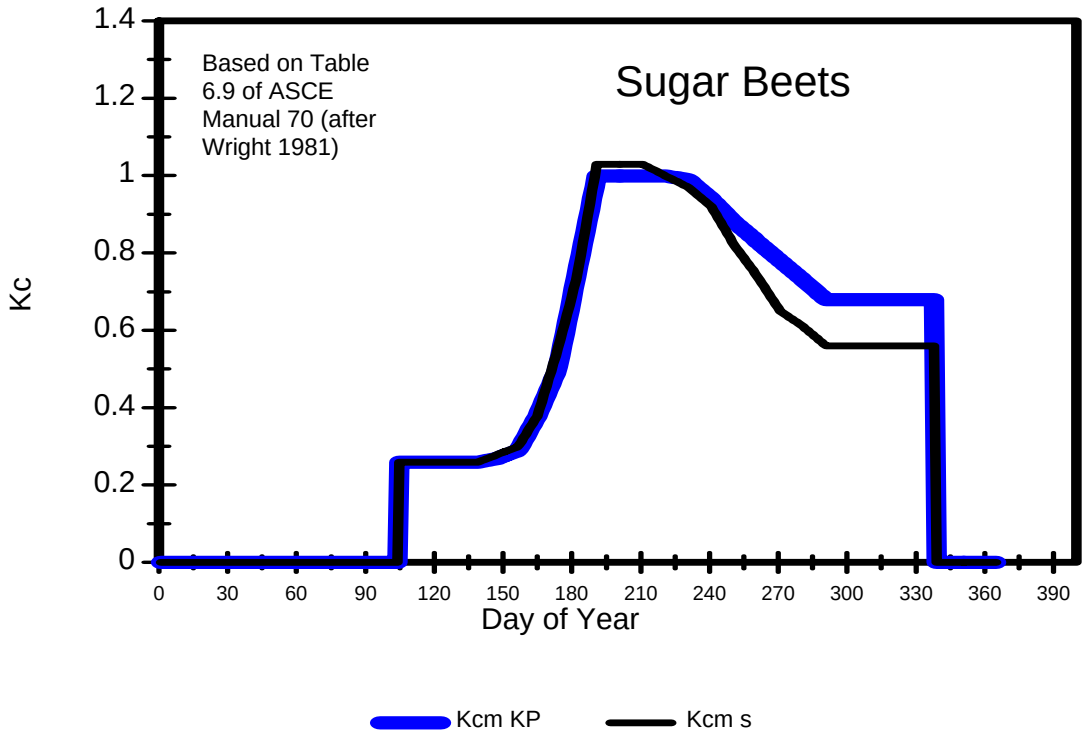

Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981) and Kcm adjusted for ASCE std. PM
Crop ET, mm
700
600
500
400
300
200
100
0
Field Corn
1976
0 20 40 60 80 100 10 30 50 70 90
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

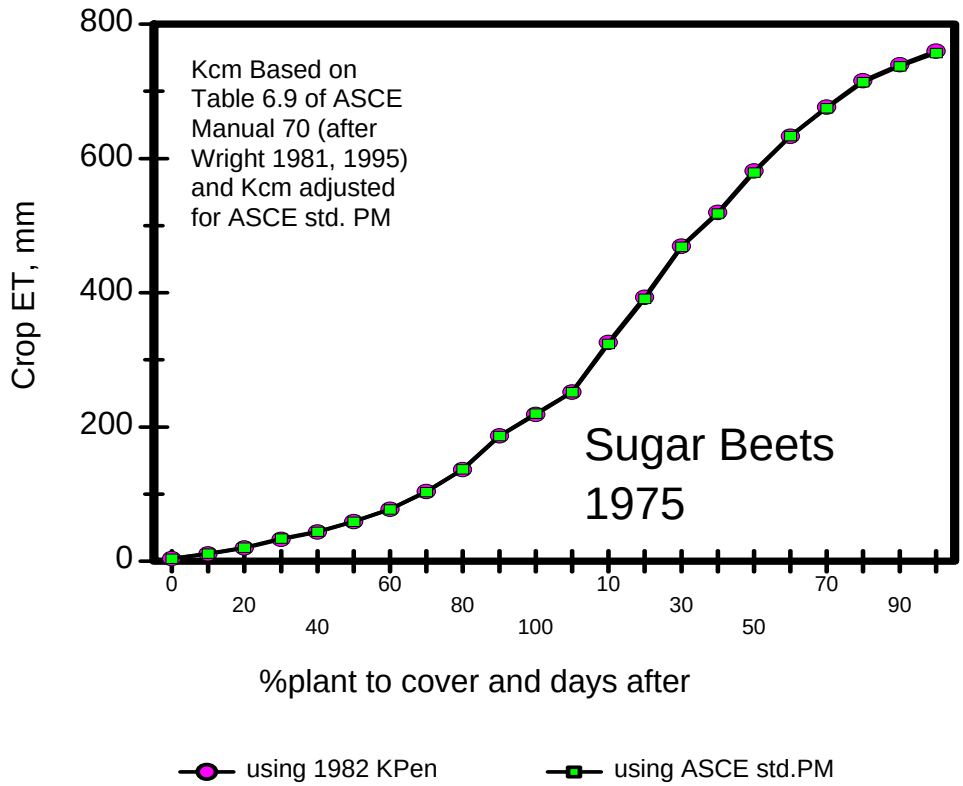

Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Sweet Corn
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcm KP
Kcm s

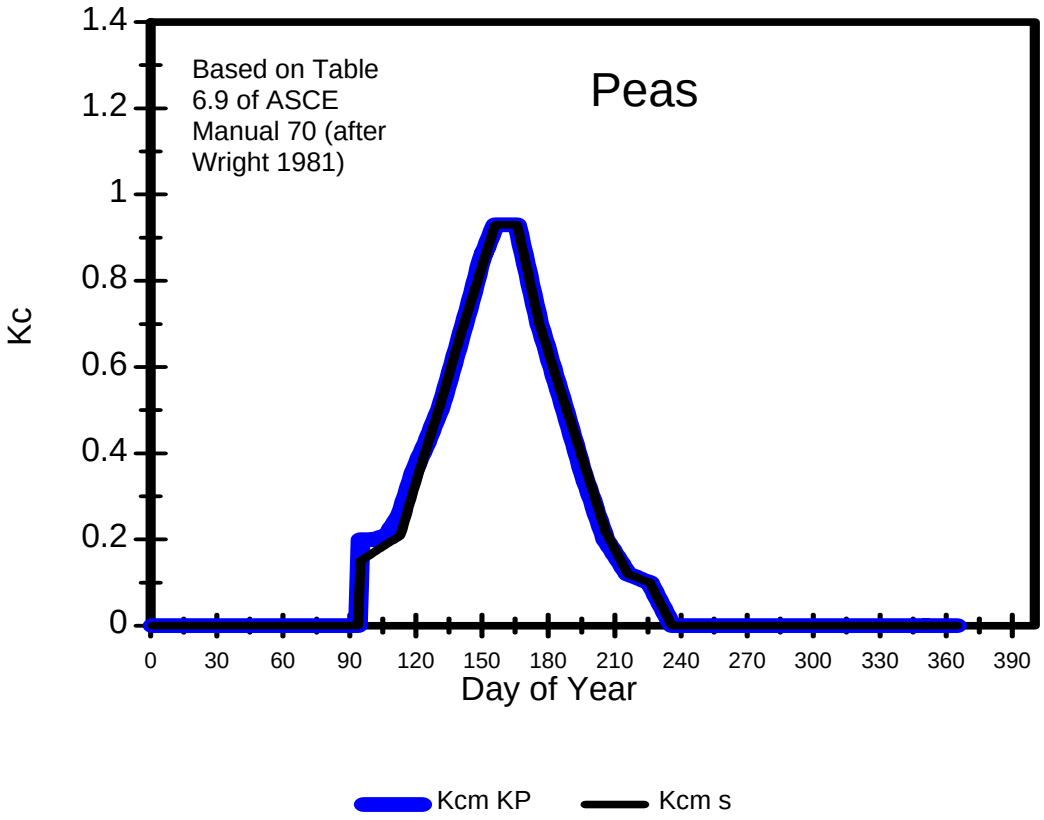

Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981) and Kcm adjusted for ASCE std. PM
Sweet Corn
1976
Crop ET, mm
600
500
400
300
200
100
0
0 20 40 60 80 100 10 30 50 70 90
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

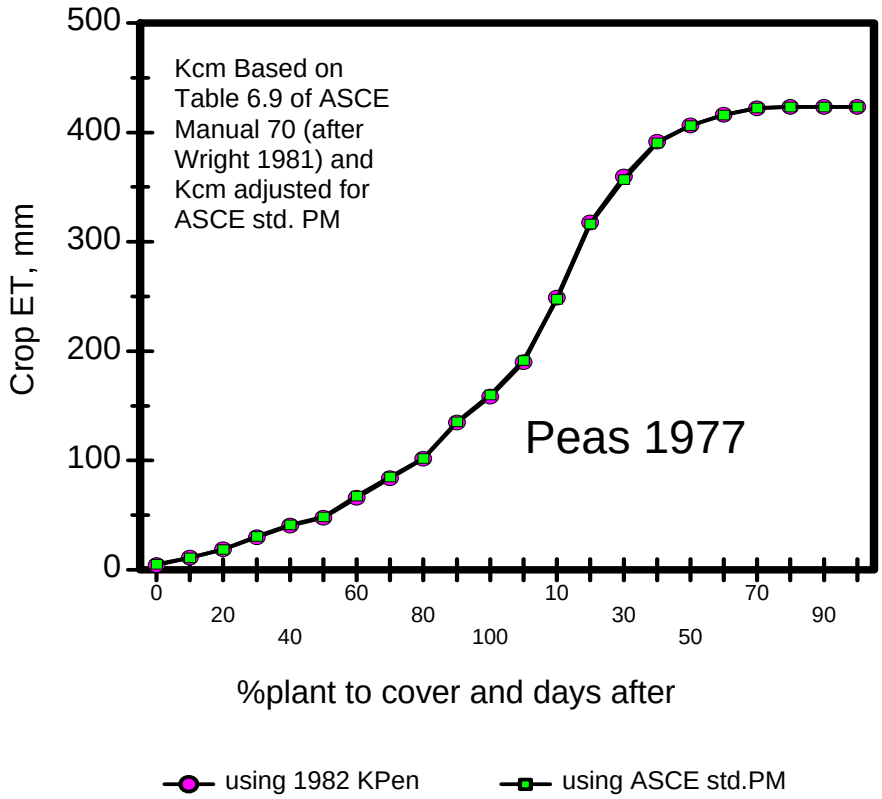

Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Spring Wheat
Kc
Day of Year
Kcm KP
Kcm s

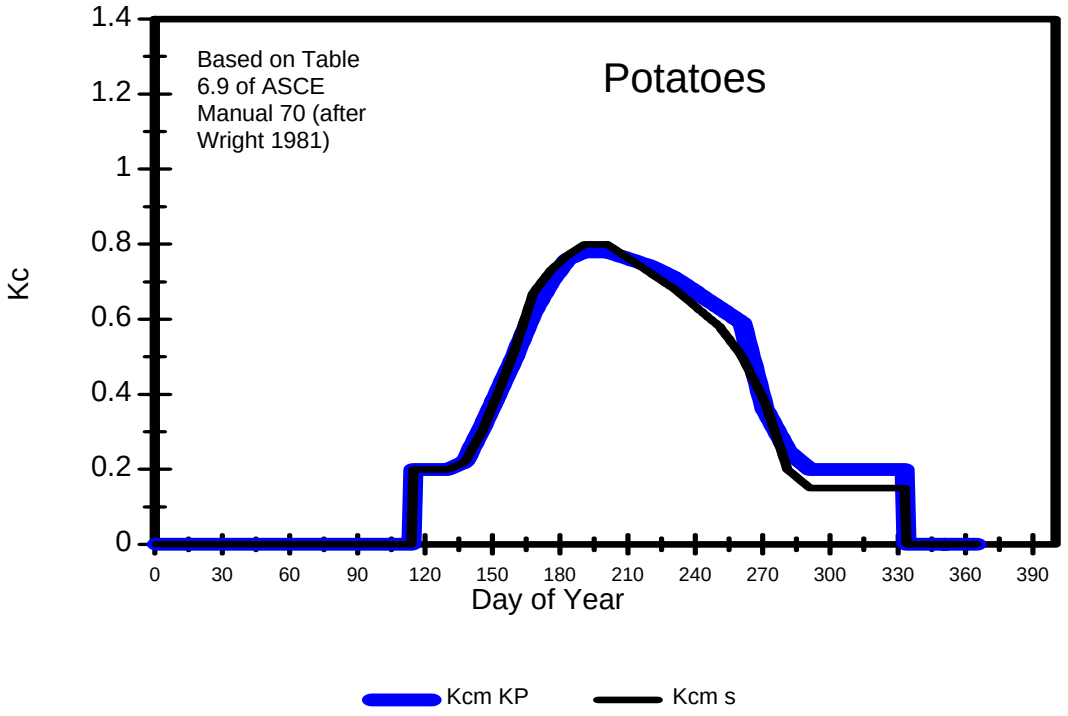

Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981, 1995) and Kcm adjusted for ASCE std. PM
Spring Grain 1979
Crop ET, mm
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

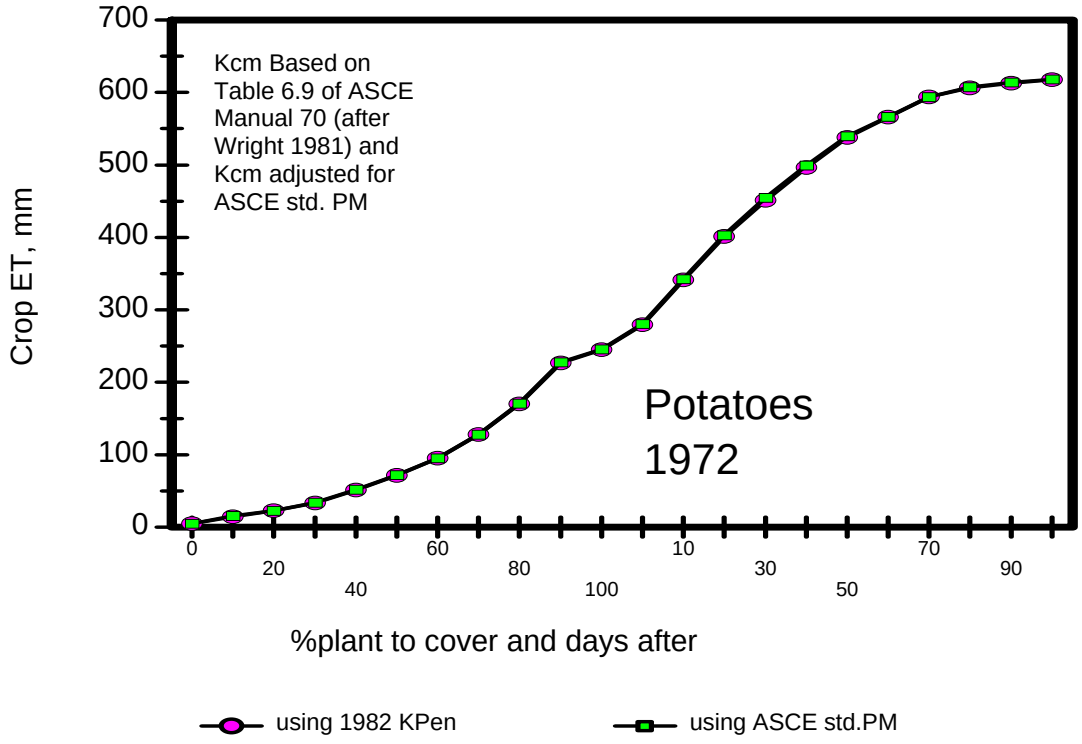

Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Sugar Beets
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcm KP
Kcm s

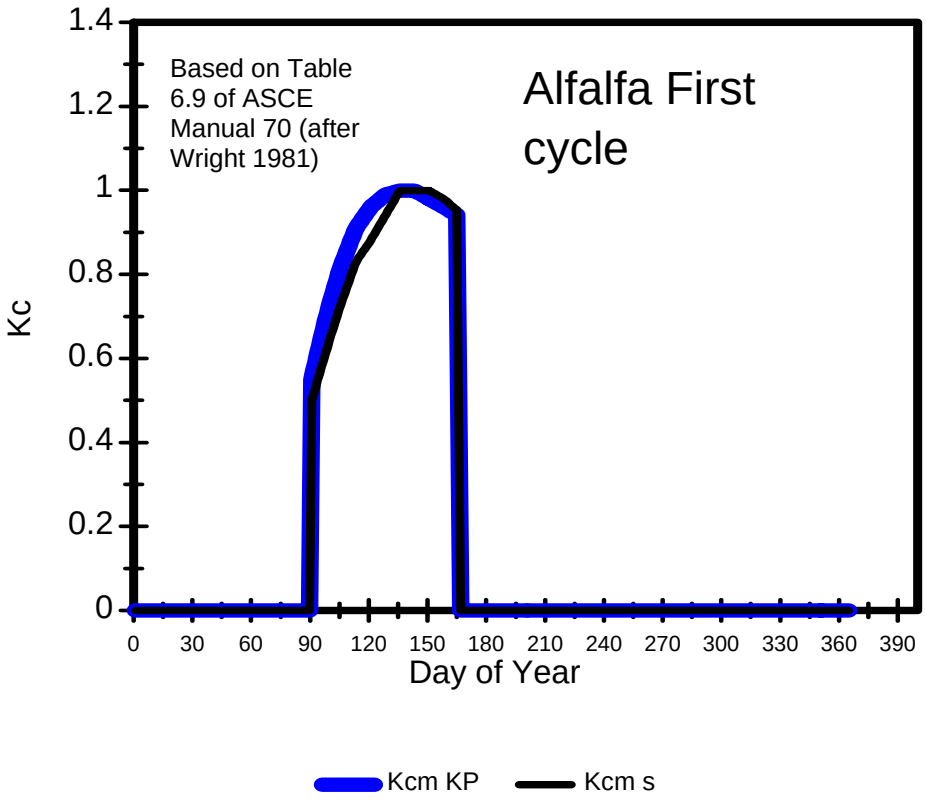

Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981, 1995) and Kcm adjusted for ASCE std. PM
Sugar Beets 1975
Crop ET, mm
800
600
400
200
0
0 20 40 60 80 100 10 30 50 70 90
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

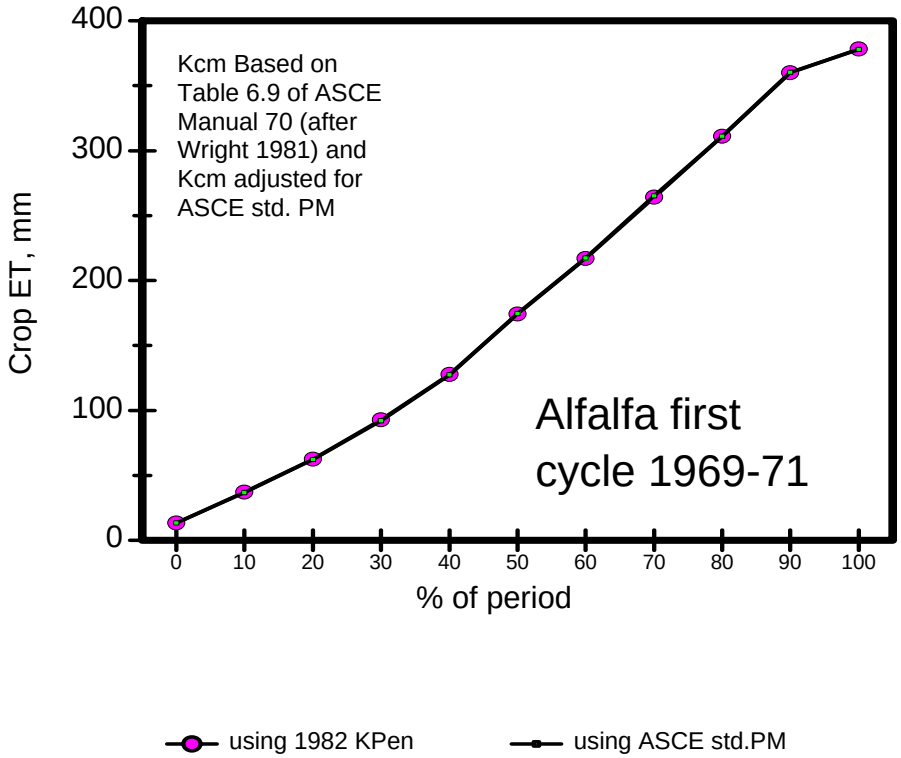

Peas
Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Kc
Day of Year
Kcm KP
Kcm s

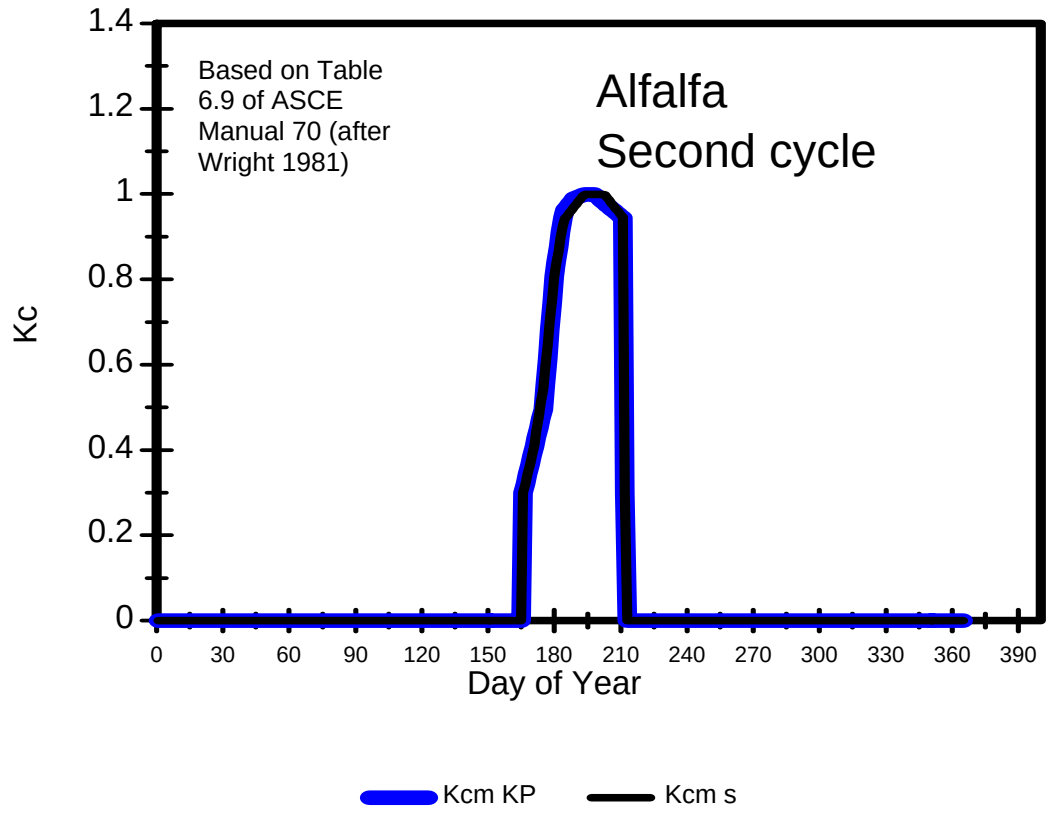

Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981) and Kcm adjusted for ASCE std. PM
Peas 1977
Crop ET, mm
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

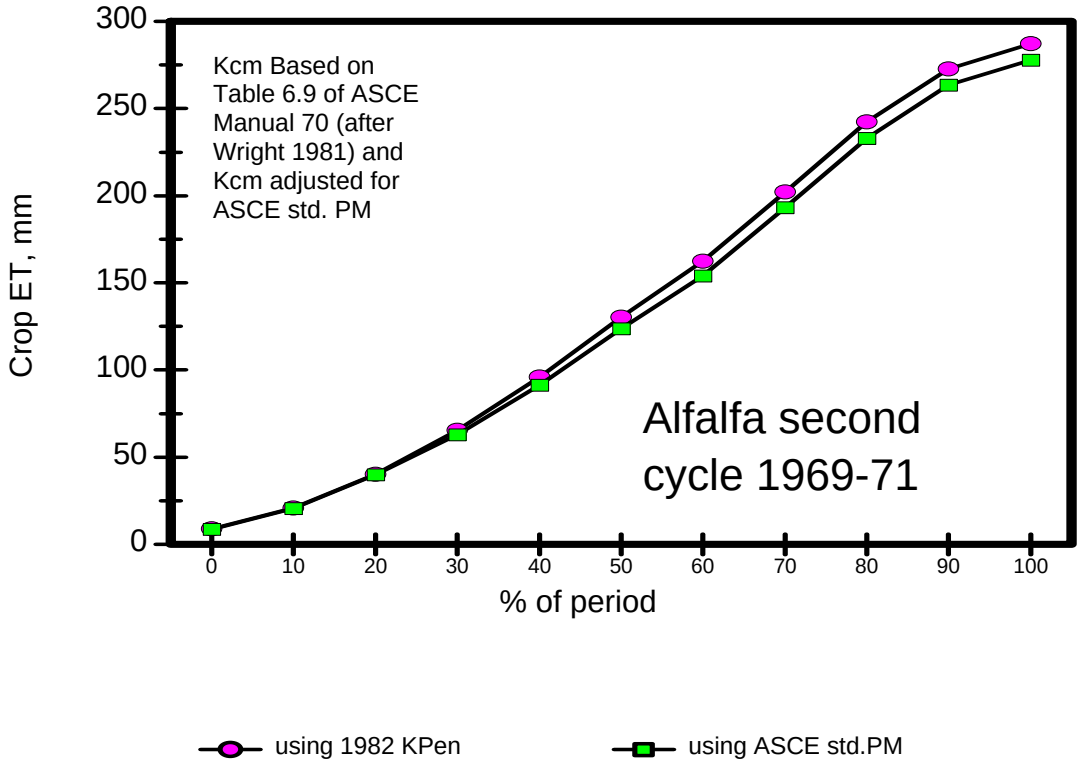

Potatoes
Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Kc
Day of Year
Kcm KP
Kcm s

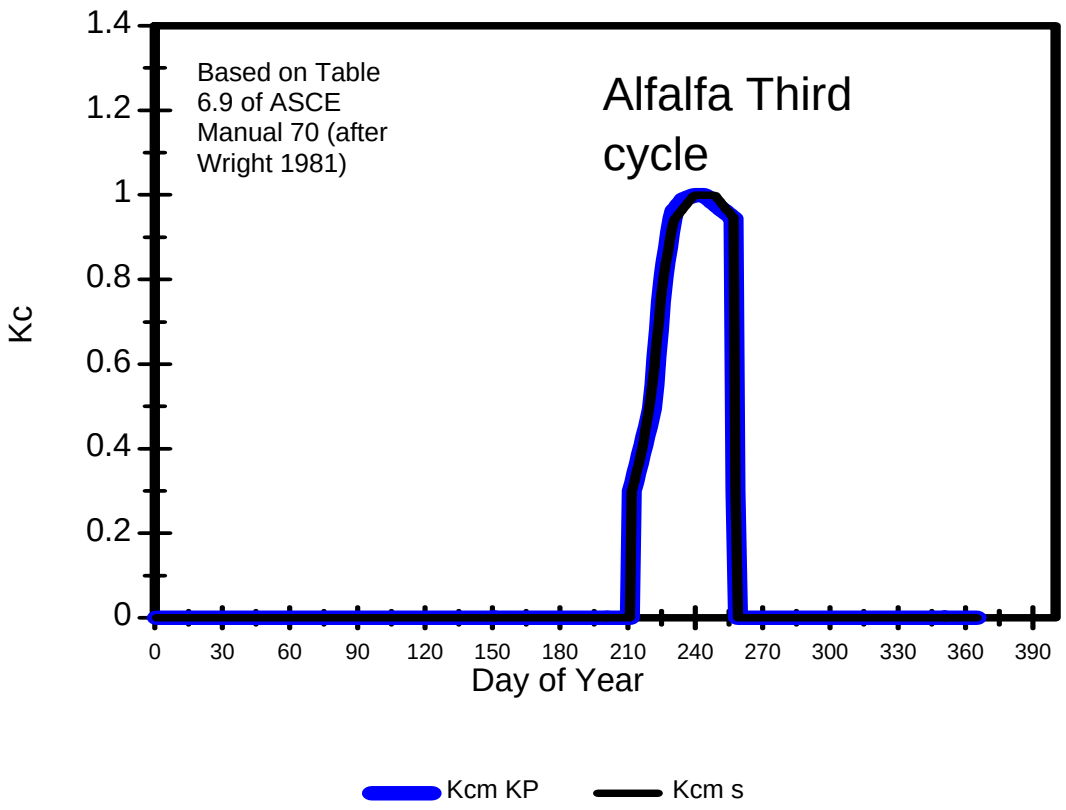

Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981) and Kcm adjusted for ASCE std. PM
Potatoes
1972
Crop ET, mm
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

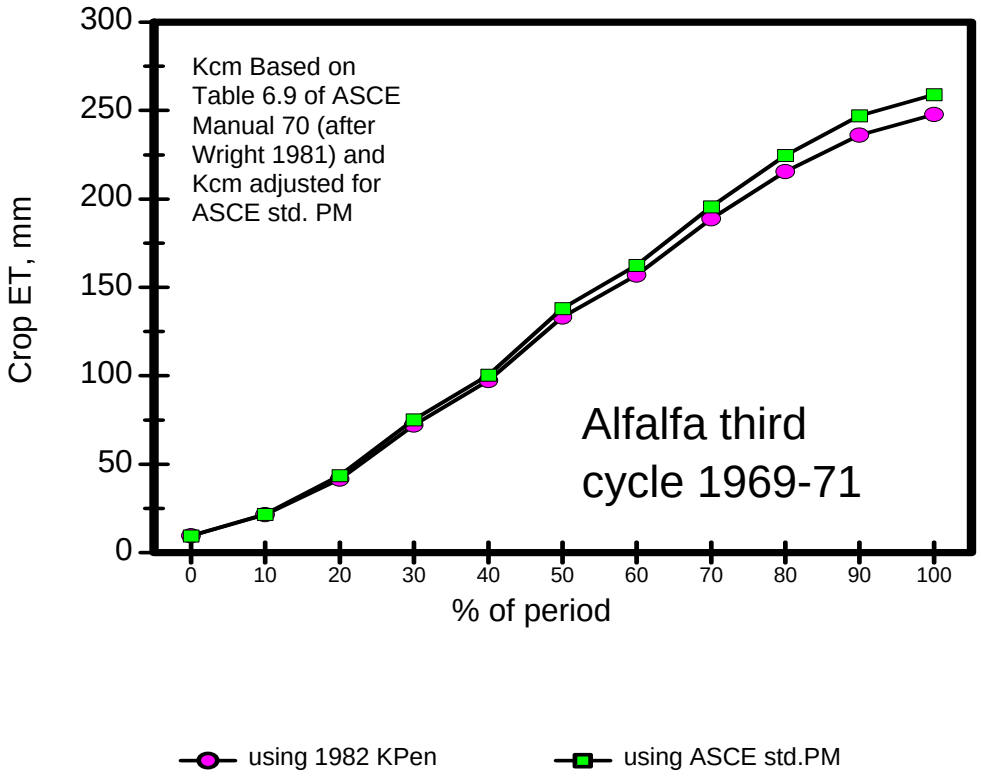

Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Alfalfa First cycle
Kc
Day of Year
Kcm KP
Kcm s

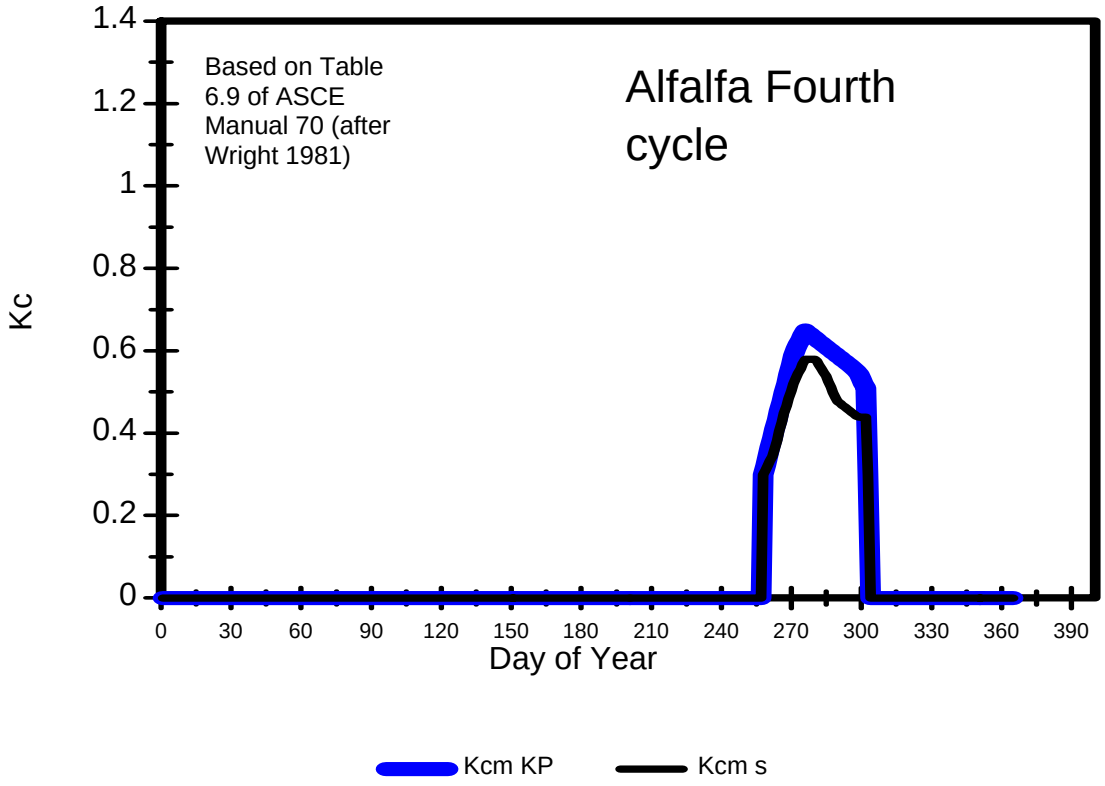

Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981) and Kcm adjusted for ASCE std. PM
Alfalfa first cycle 1969-71
Crop ET, mm
% of period
using 1982 KPen
using ASCE std.PM

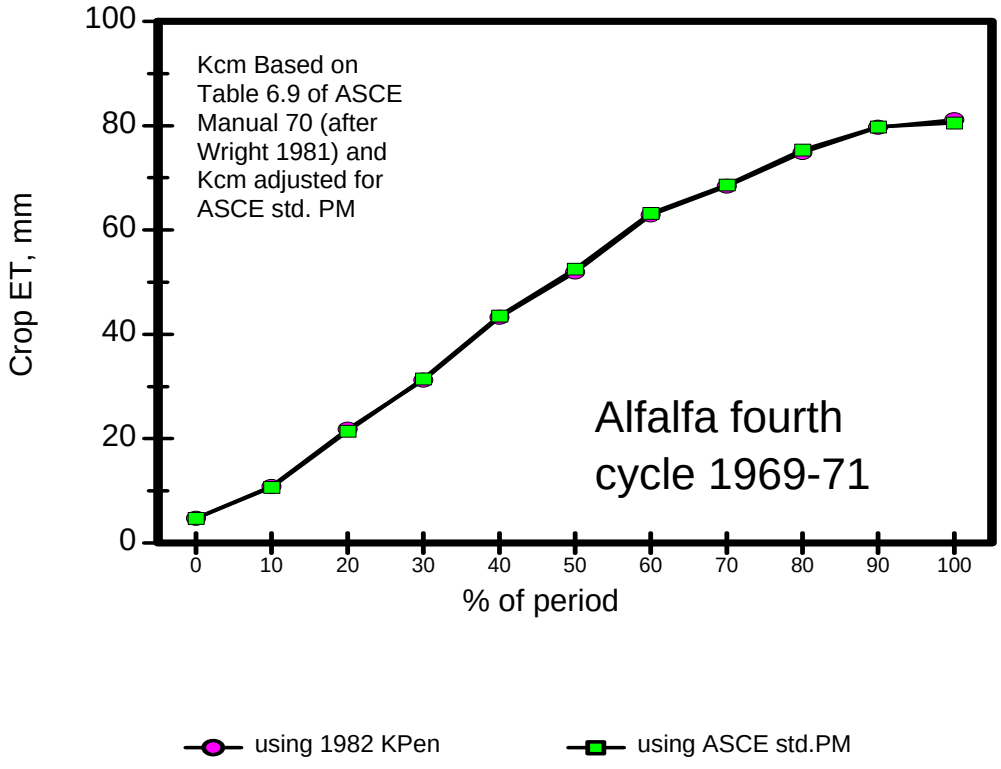

Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Alfalfa
Second cycle
Kc
Day of Year
Kcm KP
Kcm s

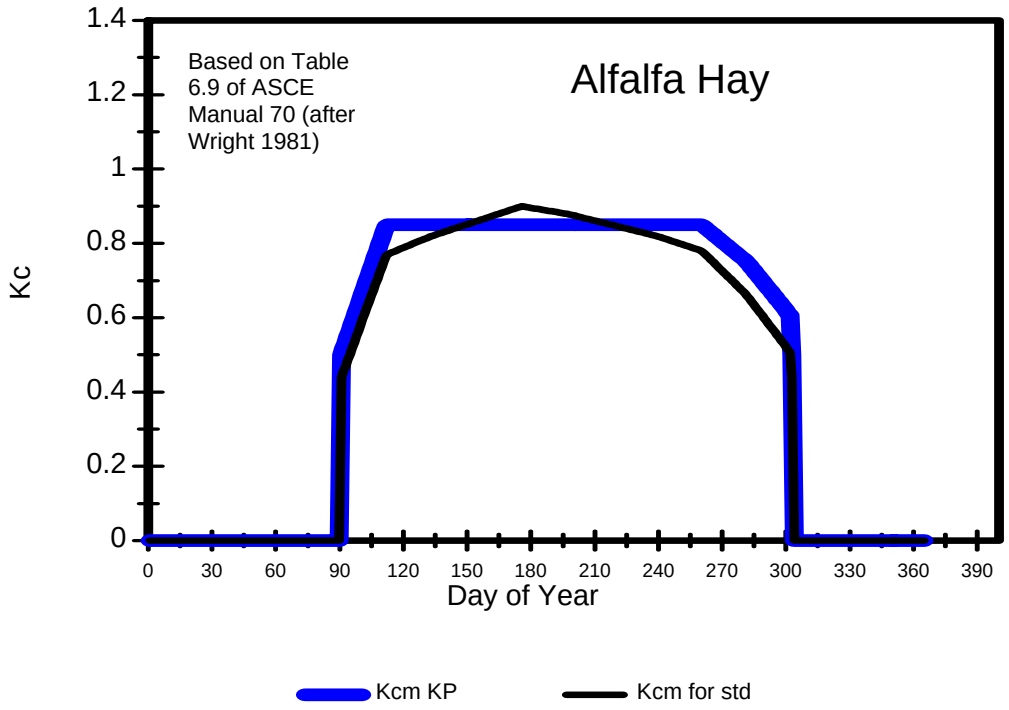

Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981) and Kcm adjusted for ASCE std. PM
Alfalfa second cycle 1969-71
Crop ET, mm
% of period
using 1982 KPen
using ASCE std.PM

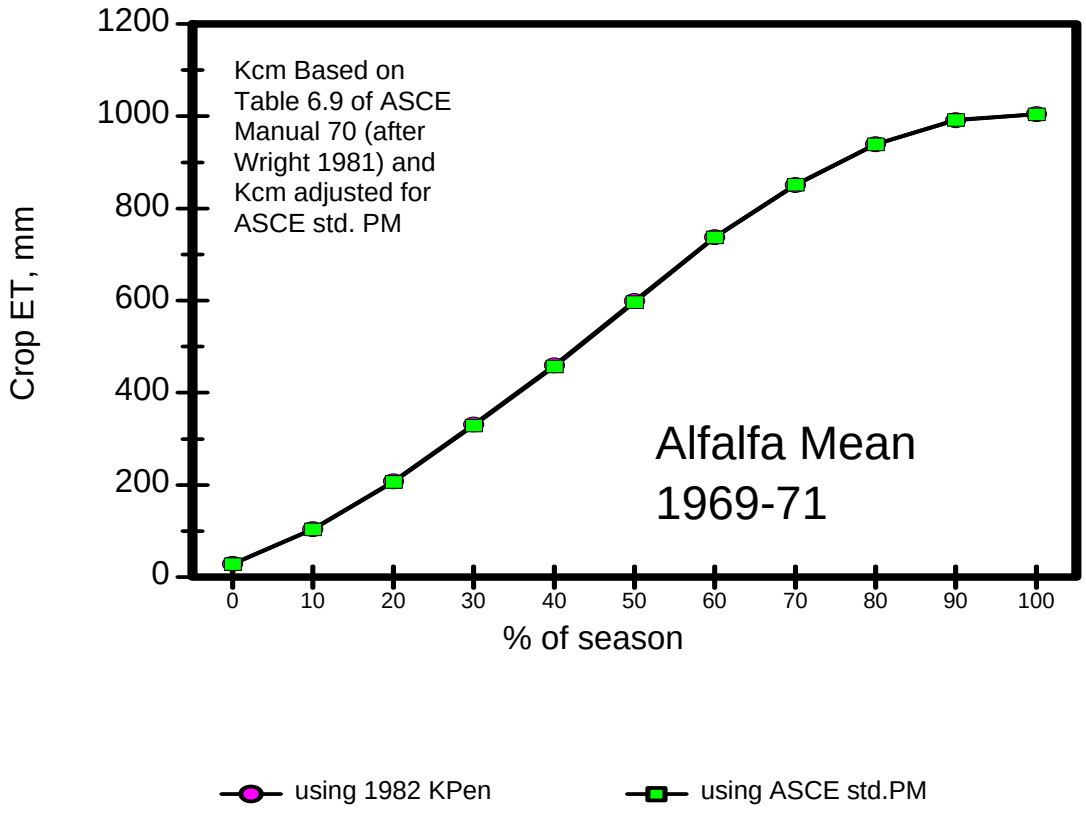

Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Alfalfa Third cycle
Kc
Day of Year
Kcm KP
Kcm s

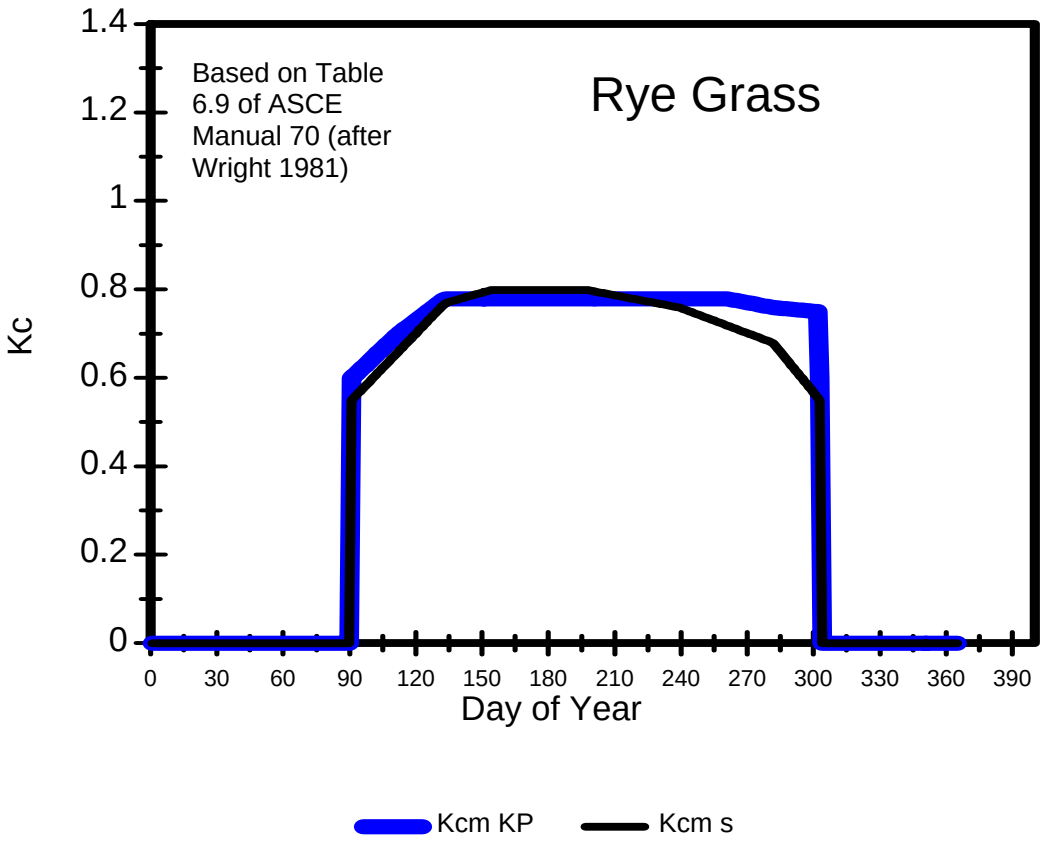

Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981) and Kcm adjusted for ASCE std. PM
Alfalfa third cycle 1969-71
Crop ET, mm
% of period
using 1982 KPen
using ASCE std.PM

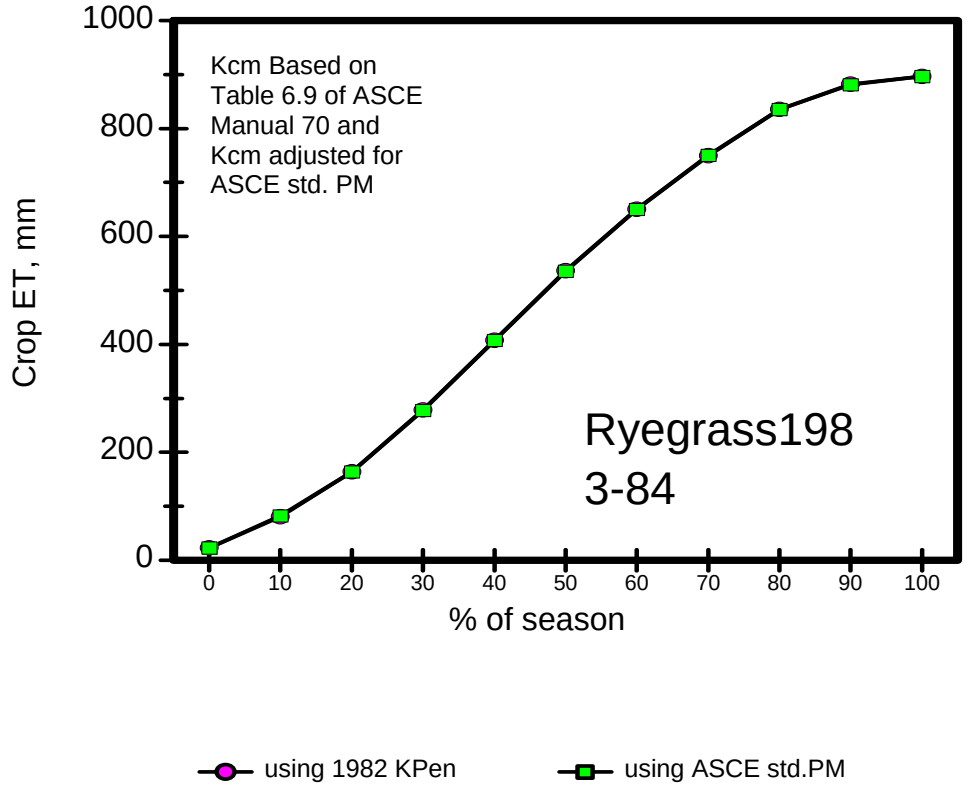

Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Alfalfa Fourth cycle
Kc
Day of Year
Kcm KP
Kcm s


Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981) and Kcm adjusted for ASCE std. PM
Alfalfa fourth cycle 1969-71
Crop ET, mm
% of period
using 1982 KPen
using ASCE std.PM


Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Alfalfa Hay
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcm KP
Kcm for std


Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981) and Kcm adjusted for ASCE std. PM
Alfalfa Mean 1969-71
Crop ET, mm
1200
1000
800
600
400
200
0
0 10 20 30 40 50 60 70 80 90 100
% of season
using 1982 KPen
using ASCE std.PM

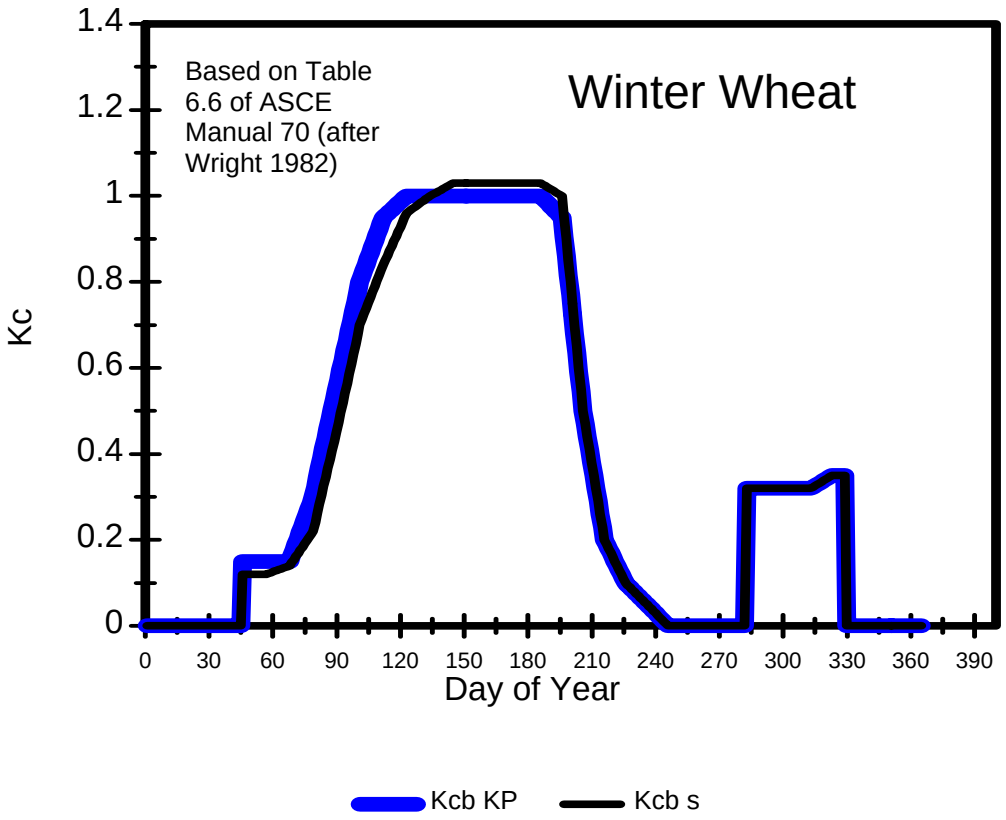

Based on Table 6.9 of ASCE Manual 70 (after Wright 1981)
Rye Grass
Kc
Day of Year
Kcm KP
Kcm s

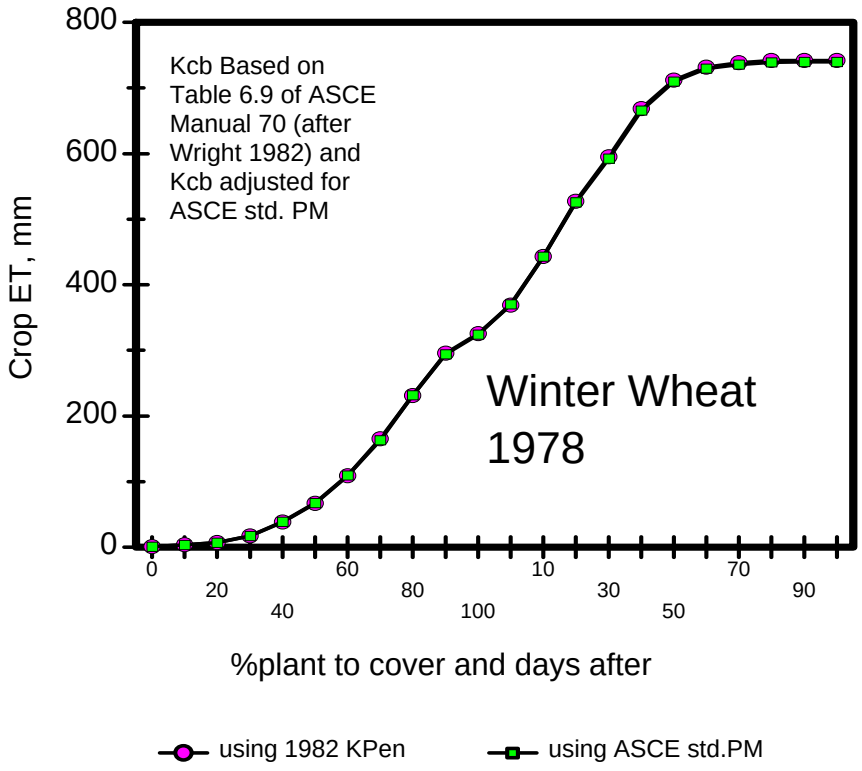

Kcm Based on Table 6.9 of ASCE Manual 70 and Kcm adjusted for ASCE std. PM
Ryegrass198 3-84
Crop ET, mm
% of season
using 1982 KPen
using ASCE std.PM

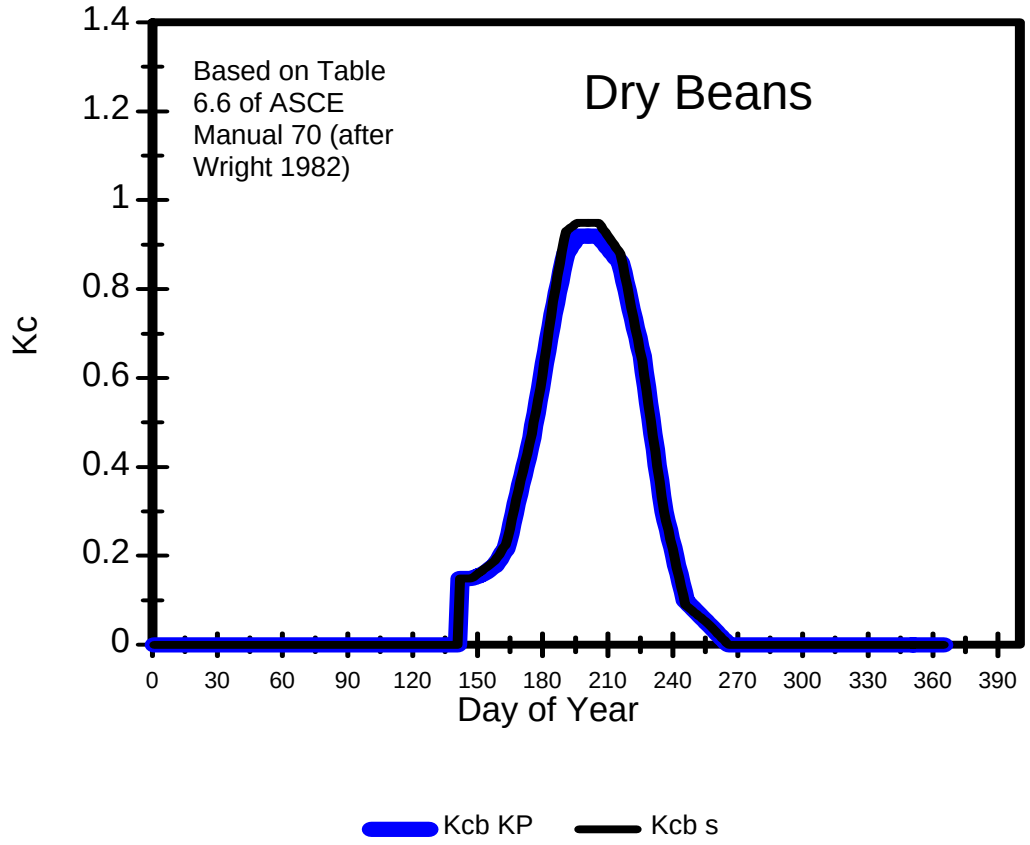
Basal Crop Coefficients

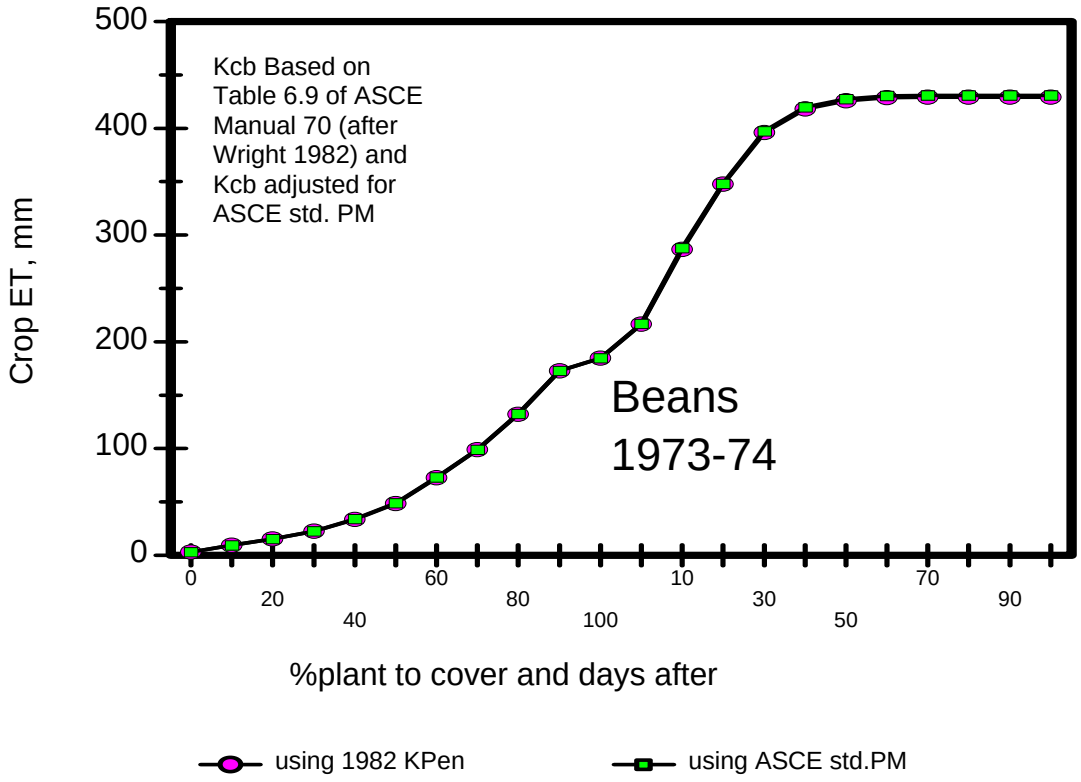
$K_{cb\ KP}$ = original basal crop coefficient curves for use with the 1982 Kimberly Penman

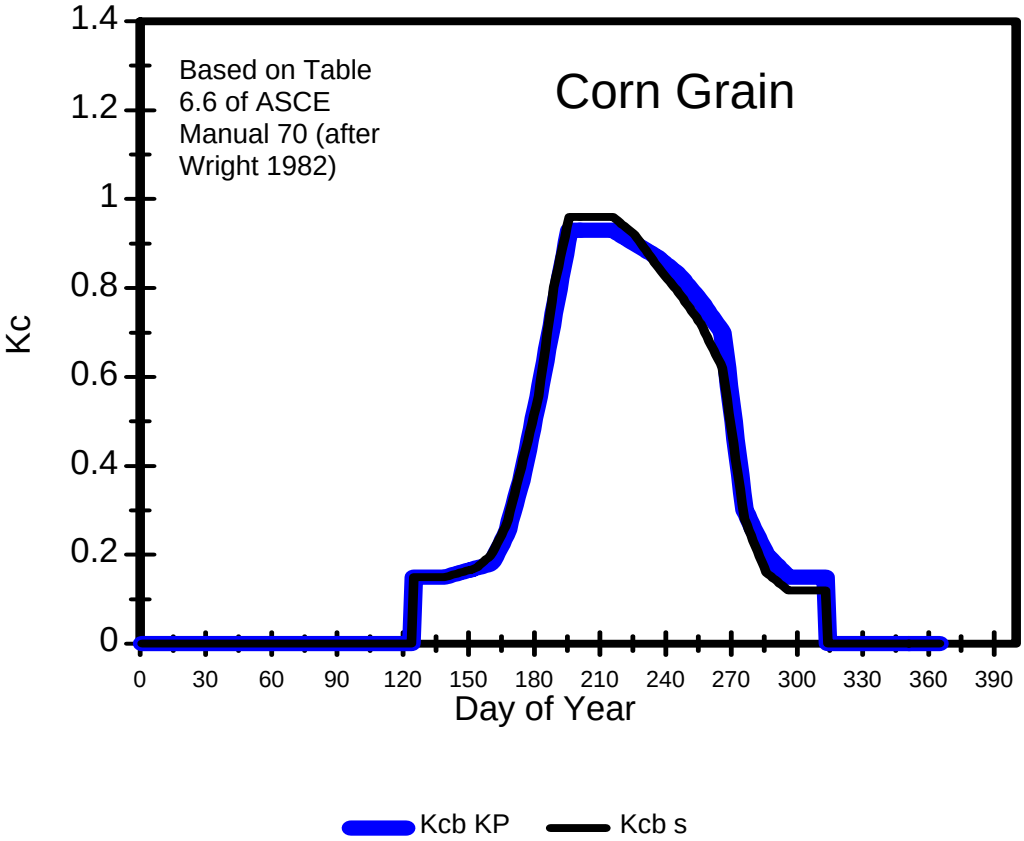
$K_{cb\ s}$ = converted basal crop coefficient curves for use with the ASCE Standardized Penman-Monteith method

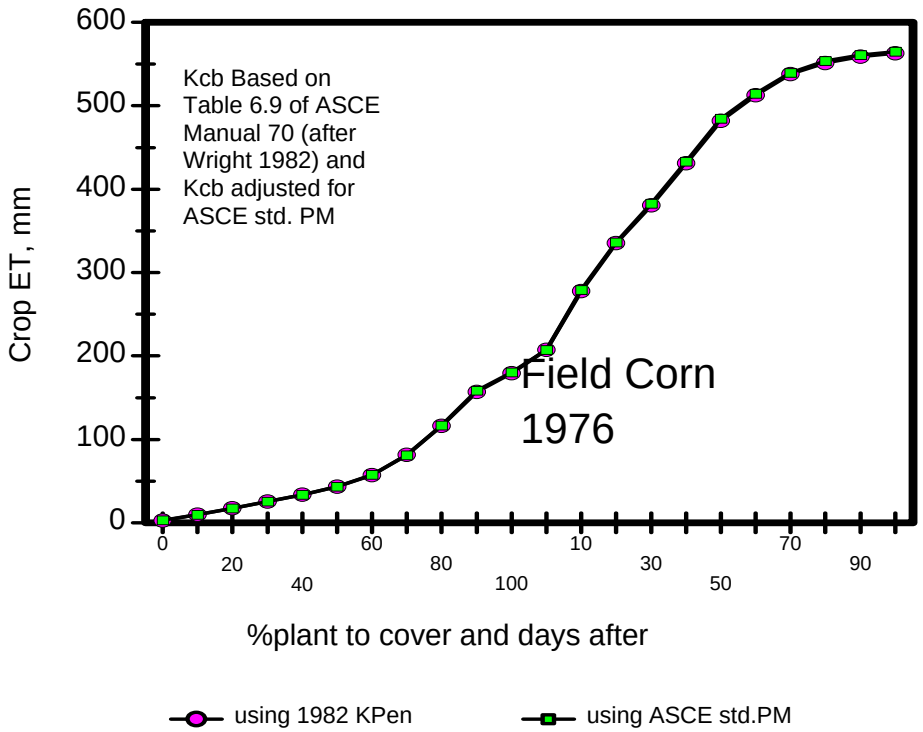

Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Winter Wheat
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcb KP
Kcb s

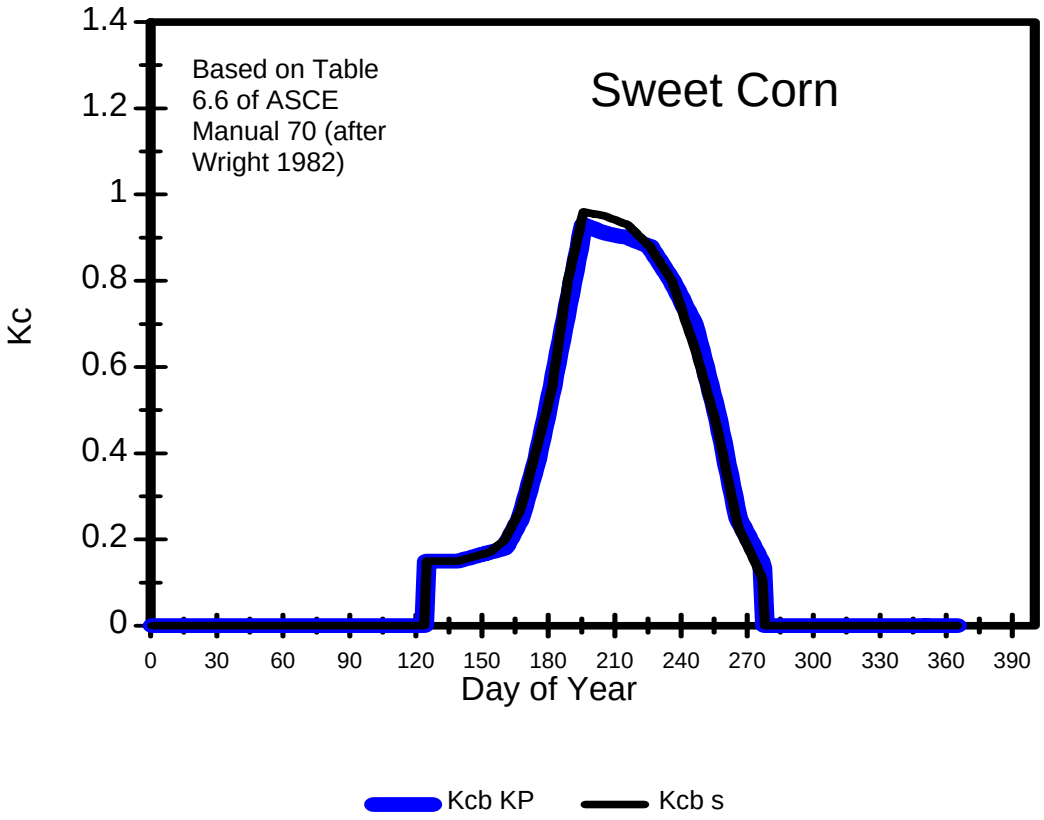

Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982) and Kcb adjusted for ASCE std. PM
Winter Wheat 1978
Crop ET, mm
800
600
400
200
0
0 20 40 60 80 100 10 30 50 70 90
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

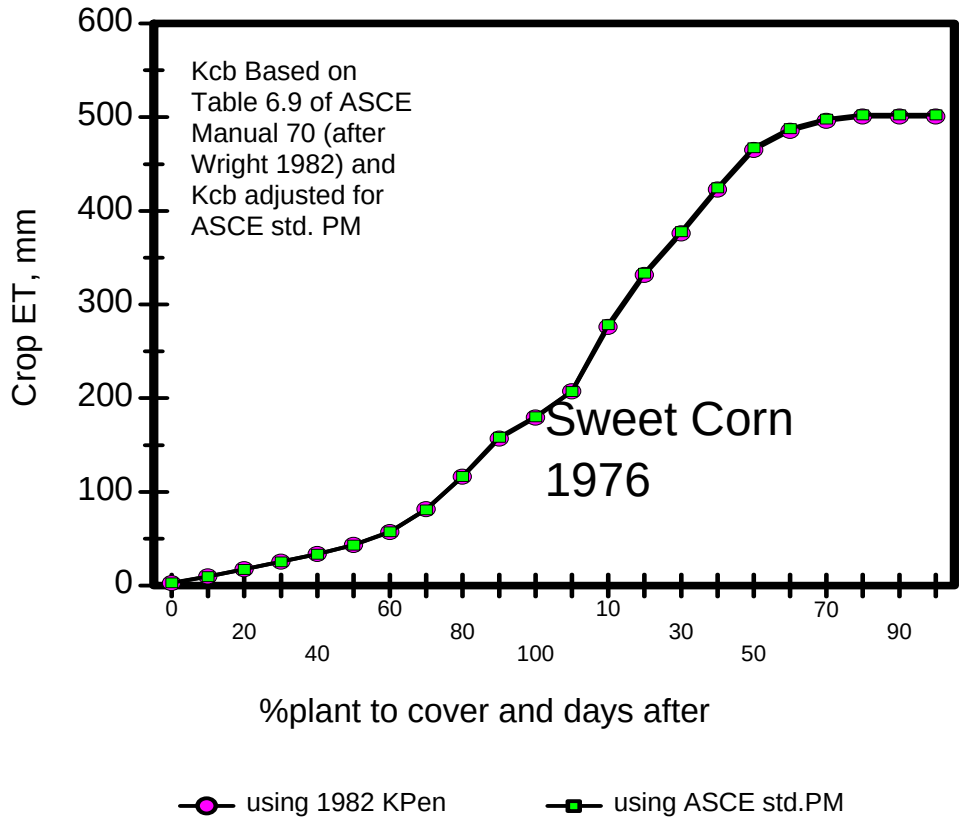

Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Dry Beans
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcb KP
Kcb s

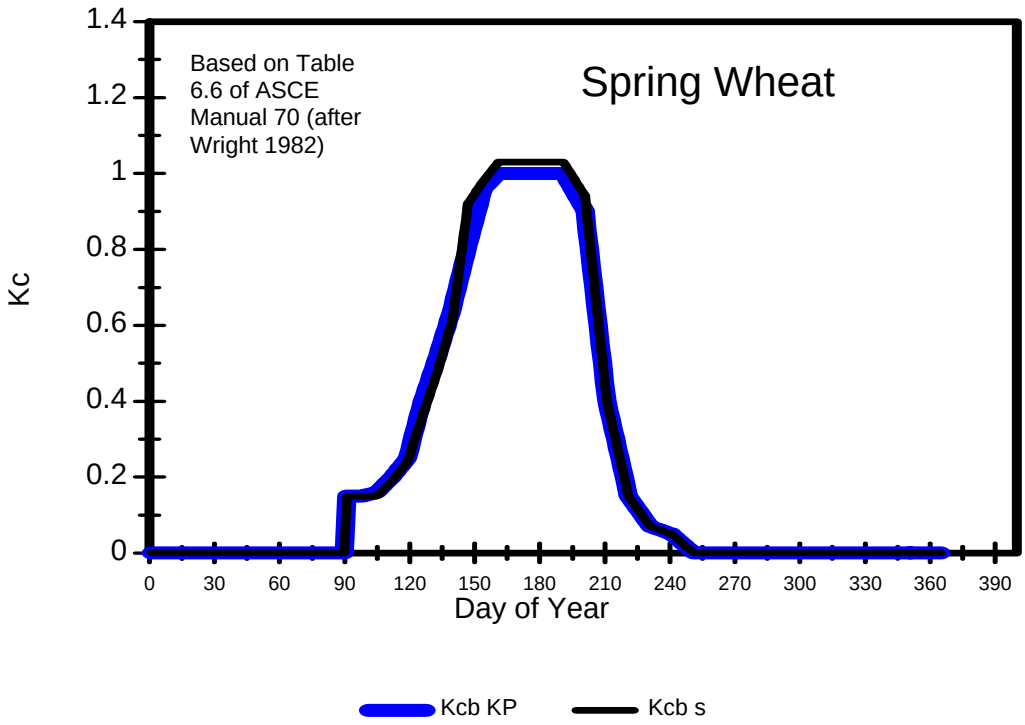

Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982) and Kcb adjusted for ASCE std. PM
Beans
1973-74
Crop ET, mm
500
400
300
200
100
0
0 20 40 60 80 100 10 30 50 70 90
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

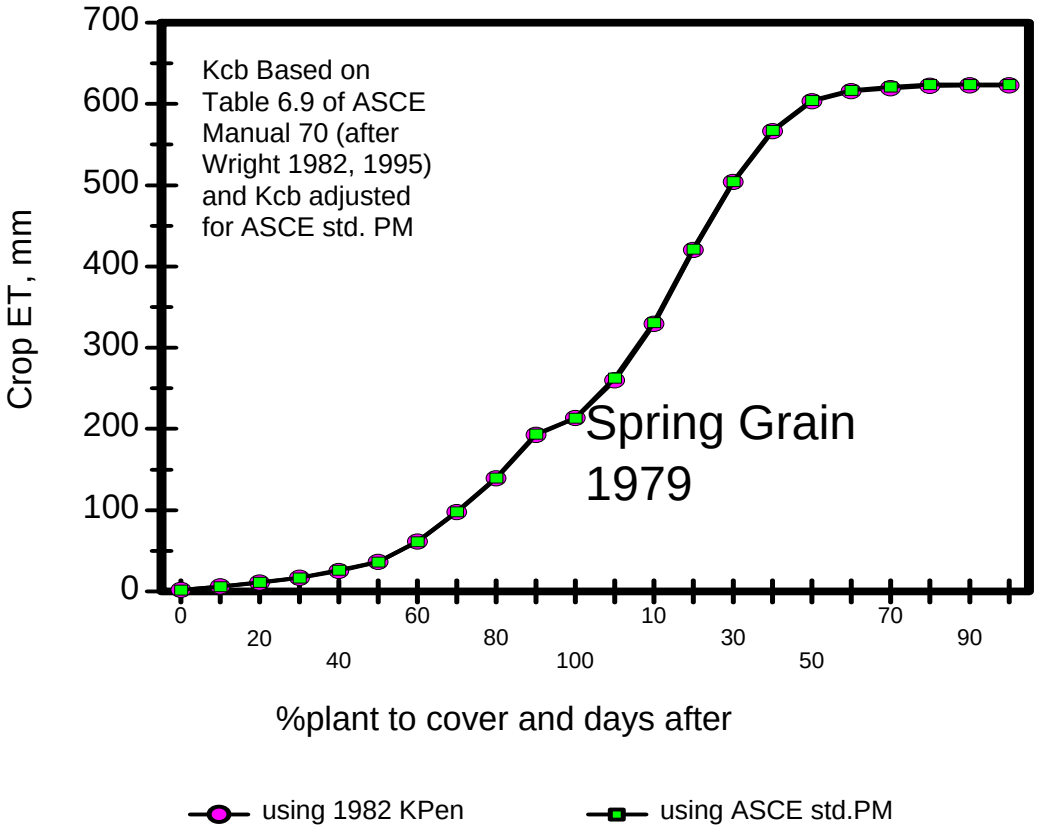

Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Corn Grain
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcb KP
Kcb s

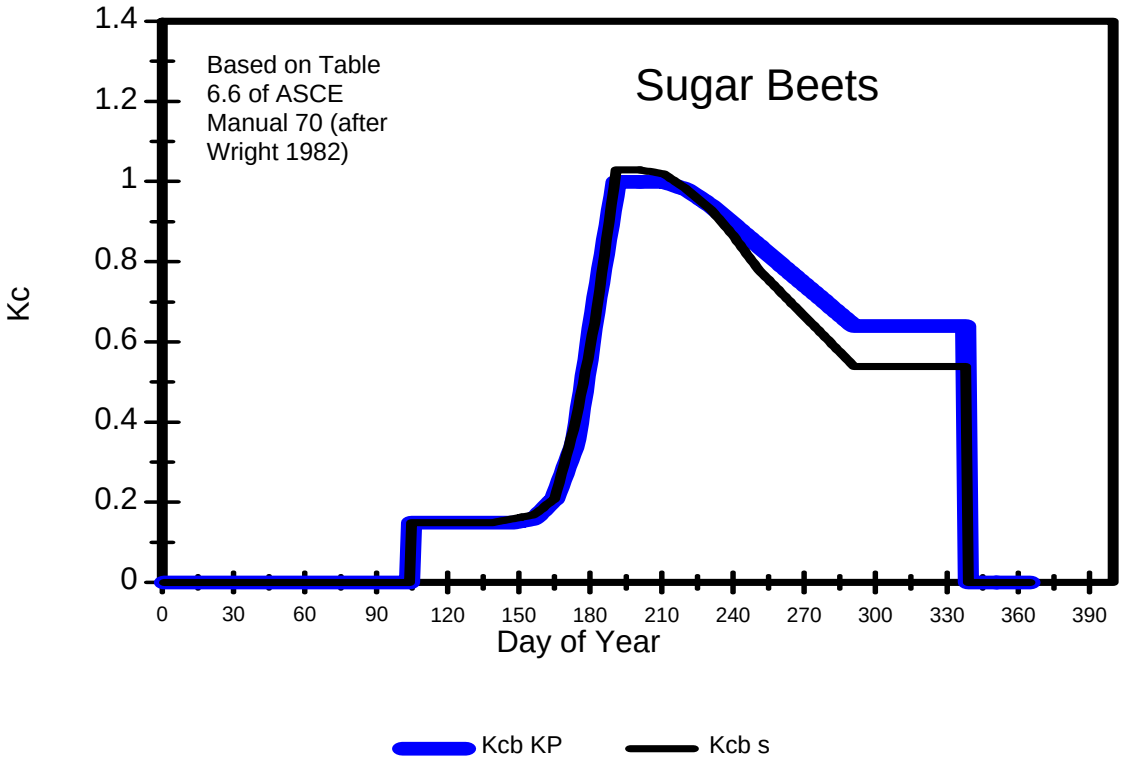

Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982) and Kcb adjusted for ASCE std. PM
Field Corn
1976
Crop ET, mm
600
500
400
300
200
100
0
0 20 40 60 80 100 10 30 50 70 90
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

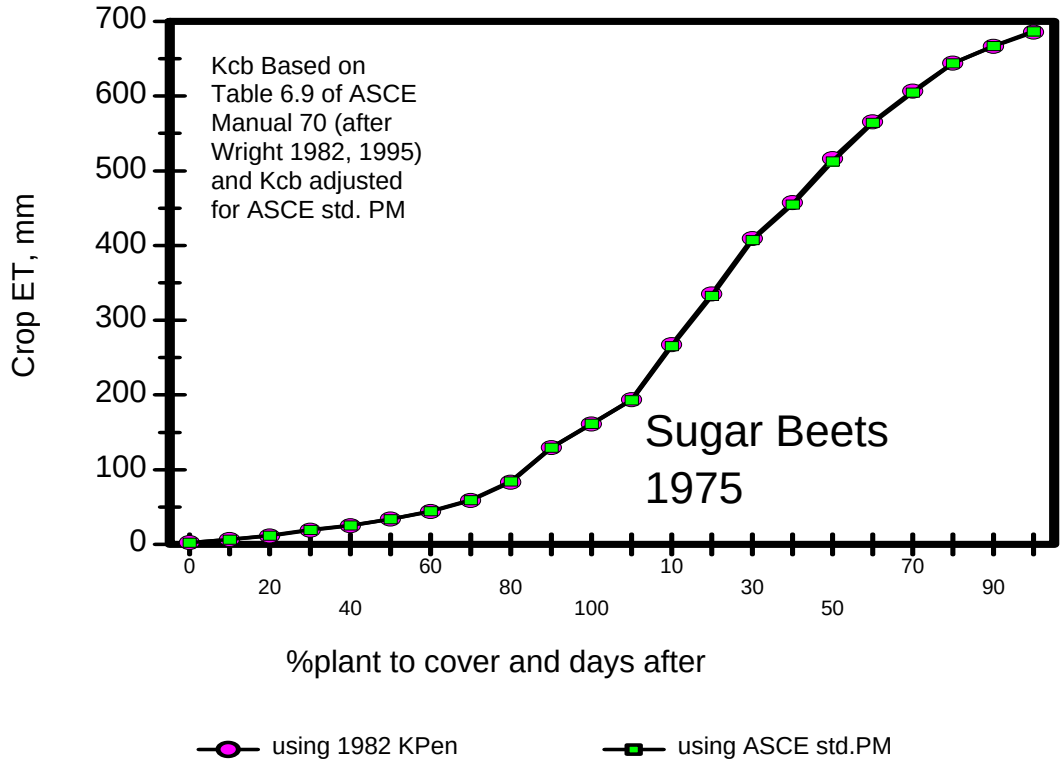

Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Sweet Corn
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcb KP
Kcb s

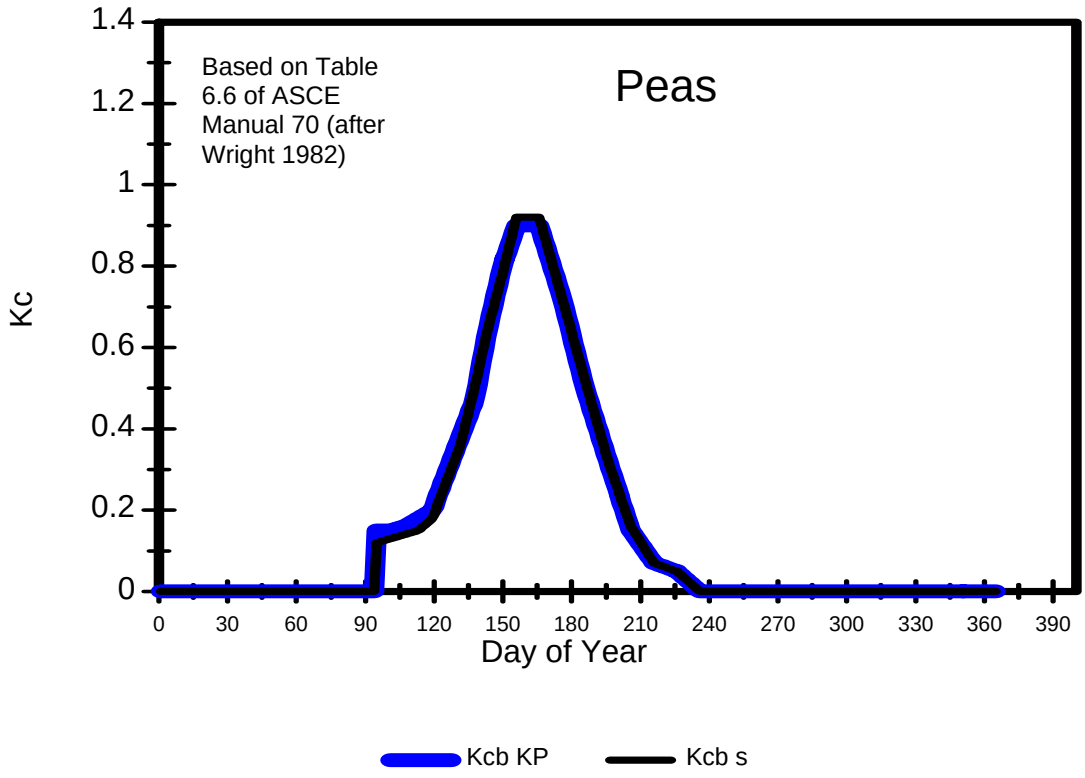

Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982) and Kcb adjusted for ASCE std. PM
Crop ET, mm
600
500
400
300
200
100
0
Sweet Corn
1976
0 20 40 60 80 100 10 30 50 70 90
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

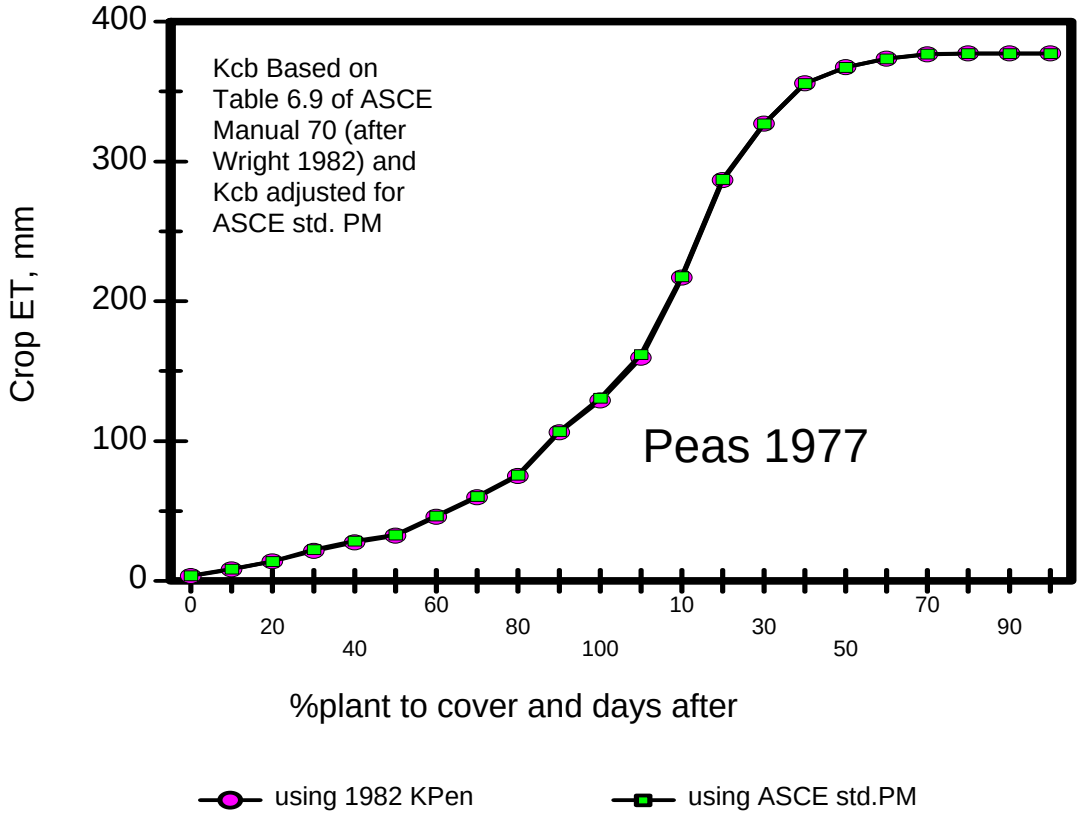

Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Spring Wheat
Kc
Day of Year
Kcb KP
Kcb s

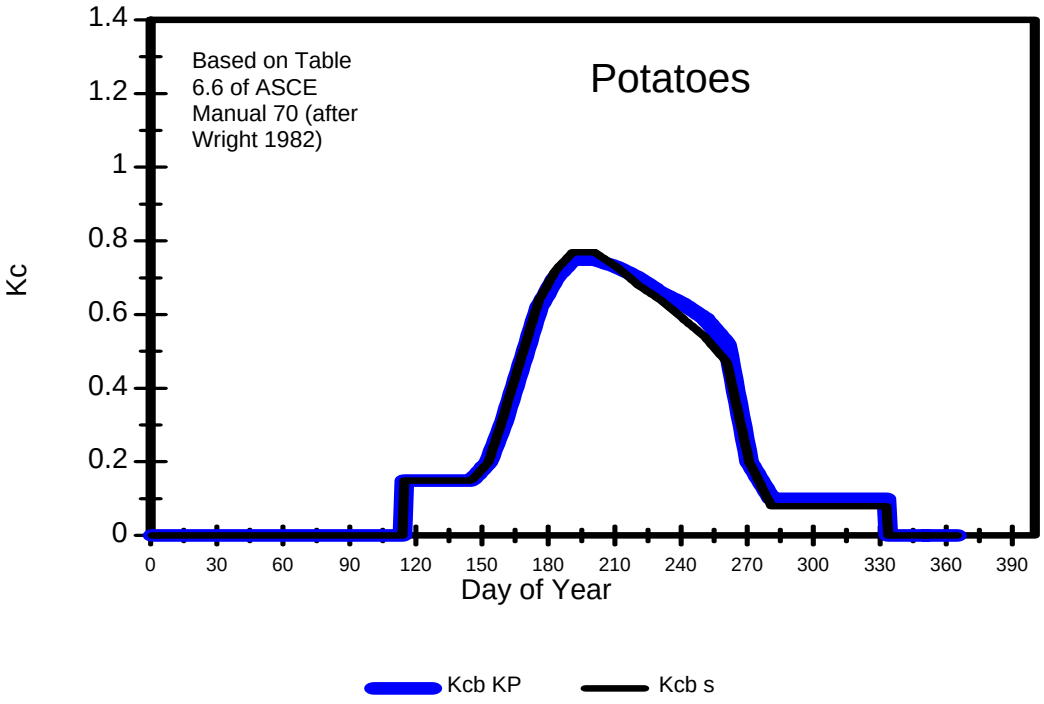

Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982, 1995) and Kcb adjusted for ASCE std. PM
Spring Grain 1979
Crop ET, mm
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

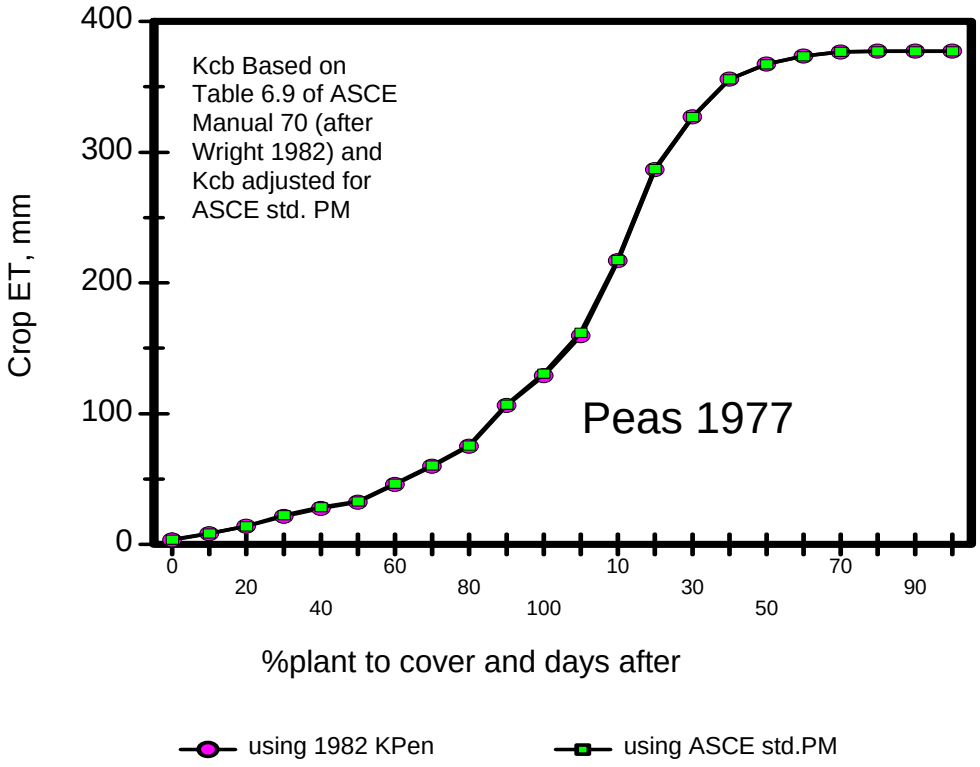

Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Sugar Beets
Kc
Day of Year
Kcb KP
Kcb s

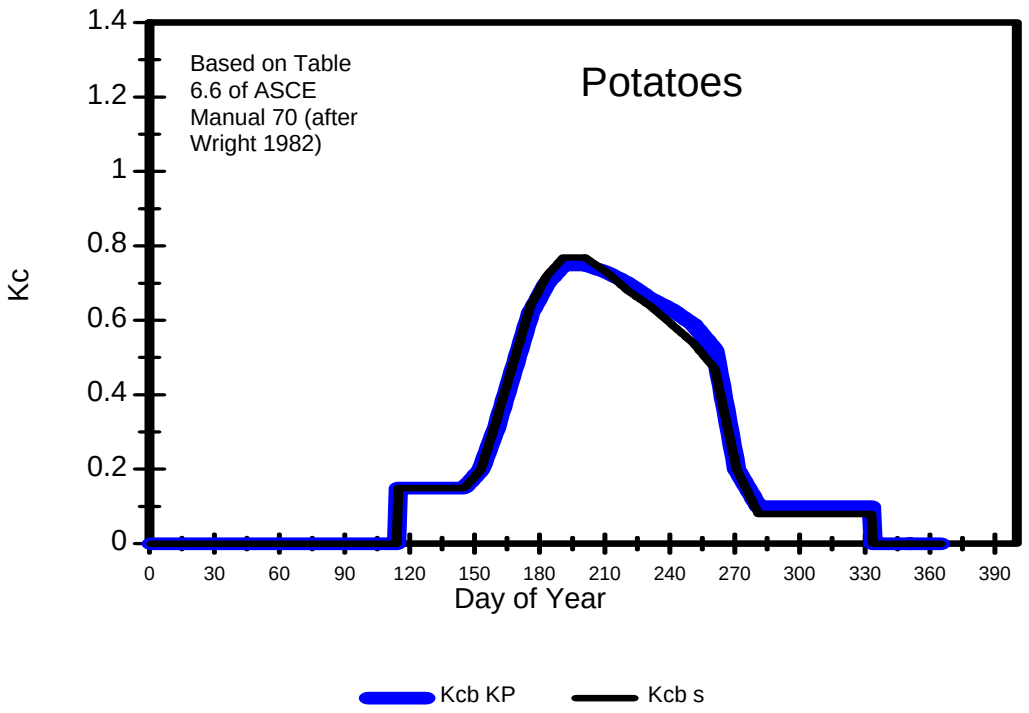

Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982, 1995) and Kcb adjusted for ASCE std. PM
Sugar Beets 1975
Crop ET, mm
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

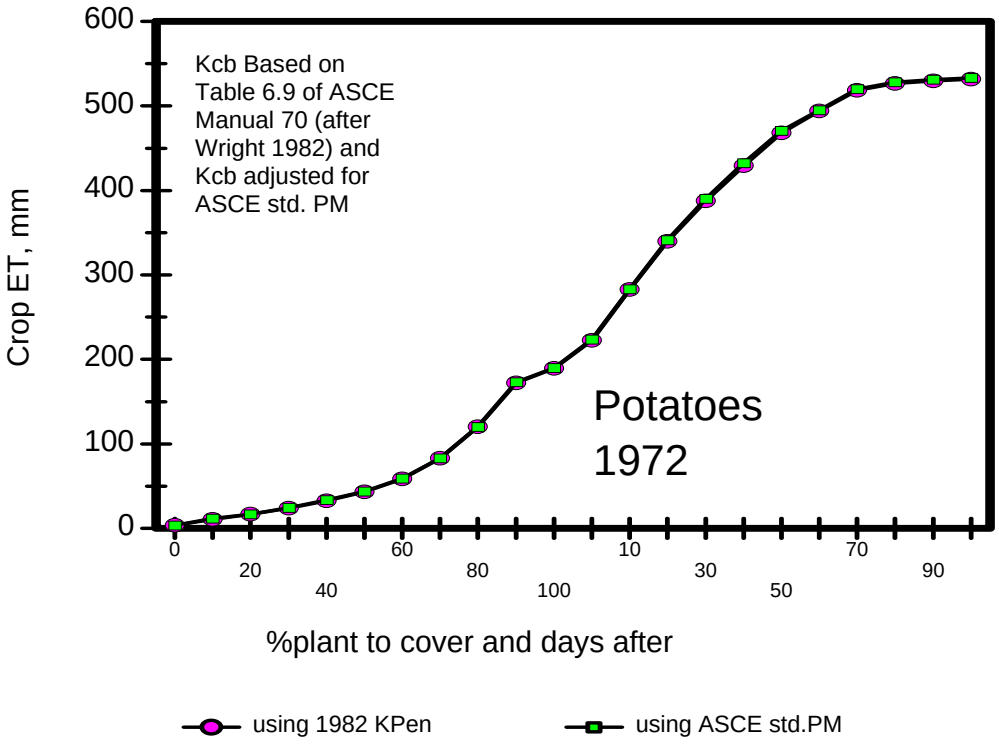

Peas
Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Kc
Day of Year
Kcb KP
Kcb s

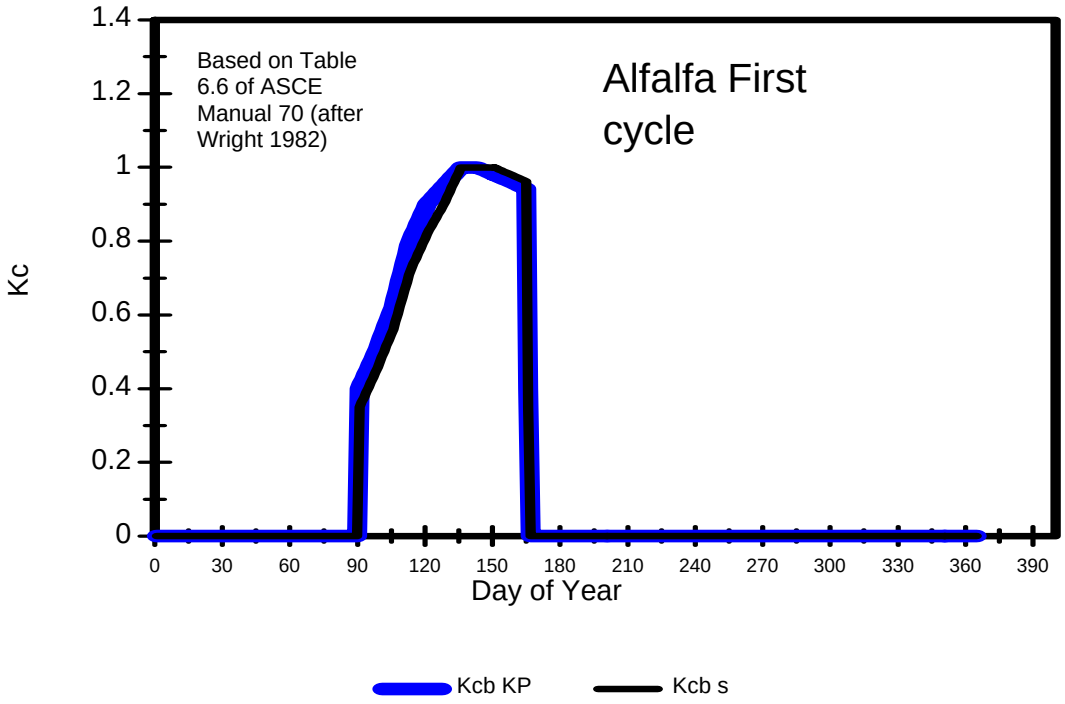

Peas 1977
Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982) and Kcb adjusted for ASCE std. PM
Crop ET, mm
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

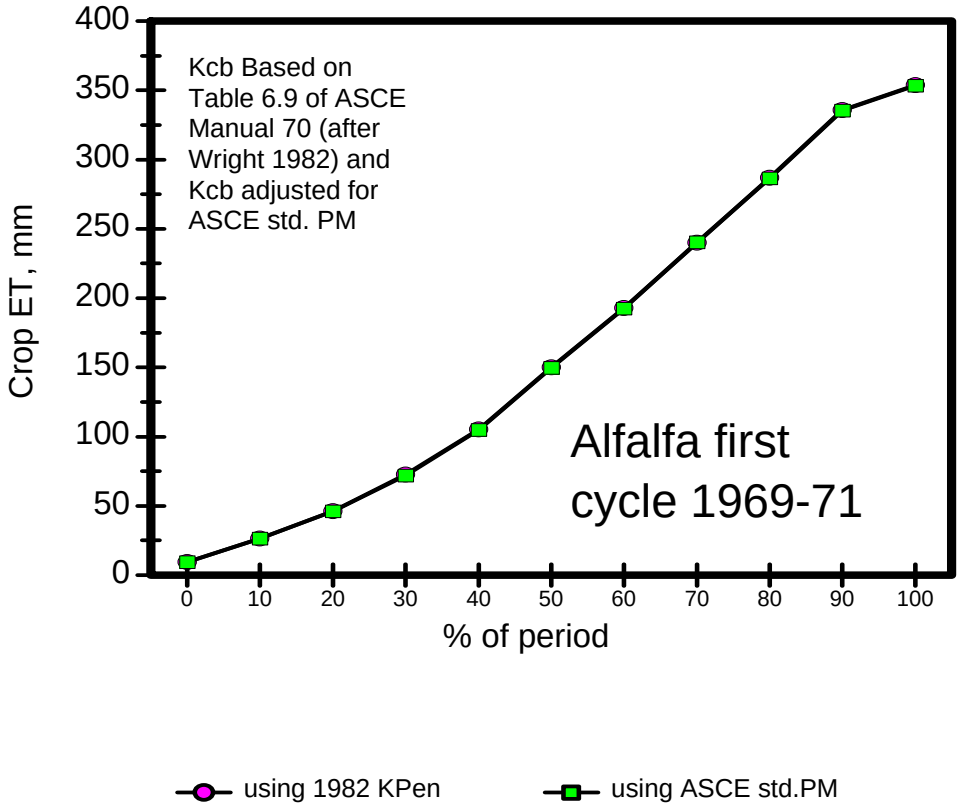

Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Potatoes
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcb KP
Kcb s

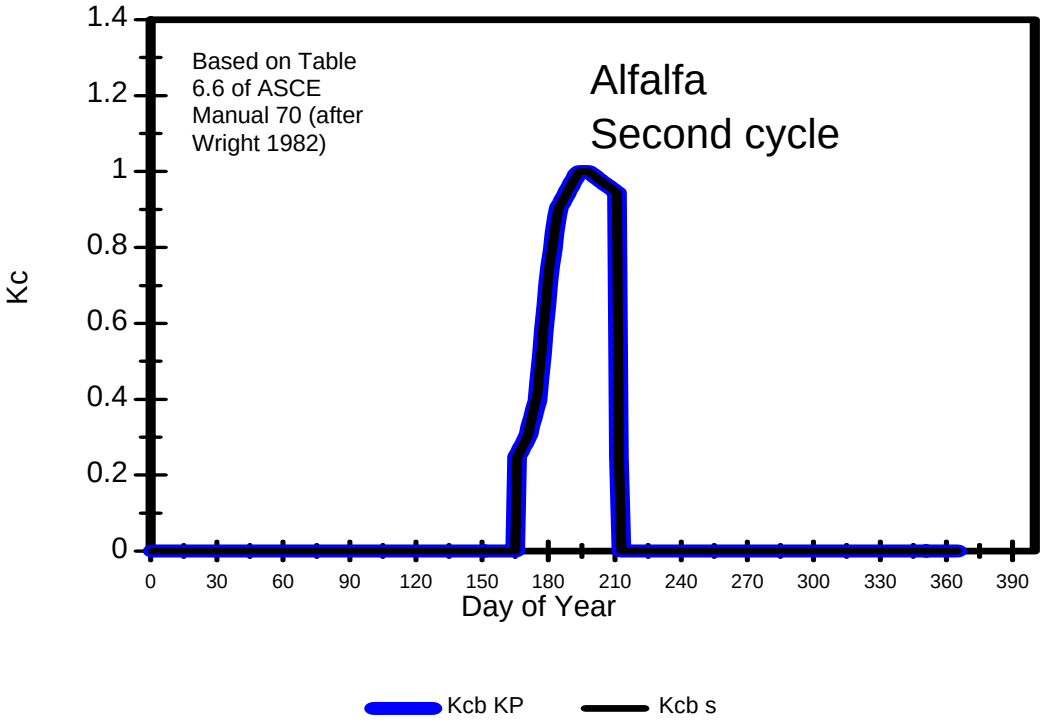

Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982) and Kcb adjusted for ASCE std. PM
Peas 1977
Crop ET, mm
400
300
200
100
0
0 20 40 60 80 100 10 30 50 70 90
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

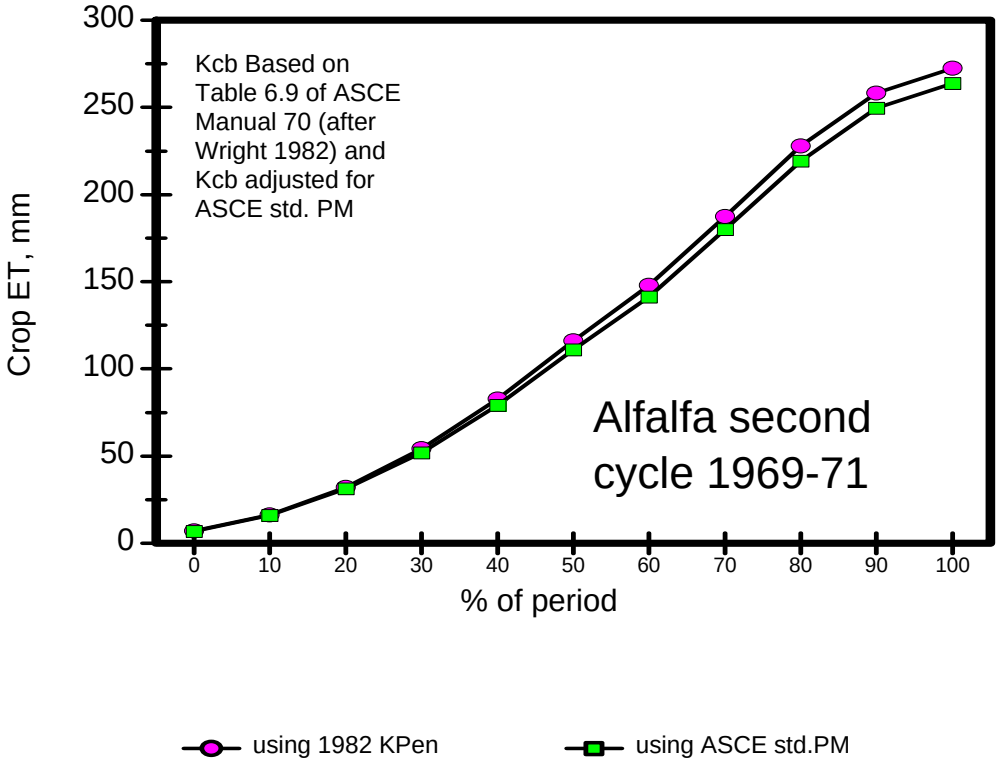

Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Potatoes
Kc
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
Kcb KP
Kcb s

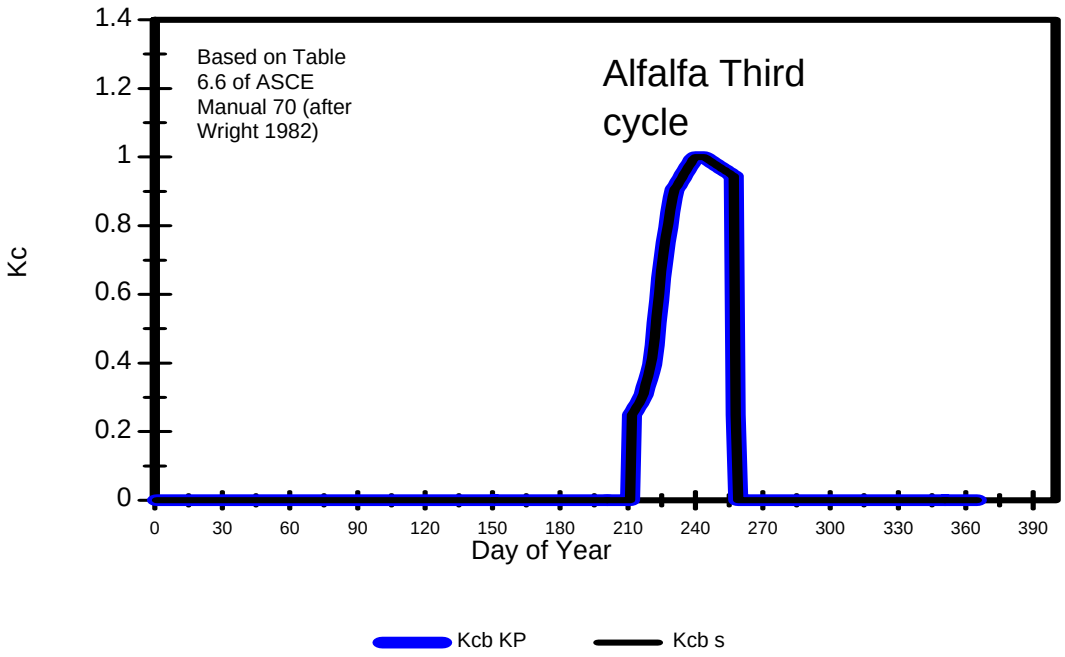

Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982) and Kcb adjusted for ASCE std. PM
Potatoes
1972
Crop ET, mm
600
500
400
300
200
100
0
0 20 40 60 80 100 10 30 50 70 90
%plant to cover and days after
using 1982 KPen
using ASCE std.PM

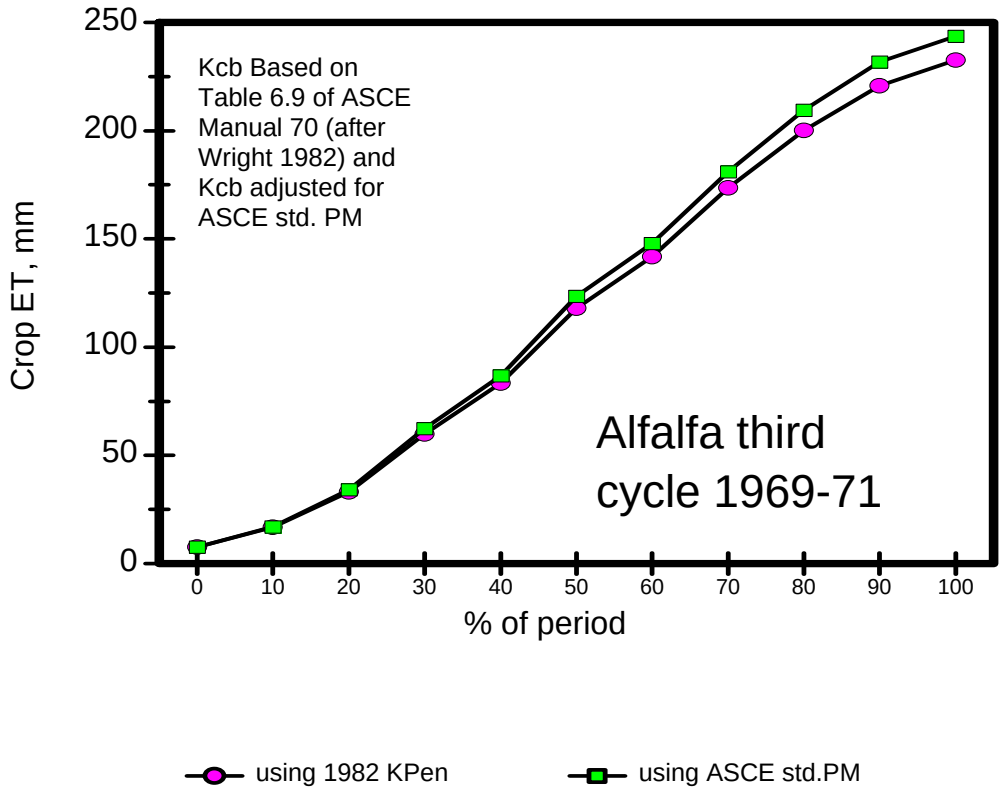

Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Alfalfa First cycle
Kc
Day of Year
Kcb KP
Kcb s

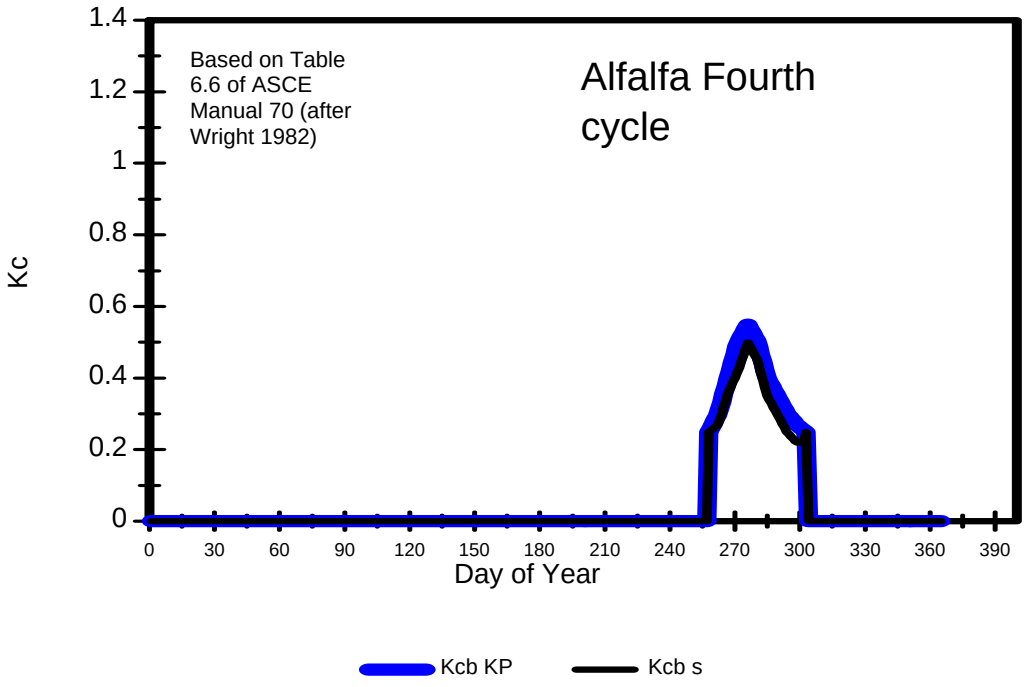

Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982) and Kcb adjusted for ASCE std. PM
Alfalfa first cycle 1969-71
Crop ET, mm
% of period
using 1982 KPen
using ASCE std.PM

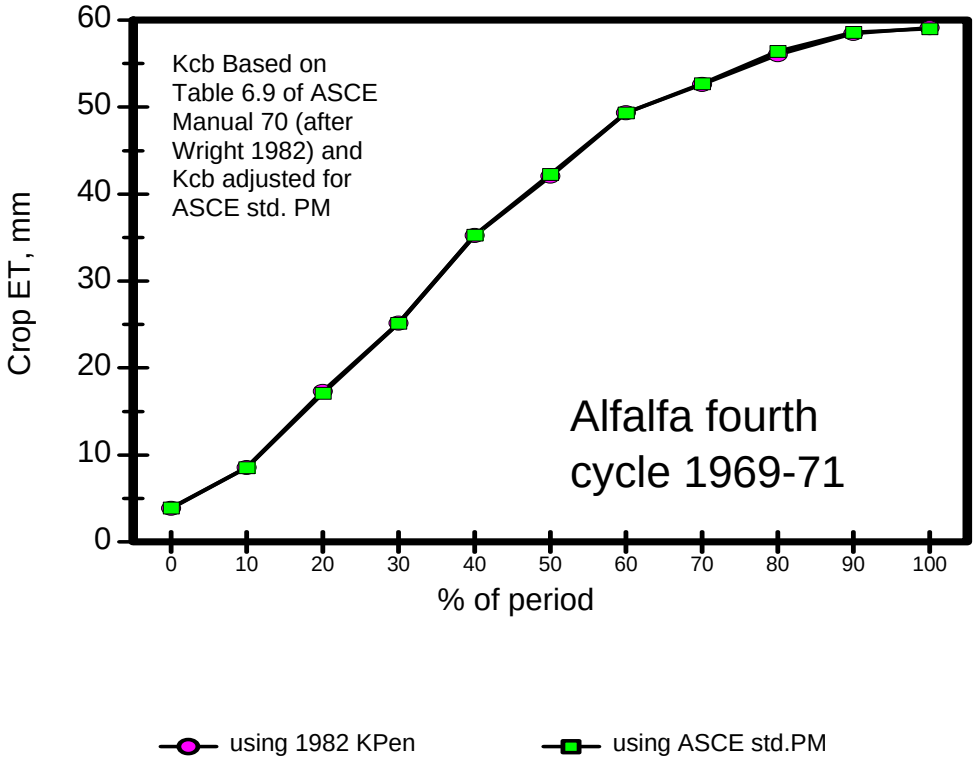

Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Alfalfa
Second cycle
Kc
Day of Year
Kcb KP
Kcb s


Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982) and Kcb adjusted for ASCE std. PM
Alfalfa second cycle 1969-71
Crop ET, mm
% of period
using 1982 KPen
using ASCE std.PM


Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Alfalfa Third cycle
Kc
Day of Year
Kcb KP
Kcb s


Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982) and Kcb adjusted for ASCE std. PM
Alfalfa third cycle 1969-71
Crop ET, mm
% of period
using 1982 KPen
using ASCE std.PM


Based on Table 6.6 of ASCE Manual 70 (after Wright 1982)
Alfalfa Fourth cycle
Kc
Day of Year
Kcb KP
Kcb s


Kcb Based on Table 6.9 of ASCE Manual 70 (after Wright 1982) and Kcb adjusted for ASCE std. PM
Alfalfa fourth cycle 1969-71
Crop ET, mm
% of period
using 1982 KPen
using ASCE std.PM