Comparison of Cumulative Evapotranspiration at Kimberly, Idaho using Mean Crop Coefficients from Table 6.9 of ASCE Manual 70 for Years of Measurement by Crop and the 1982 Kimberly Penman and ASCE Standardized Penman-Monteith Reference Methods

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Dr. Richard G. Allen
University of Idaho
Kimberly, Idaho 83301

The following graphs show cumulative evapotranspiration (ET) computed for the specific years of lysimeter measurement used by Wright (1981) to develop the relevant mean K_c curves at Kimberly, Idaho. The graphs compare ET as computed using the 1982 Kimberly Penman (Wright, 1982) and using the ASCE standardized Penman-Monteith (ASCEstdPM) (EWRI, 2002) alfalfa reference ET methods. The crop coefficients (K_c) used are those of Wright (1981) as reported in ASCE Manual 70 Table 6.9 (Jensen et al., 1990), with the exception of the K_c for sugar beets, which was updated by Wright (1995). These are reproduced in Table 1.

Comparisons were made for the year that the lysimeter data were collected for the specific crop. Weather data were collected by the National Weather Service located at the USDA-ARS center at Kimberly. Reference ET was computed using the REF-ET software following adjustment of solar radiation data to fit the theoretical clear sky solar radiation curve predicted by REF-ET based on ASCE Task Committee report on Standardization of Calculation of Reference Evapotranspiration. In the case of beans and alfalfa, ET was measured over multiple years. Daily reference ET was averaged over these two and three year periods. The use of the weather data for the year of ET data collection reproduces the same conditions as occurring during collection and provides an accurate means of assessing differences in ET caused by using the different reference basis.

Crop dates (planting, full cover, and harvest) are identical to those reported by Manual 70 (Table 6.7) following Wright (1981, 1982). These are reproduced in Table 2. Crop coefficients were computed daily by interpolating between the tabular entries of Table 1. The same values were applied to each reference method. The product of K_c and reference ET (ET_r) were then summed vs time to calculate a cumulative ET vs. time. The results are compared for each crop in the following figures.

The seasonal ratios of cumulative crop ET were surprisingly close between the two ET_r methods, as summarized in Table 3. The average of the seasonal ratios of ET over all

crops was 1.001, indicating only 0.1% difference in seasonal ET on average (given equal weighting among crops). The largest positive difference in seasonal ET between reference methods was 2.7% for winter wheat (ratio = 1.027) and the largest negative difference was –3.2% for sweet corn (ratio = 0.968). The standard deviation of ratios was only 2 percent, which is considered to be small.

Differences between ET_c based on the two references are larger for individual months of the growing periods, where the ASCE standardized P-M based calculations are larger than those based on the 1982 Kimberly Penman in the early spring and fall and are smaller than those based on the 1982 Kimberly Penman toward mid-summer. However, the early spring and fall differences are relatively small because the values for the crop coefficients are small during these periods. The positive biases in the computed ET_c using the ASCEstdPM during early spring and fall are to a large extent offset by negative biases during summer, thereby reducing seasonal differences.

Conclusions that can be drawn from these comparisons are that differences in seasonal ET that result from using the ASCE standardized Penman-Monteith alfalfa reference vs. the 1982 Kimberly Penman alfalfa reference are small at Kimberly, and that crop coefficient tables by Wright (1981, 1982) can be applied with the ASCEstdPM with no adjustment. Differences are larger during individual portions of the growing periods, although the differences are probably smaller than the uncertainties in the ET_c estimates themselves. When applying the ASCEstdPM to derive ET_c sums for monthly or shorter periods, one could consider making adjustments to the K_c curves to account for the differences between the two reference methods. However, for most practical purposes, no adjustments are probably needed.

Table 1. Original "Mean" ET Crop Coefficients, K_{cm}, for Normal Irrigation and Precipitation Conditions, for Use with Alfalfa Reference ET_r (*Original Crop Coefficients* by Wright, 1981; Manual 70 Table 6.9; and updated by Wright, 1995)

	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 (1981) reflect additional data for some crops (Wright, 1984, personal communication).

Table 2. 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 3. Summary of evapotranspiration calculated for the year of lysimeter measurements using the 1982 Kimberly Penman and ASCE Standardized Penman-Monteith methods and mean crop coefficients from ASCE Manual 70 Table 6.9.

		Seasonal ET_c, mm		Ratio of seasonal ET_c
Crop	**Year**	**$ET_{c\ KP}$**	**$ET_{c\ PM}$**	**PM/KP**
Winter Wheat	1977-78	801	823	1.027
Dry Beans	1973, 74	461	452	0.981
Corn Grain	1976	584	577	0.988
Sweet Corn	1975	424	411	0.968
Spring Grain	1979	664	654	0.985
Sugar Beets	1975	746	758	1.016
Peas	1977	401	404	1.008
Potatoes	1972	611	617	1.010
Alfalfa Mean	1969-71	1005	1029	1.024
Ryegrass	1983,84	897	914	1.020
average for first nine crops		586	587	1.001
std deviation of ratios				0.020
maximum ratio				1.027
minimum ratio				0.968

References

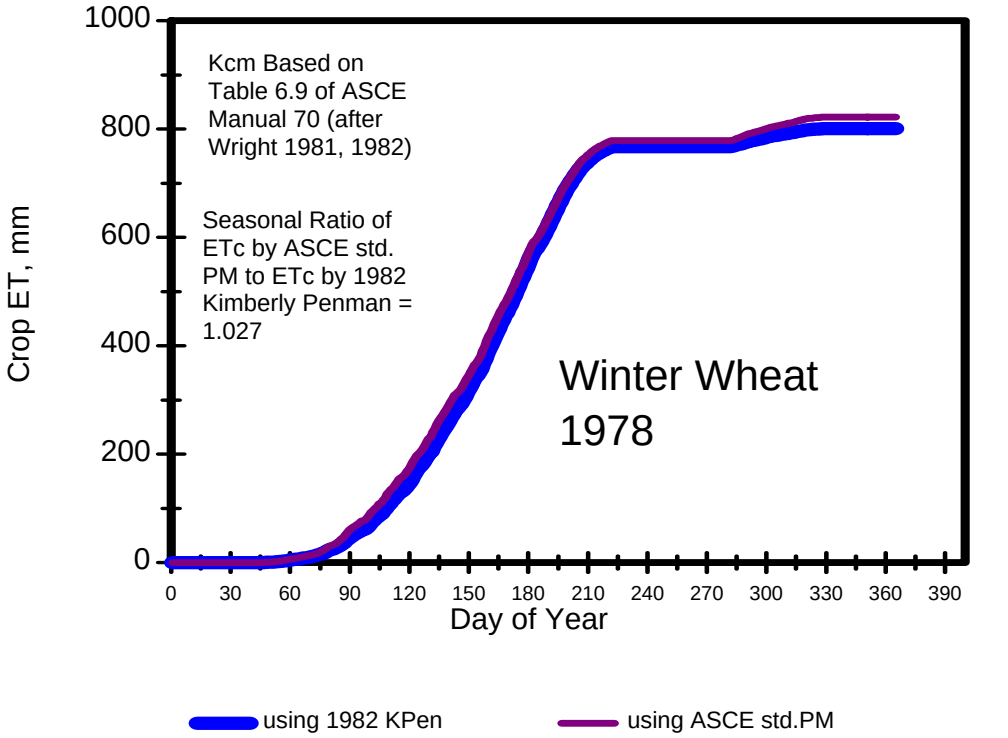
EWRI, 2002. The ASCE Standardized Reference Evapotranspiration Equation. Report of the Task Committee on Standardization of Reference Evapotranspiration, Environmental and Water Resources Institute of the American Society of Civil Engineers. Members: I. A. Walter (Chair), R. G. Allen (Vice-chair), R. Elliott, D. Itenfisu, P. Brown, M. E. Jensen, B. Mecham, T. A. Howell, R. Snyder, S. Eching, T. Spofford, M. Hattendorf, D. Martin, R. H. Cuenca, and J. L. Wright. 171 p.

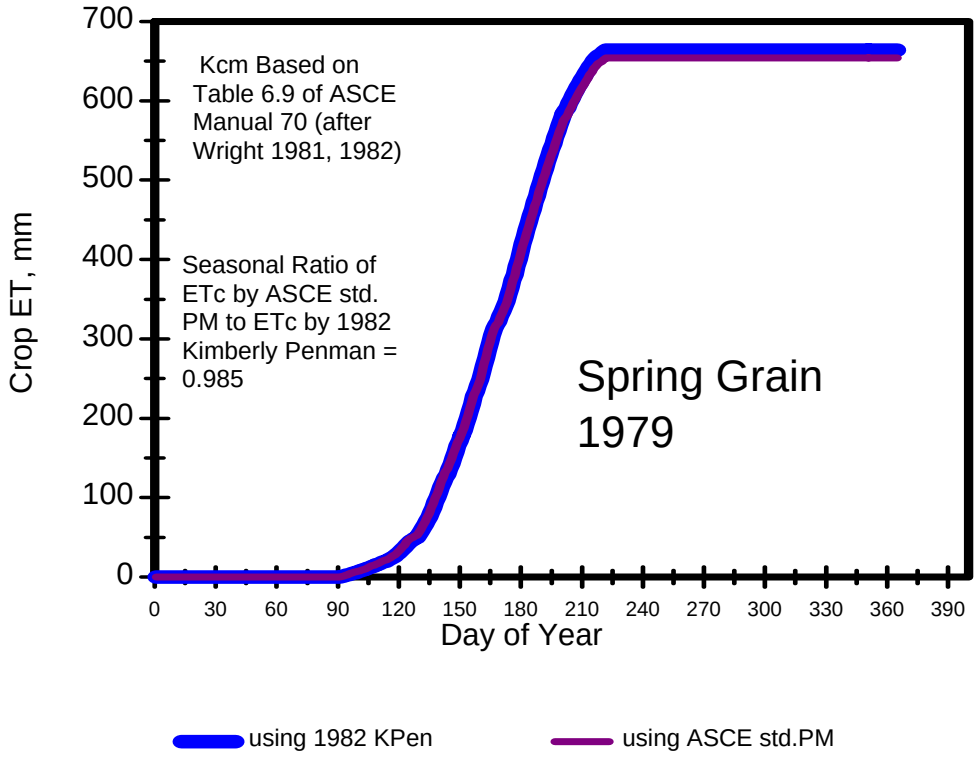
Jensen, M.E., R.D. Burman, and R.G. Allen (ed.). 1990. Evapotranspiration and irrigation water requirements. ASCE Manual 70.

Wright, J.L., 1981. Crop coefficients for estimates of daily crop evapotranspiration *Irrig. Sched. for Water and Engergy Conserv. in the 80's*, ASAE, p. 18-26.

Wright, J.L. 1982. New Evapotranspiration Crop Coefficients. *Journal of Irrigation and Drainage Division*, ASCE, 108:57-74.

Wright, J.L. 1995. Calibrating an ET procedure and deriving ET crop Coeficients. Proceedings of the 1995 Seminar on Evapotranspiration and Irrigation Efficiency., American Consulting Engineers Council of Colorado and Col. Div. Water Resources, Arvada, CO. 27 p.


Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981, 1982)
Seasonal Ratio of ETc by ASCE std. PM to ETc by 1982 Kimberly Penman = 1.027
Winter Wheat 1978
Crop ET, mm
Day of Year
0
200
400
600
800
1000
0 30 60 90 120 150 180 210 240 270 300 330 360 390
using 1982 KPen
using ASCE std.PM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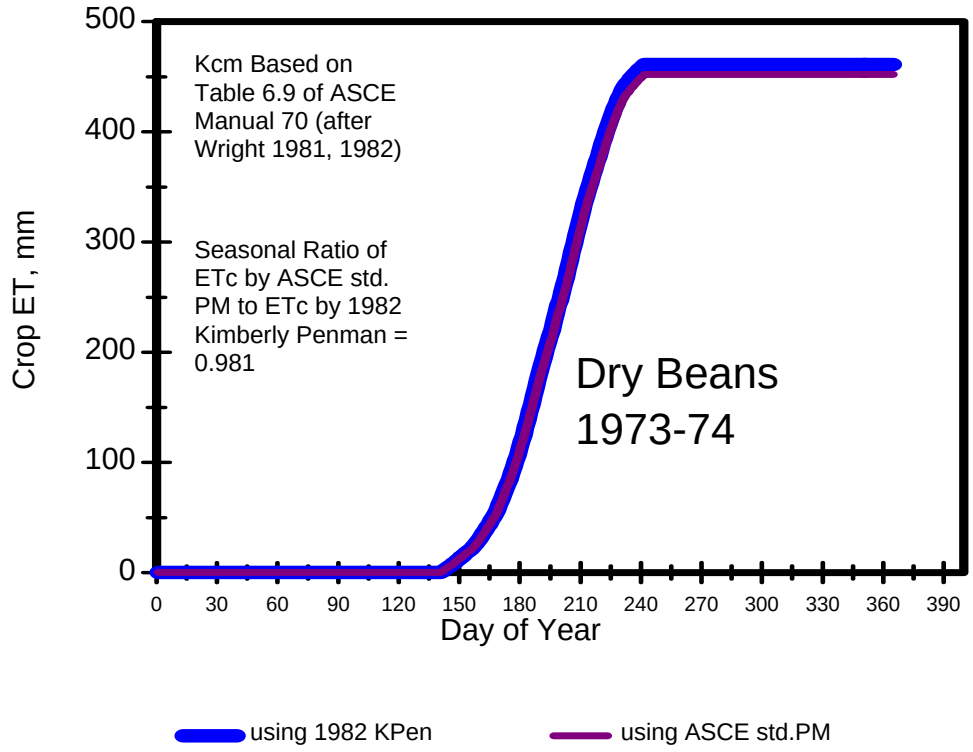
Spring Grain 1979
Crop ET, mm
Day of Year
0
100
200
300
400
500
600
700
0 30 60 90 120 150 180 210 240 270 300 330 360 390
using 1982 KPen
using ASCE std.PM


Crop ET, mm
500
400
300
200
100
0
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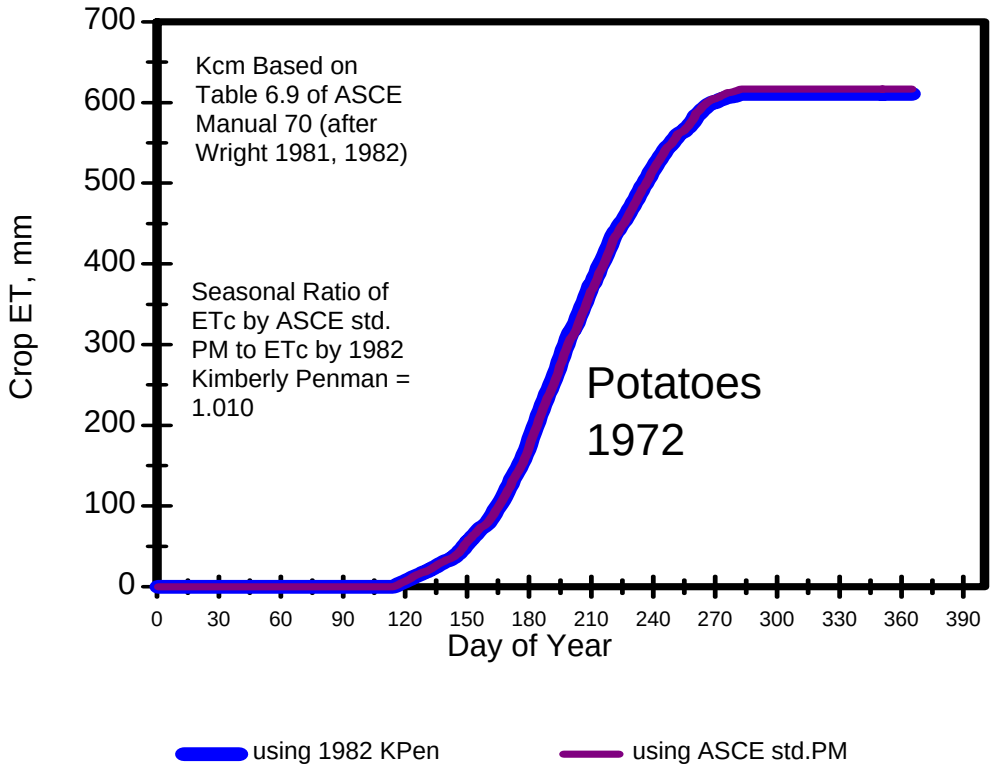
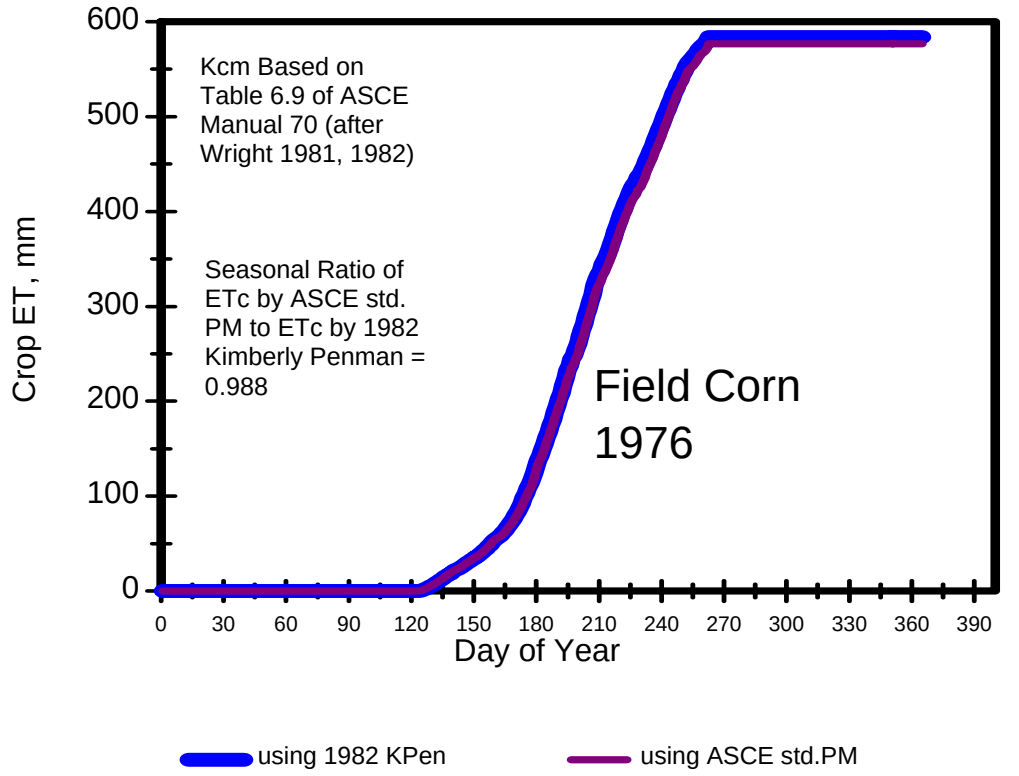
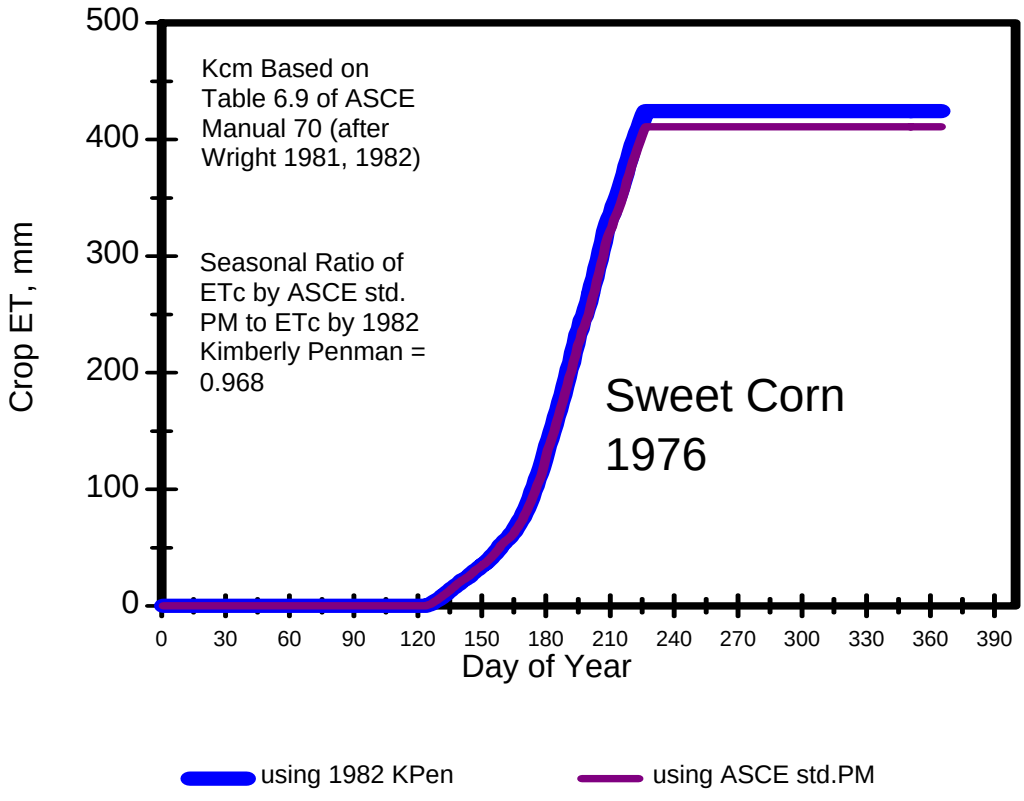
Seasonal Ratio of ETc by ASCE std. PM to ETc by 1982 Kimberly Penman = 0.981
Dry Beans
1973-74
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
using 1982 KPen
using ASCE std.PM


Crop ET, mm
700
600
500
400
300
200
100
0
Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981, 1982)
Seasonal Ratio of ETc by ASCE std. PM to ETc by 1982 Kimberly Penman = 1.010
Potatoes
1972
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
using 1982 KPen
using ASCE std.PM


Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981, 1982)
Seasonal Ratio of ETc by ASCE std. PM to ETc by 1982 Kimberly Penman = 0.988
Field Corn 1976
Crop ET, mm
Day of Year
0
100
200
300
400
500
600
0 30 60 90 120 150 180 210 240 270 300 330 360 390
using 1982 KPen
using ASCE std.PM


Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981, 1982)
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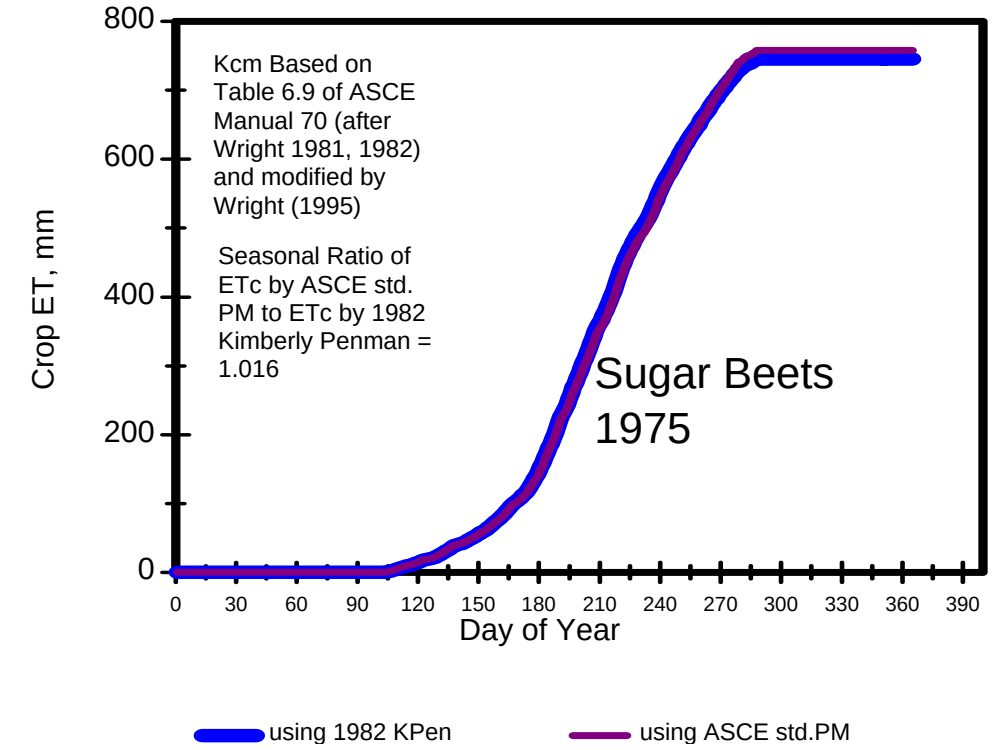
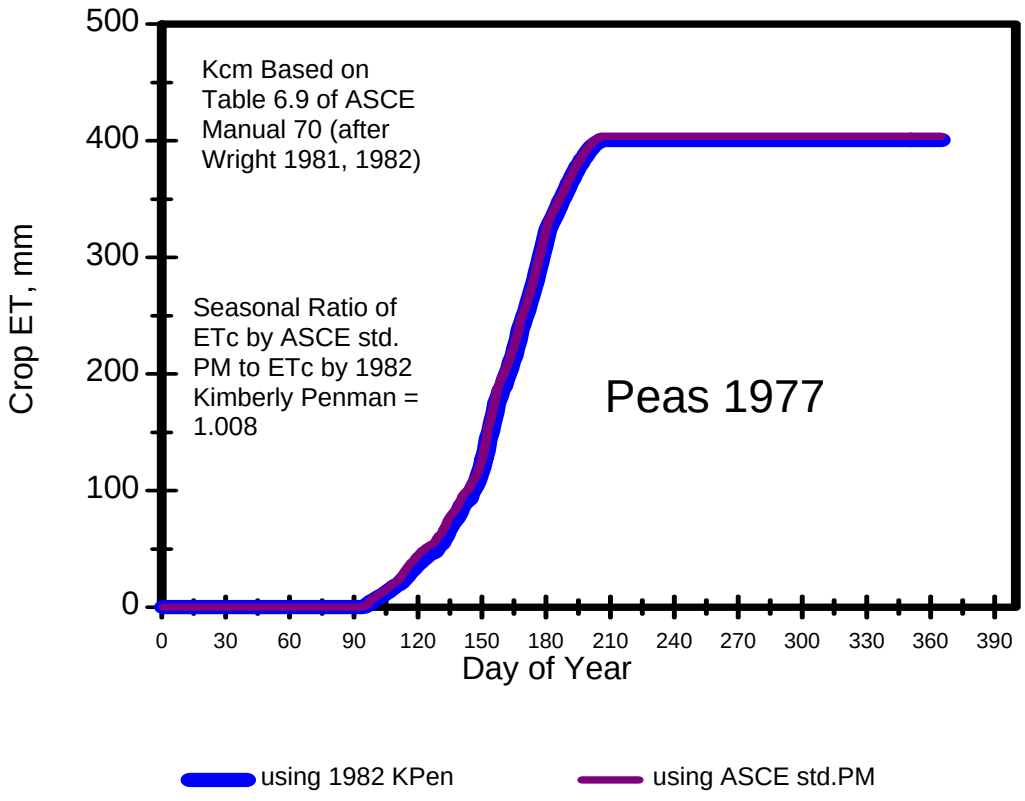
Sweet Corn 1976
Crop ET, mm
Day of Year
0
100
200
300
400
500
0 30 60 90 120 150 180 210 240 270 300 330 360 390
using 1982 KPen
using ASCE std.PM


800
600
400
200
0
Crop ET, mm
Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981, 1982) and modified by Wright (1995)
Seasonal Ratio of ETc by ASCE std. PM to ETc by 1982 Kimberly Penman = 1.016
Sugar Beets 1975
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
using 1982 KPen
using ASCE std.PM


500
400
300
200
100
0
Crop ET, mm
Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981, 1982)
Seasonal Ratio of ETc by ASCE std. PM to ETc by 1982 Kimberly Penman = 1.008
Peas 1977
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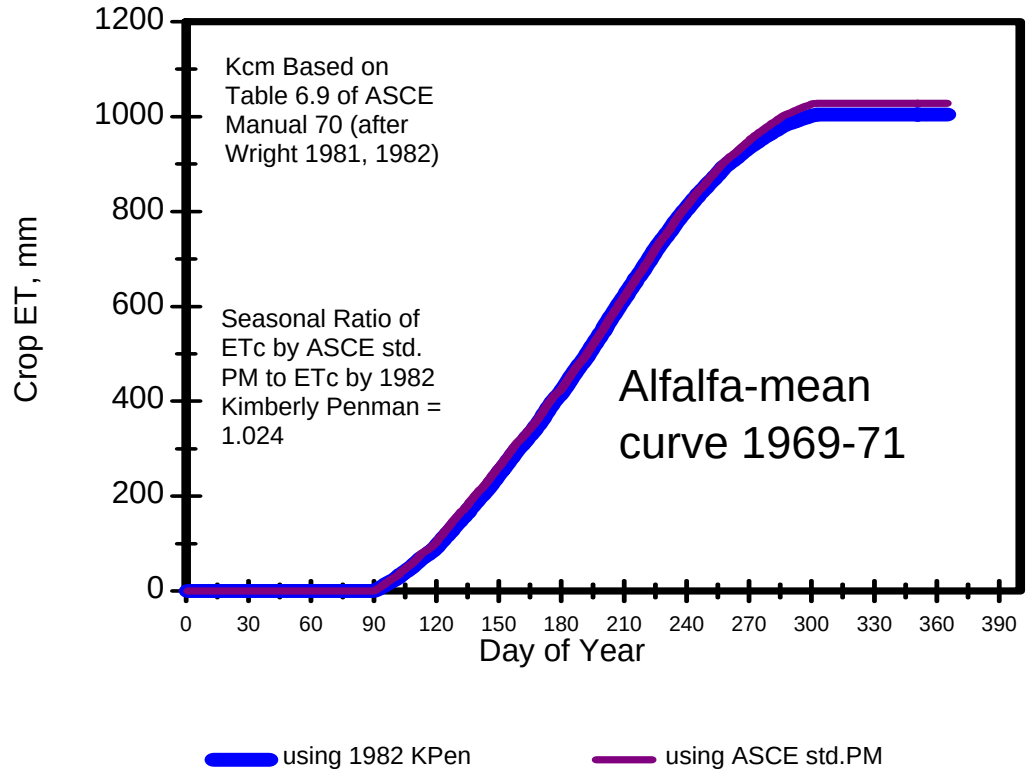
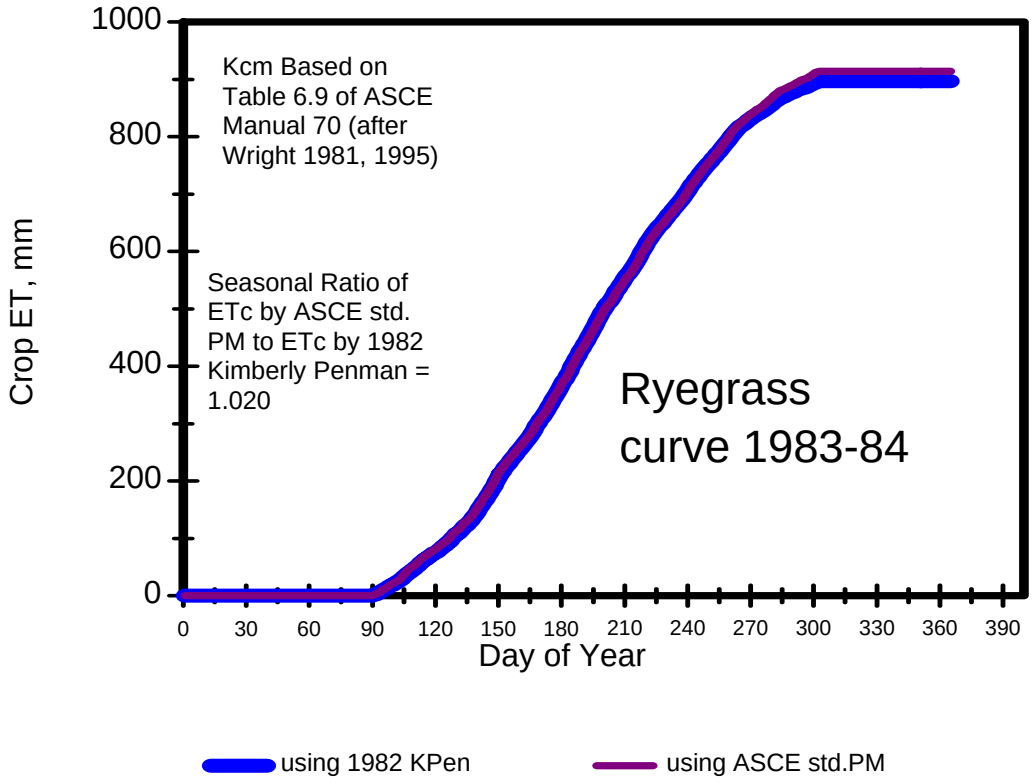
Day of Year
using 1982 KPen
using ASCE std.PM


1200
1000
800
600
400
200
0
Crop ET, mm
Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981, 1982)
Seasonal Ratio of ETc by ASCE std. PM to ETc by 1982 Kimberly Penman = 1.024
Alfalfa-mean curve 1969-71
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
using 1982 KPen
using ASCE std.PM


1000
800
600
400
200
0
Crop ET, mm
Kcm Based on Table 6.9 of ASCE Manual 70 (after Wright 1981, 1995)
Seasonal Ratio of ETc by ASCE std. PM to ETc by 1982 Kimberly Penman = 1.020
Ryegrass curve 1983-84
0 30 60 90 120 150 180 210 240 270 300 330 360 390
Day of Year
using 1982 KPen
using ASCE std.PM