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Research Article / Araştırma Makalesi

THE DETERMINING PHYSIOLOGICAL MATURITY TIME IN SUNFLOWER

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Abstract: The genotype of sunflower (*Helianthus annuus* L.) affects maturity time but maturity is also influenced by environmental conditions such as temperature, planting date and location. The easiest and most economical method for determining maturity was phenological or visual observation. The best character to define physiological maturity (PM) was head first stage, when the brown color (1 to 10 %) was visually observed at back of sunflower heads in visual observations. Determination of PM with phenological observation and seed moisture or seed maximum oil content together was the most accurate method for evaluation of physiological maturity. Hybrids decreased to about 300-400 g/kg moisture and reached maximum oil content at physiological maturity. Correlation results at physiological maturity showed that hybrids usually displayed similar days and heat unit accumulations at flowering and other early stages. Therefore, the earliest stage to accurately predict PM was 50 % blooming stage for most hybrids. Day accumulations were found to be less variable than heat unit accumulations in this study.

Key words: Sunflower, Physiological Maturity, Growth stages

Ayçiçeğinde Fizyolojik Olgunluk Zamanının Belirlenmesi

Özet: Ayçiçeğinde genetik faktörler olgunlaşma zamanının belirlenmesinde önemli rol oynamasına rağmen, bu öğenin oluşmasında ayrıca sıcaklık, ekim zamanı ve ekildiği yer gibi çevresel faktörlerin etkisi büyüktür. Olgunluğun ayçiçeği bitkisinde belirlemenin en kolay ve ekonomik yolu fenolojik ve görsel gözlemlerdir. Fizyolojik olgunluğun belirlenmesinde en önemli özellik; ayçiçeği tablasının arka kısımlarının % 10 civarında kahverengine döndüğü zamandır. Araştırmada; ayçiçeği tanelerinin maksimum yağ oranına ulaşması ve nem oranının fenolojik gözlemler ile kullanılarak fizyolojik olgunluk zamanının belirlenmesi en uygun metot olarak bulunmuştur. Bu zamanda tanelerde 300-400 g/kg nem oranı mevcut olup, tanelerde yağ oranı maksimum seviyeye ulaşmıştır. Araştırmadaki korelasyon sonuçlarında, hem gün, hem de gün derece toplamlarında fizyolojik olgunluk zamanında benzer sonuçlar elde edilmiş olup, olgunluğun en erken % 50 çiçeklenme zamanında doğru olarak tahmin edilebileceğini belirlenmiştir. Denemelerde fizyolojik olgunluk gün süreleri, gün derece toplamlarına göre daha az değişkenlik göstermiştir.

Anahtar kelimeler: Ayçiçeği, Fizyolojik Olgunluk, Gelişme Devreleri

Introduction

Physiological maturity (PM) is defined for many crops, as the time plants reach the maximum seed weight, the highest quality or maximum marketable product. This stage is an important phenomenon in crop phenology as it is the end point of grain production as influenced by cultural practices such as planting, fertilizing, irrigating, harvest etc...

Physiological maturity has been identified in sunflower using different methods and different characteristics in several studies. One of the common indicators of PM is when sunflower changes color in the back of the head and bracts. Sunflower PM is visually determined by the color change from green to yellow on the back of heads and involucral bracts (Robinson, 1983; Johnson and Jellum, 1972). Robinson (1971) considered sun flower plants to be physiologically mature when leaves and petioles were dry and the back of heads turned yellow. Schneiter and Miller (1981) determined all vegetative (V) and reproductive (R) stages in the sunflower including physiological maturity (R-9 stage). The R-9 stage was defined as the time when the backs of plant heads begin to change from yellow to brown.

Some studies supplemented visual characteristics with seed moisture content and maximum seed dry weight measurements as indicators of PM in sunflower. Anderson (1975) defined PM as the time that seed dry weight, linoleic acid and oil content reach maximum values, the back of heads were yellow and 10 % were brown, seeds contained 40 % water and capitulum moisture dropped to 70 %. Seed moisture at this stage was approximately 300 to 350 g / kg (Anfinrud, 1997).

Environmental factors such as temperature influence development of sunflower phenological stages and seed compositions (Connor and Hall, 1997). Oil content are important characters for oil type sunflower production, so sunflower seed should contain maximum oil content at harvest time. Another indicator of PM in sunflower is maximum seed dry weight noted by several studies. Connor and Sadras (1992) implied that the stability of seed dry weight was the most accurate technique to detect PM in sunflower. Browne (1978) observed that PM and phenomenon of floret abscission occurred at the same time and maximum seed dry weight or PM occurred 30 days after last anthesis at 30 % seed moisture content.

Heat Unit (HU) summation by accumulating the mean daily temperature minus some base temperature is one of the most common methods to measure time between phenological stages and maturity classification. HU accumulations could be used more precisely than day accumulations to measure time from planting date to physiological maturity in sunflower and other field crops. Robinson (1971) found that HU accumulation was less variable than day accumulations except between the head visible to last anther stage. Unlike other field crops, sunflower heads mature before the leaves start to dry. A common measure of physiological maturity in the sunflower was defined in the literature mainly determined by four characteristics. These characters were seed moisture (Anderson, 1975; Kole and Gupta, 1982), maximum dry weight (Connor and Sadras, 1992; Browne, 1978; Connor and Hall, 1997), oil content (Harris et al., 1978; Johnson and Jellum, 1972) and visual characteristics (color of bracts and back of heads) (Robinson, 1971; 1983; Schneiter and Miller, 1981). However, to detect hybrid differences in sunflower, relative maturity should be observed at all stages from planting to PM. Moisture content and maximum dry weight are dependent on each other. Therefore, moisture and oil content, visual color observations were related to day and HU accumulations to determine PM using 12 sunflower hybrids in this research.

This study was conducted to determine an economical and accurate measurement of physiological maturity, to define adequate criteria for the description of PM in sunflower and determine the best technique to measure PM in sunflower, to compare day and HU accumulations in growth stages, to determine the earliest growth stage to accurately and economically predict physiological maturity.

Material and methods

Research was conducted in Western Nebraska in 1997. Experiments were conducted with two locations, two planting dates (early and late), twelve commercial sunflower hybrids and four replications. Experimental design was split-split plot. Location one was conducted in dry land conditions in Sidney, NE. The distance between rows was 76 cm and plants were 30.5 cm. Early planting date in Sidney was on June 7 and late planting on June 20, 1997. The other location was under irrigated conditions in Scottsbluff, NE. The distance in the planting between rows was 76.2 cm and between plants was 23 cm. The early planting in Scottsbluff was on May 20 and late planting on June 16, 1997.

Following data were collected: Planting date, Emergence date, Dates when 50% and 100% of plants in the plot with first open ligule petals, Petal dropping date, First date when the back of plants' heads turned to yellow from green color, Dates of brown color observations at the bracts, the back of heads and at the stems of the plants, seed moisture and oil content % at one week before PM, at PM week and one week after PM, HU accumulation for all these data. Twelve hybrids in five maturity groups were evaluated. The hybrids were Hysun-311, IS 7000 at very early group; IS-6111, Pioneer 6230, NK 231 at early; SF 270, DeKalb 3868 at medium, Pioneer 6451, Cargill 187, Mycogen 980 at mid-late, T 571, Kaystar 8806 at late group.

Blooming and other observations were obtained and maturity data were collected until two weeks after the last frost date in the climatic data for the region. Visual observations at different growth stages were evaluated using the plant staging system developed by Schneiter and Miller (1981). They defined sunflower PM as first brown color (1-10 %) at the back of the head of sunflower. Therefore, head first stage was called PM in our experiment.

Seed moisture samples were collected when the back of heads started to turn from green to yellow color until they turned brown at weekly intervals. Seed moisture samples were collected three times at Sidney and four times at Scottsbluff for early and late planting dates. First moisture content data were collected approximately 84 days after planting (DAP). This was prior to turning yellow stage according to visual color observations. The 2nd sampling date was 92 DAP which were at bract first stage for irrigated and at PM for the dryland site. The third sampling, 99 DAP was about at PM for irrigated and about at head 100 % (harvest maturity) for the dry land location. The fourth date was collected only at the irrigated location, 110 DAP for the early and 102 DAP for the late planting date, about at head 50% stage. Sixty seeds were removed from the head and fresh weights were obtained. Samples dried in the oven at 40 °C for at least 48 hours (Cukadar - Olmedo et al., 1997) were weighed and moisture data were obtained from using the formula, seed moisture (g / kg) = [(Fresh Weight - Dry Weight) / Fresh Weight] x 1000. Samples were analyzed for oil using NMR.

For the HU equation, 6.67 °C base temperature for sunflower was chosen as a reasonable compromise among several HU studies; base temperature of 6 °C (Kiniry et al., 1992), 6.6 °C (Hammer et al., 1982) and 7.2 °C (Robinson, 1971). HU accumulations between planting date and determined observation dates were calculated for each day by averaging the minimum [at least 6.67 °C base temperature] and maximum temperature and subtracting the 6.67 °C base temperature. Daily maximum and minimum temperatures were taken from the National Meteorological database for Sidney and Scottsbluff. Data were processed by analysis of variance procedures, correlation analysis using the SAS (Statistical Analysis System) program (SAS / STAT User's guides, 1990).

Results and discussions

The three way interactions, genotype by environment (L*D*H), occurred only at bloom 50 %, petal drop and turning yellow stages (Table 1). This interaction indicated that the effects of location on planting date and hybrid played an important role on plant development because of the different environmental factors of location, such as irrigation, temperature, and soil type. Additionally, this confirmed that recommendation of planting date and hybrid choice should change depending on location that sunflower is planted. The planting date by hybrid interaction occurred in earlier development stages. Goyne et al. (1977) reported similar results. They indicated that interactions in the early stages were evidence of photoperiodic effect. However, the lack of interaction at PM and later stages showed that these two main effects were not influenced by each other after PM was reached. The decreased influence in the later stages was probably due to the reduced photoperiod effect and increased plant water needs.

The main effects of location, date, and hybrid for day summations occurred all at stages of sunflower development (Table 1). Similarly, Thompson and Dougherty (1998), also found differences among locations and hybrids at flowering and PM stages. Location by date interactions occurred at all stages at which data were collected indicating that water and length of growing season affected each other in development of sunflower stages. Additionally, the location by hybrid interaction occurred at all stages except late stages such as head 100 % (harvest maturity) stem 50% and stem 100 %. However, date by hybrid interaction was found only at blooming, bract first and 50% petal drop, and turning yellow.

Locations by date interactions were found at all growth stages except blooming 50 % and bract first stages (Table 1). The location by hybrid and date by hybrid interactions occurred until head 50 % stage, and these two-way interactions were not found at later stages except at stem first stage. The main effects of location and hybrid on HU accumulations were found at all stages as also found for day accumulations (Table 1). The HU required reaching comparable stages of maturity varied greatly between the irrigated and dryland site. This is probably due to water stress differences.

Planting date had no influence at blooming and petal drop stages. In contrast to day accumulations, there were HU effects the location by date by hybrid (L*D*H) interaction at all stages except PM stage. The lack of genotype-by- environment interactions (L*D*H) in days from planting date and HU accumulations at PM stage indicated that determining PM in sunflower was influenced by mutual effects of these three main factors. Due to stem remaining green especially under irrigated location, the location by hybrid and date by hybrid interactions were not found at head 100 % (harvest maturity) and brown color stages of stem (Table 1). Similar results were found by Miller and Fick (1997).

The two and three way interactions for seed oil content indicated that oil concentration of hybrids was strongly influenced by environmental factors (Table 2). In addition to hybrid differences, environmental factors such as temperature, irrigation, drought and their interactions also influence oil content of sunflower (Connor and Hall, 1997). Similar to HU and day accumulations, location and hybrid main effects were found for all sampling dates for seed moisture and oil content (Table 2). No interaction effects were present; therefore, the pattern of seed moisture loss between early and late plantings in the two locations was similar.

Table 1. Mean square and level of significance of days and HU measured from planting date to different plant development stages.

SOURCE		Bloom 50%		Bloom 100%		Petal Drop		Turning Yellow		Bract First		Bract 50%		Head First		Bract 100%		Head 50%		Head 100%		Stem First		Stem 50%		Stem 100%	
	DF	Day	HU	Day	HU	Day	HU	Day	HU	Day	HU	Day	HU	Day	HU	Day	HU	Day	HU	Day	HU	Day	HU	Day	HU	Day	HU
Location (L)	1	**	**	**	**	**	**	**	*	**	NS	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
ERROR [R* (L)]	6	1.2	279	2.8	560	4.0	887	7.6	1331	13	2771	13	1740	6.1	614	19	1201	21	331	5.2	349	20	1123	20	1445	6.8	352
CV (%)		1.7	1.8	2.4	2.3	2.5	2.5	3.1	2.8	3.8	3.9	3.6	2.9	2.4	1.7	4.1	2.3	4.2	2.4	2.0	1.2	4.1	2.2	4.0	2.4	2.4	1.2
Date (D)	1	**	NS	**	NS	**	NS	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	NS	**	NS	.
L* D	1	**	**	**	NS	**	*	**	*	**	NS	**	*	**	**	**	**	*	*	.	.	.	.	.	.	.	.
ERROR [*(L*D)]	6	0.9	204	4.1	904	3.5	802	0.4	156	2.8	339	10	1713	2.5	254	3.9	327	1.9	383	5.1	260	1.0		12	986	.	.
CV (%)		1.5	1.5	2.9	2.9	2.3	2.4	0.7	1	1.8	1.3	3.1	2.9	1.6	1.1	1.8	1.2	1.3	1.3	2	1	0.9	0.4	3.1	2	.	2
Hybrid (H)	11	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
L* H	11	**	**	**	**	**	*	**	**	**	**	**	**	**	*	*	**	**	**	NS	NS	**	**	NS	NS	NS	NS
D* H	11	**	**	**	**	**	**	*	**	**	**	*	**	NS	**	**	**	NS	**	NS	NS	NS	NS	NS	NS	NS	NS
L*D*H	11	*	**	NS	**	**	**	**	**	NS	*	NS	**	NS	NS	NS	NS	.	.	.	.	.	.		.	.	.
ERROR	132	0.6	130	1.0	232	0.8	312	1.3	236	1.9	415	2.6	300	2.8	285	3.2	235	4.4	392	2.1	158	2.2	156	3.4	255	2.5	141
CV (%)		1,2	1,2	1,4	1,5	1,1	1,5	1,1	1,2	1,5	1,5	1,6	1,2	1,7	1,2	1,7	1	2	1,3	1,3		1,3	0,8	1,7	1	1,5	0,8

* and ** significant at 0.05, and 0.01 levels. DF= Degree of Freedom, NS: Non significant.

Table 2. Mean square and level of significance of seed moisture and oil content measured at different sampling dates until PM stage.

SOURCE	DF	Moist1	Moist2	Moist3	Moist 4	Oil 1	Oil 2	Oil 3	Oil 4
Location(L)	1	1064**	828**	3807**	.	5812**	162**	258**	.
ERROR [Reps*(L)]	6	29	9	48	4	8	4	11	6
CV (%)		7.7	5.7	17	6.3	8.3	4.5	7.2	5.3
Date(D)	1	8321**	7951**	79NS	72*	6552**	168**	100**	8 NS
L * D	1	963**	30NS	1205**	.	946**	266**	9 NS	.
ERROR [Reps*(L*D)]	6	67	20	15	6	24	9	3	1
CV (%)		1.2	8.4	9.7	7.7	14	6.8	3.8	2.2
Hybrid(H)	11	699**	782**	1157**	563**	336**	43**	42**	22**
L *H	11	25NS	16NS	48*	.	175**	67**	35**	.
Date* H	11	30NS	22NS	77**	50*	89**	26NS	17*	15NS
L* D * H	11	13NS	39**	19NS	.	49NS	22*	19**	.
Error C	132	19	18	24	22	27	12	8	8
CV (%)		6.2	8.1	12.3	14.7	15.4	7.7	6.1	6.3

Day and HU summations

Hybrids usually reached flowering at 62 to 70 days after planting (DAP), last anthesis stage (blooming 100 %) averaged 67 to 76 DAP and petal drop stage was 77 to 86 DAP. The day accumulations data showed that there were usually average 7-10 days between all development stages from flowering to harvest maturity (Table 3).

Due to presence of stay green character, stems of some hybrids especially in the earlyirrigated site did not dry down. Similar results were found by Miller and Fick (1997). Also later maturing hybrids especially at late planting dates, did not reach harvest maturity until after the last time which data were collected. Therefore, the DAP averages at head 50 %, stem first, stem 50 % and stem 100 % stages in Table 3 are only for early maturing hybrids.

The range among hybrids in days to PM stage over locations was 28 days (Table 3). Some hybrids changed in rank with other hybrids as maturity stages progressed. This indicated that days from planting date to PM are more appropriate than days from planting to flowering to measure or compare maturity among sunflower hybrids. Under irrigated conditions, most of the hybrids were influenced by planting date in days to PM. This is probably due to drought stress hiding hybrid differences. Earlier maturing hybrids with early planting had less difference in DAP than at late planting. There was an 11 days difference in the days from planting date to PM between early planting dates, 3 days difference between the late planting date in locations and 11 days between the average of locations at PM stage. These results showed that PM was mainly affected by location and early planting based on day accumulations.

HU accumulations showed that the difference among development stages was 60 to 160 HU (Table 3). The range among hybrids from planting date to PM stage over locations was 268 heat units. Differences between planting dates and locations were found for both day and HU accumulations. Hybrids needed more HU between blooming 100 % to petal drop and petal drop to turning yellow stages than other stages. The reason is probably at the beginning of this drying period that sunflower plants needed more heat than at other stages. Hybrids were more uniform in HU summations and hybrid HU accumulation in the dry land site ranged from 1350 to 1550. The reason for small range was that hybrids dried very quickly due to high temperature and drought stress. Hybrids at the irrigation site were affected by change of planting date and day length more than those at the dry land site.

Table 3. Days and HU of hybrids from planting date to different stages at overall locations.

GROWTH STAGES	OBS	DAYS				HEAT UNITS			
		MEAN	SD	MIN	MAX	MEAN	SD	MIN	MAX
EMERGENCE	192	10	1,1	8	12	126	20	96	147
BLOOMING 50%	192	65	3,9	57	74	951	49	841	1042
BLOOMING 100%	192	71	4,2	63	81	1033	51	934	1135
PETAL DROP	192	81	4,8	71	92	1193	56	1065	1312
TURNING YELLOW	192	90	6,0	79	103	1309	64	1208	1442
BRACT FIRST	192	94	5,7	81	105	1364	53	1237	1515
BRACT 50%	192	101	7,3	88	121	1451	71	1340	1672
BRACT 100%	151	108	10,1	92	128	1522	104	1377	1709
PHY. MATURITY	192	109	7,2	89	117	1450	68	1352	1620
HEAD 50%	124	108	11,4	93	129	1530	114	1383	1709
HEAD 100%	119	115	12,5	94	134	1592	119	1384	1768
STEM FIRST	120	110	13,3	93	130	1549	128	1383	1731
STEM 50%	92	111	12,4	95	134	1566	113	1387	1768
STEM 100%	45	109	6,8	98	131	1548	63	1408	1739

Seed Moisture and Oil Content

According to the literature, seed moisture content was 30 % (Browne, 1978) 30 to 35 % (Anfinrud, 1997) and 40% (Anderson, 1975) at PM in the sunflower. Most of the hybrids, except some late maturing hybrids, reached these seed moisture content (300 to 400 g / kg) at the second sampling date at 93 DAP for early and late planting in dryland, after the third sampling date at 97 to 104 DAP for early and late planting in irrigated locations (Table 4 and 5).

Table 4. Seed moisture (MC) and oil content (OC) (g/kg) of hybrids at Scottsbluff.

HYBRID	EARLY PLANTING								LATE PLANTING							
	08-12		08-21		08-31		09-06		0 9-06		09-14		09-20		09-25	
	MC	OC	MC	OC	MC	OC	MC	OC	MC	OC	MC	OC	MC	OC	MC	OC
HYS-311	670	320	523	453	388	525	208	471	600	406	423	463	320	470	210	469
IS-7000	673	324	500	469	380	488	193	474	615	420	445	460	368	475	255	465
IS-6111	698	376	495	439	420	480	218	456	613	376	460	423	343	421	260	425
P-6230	735	284	545	458	423	510	245	486	588	433	428	469	355	458	265	450
NK-231	750	208	560	390	348	438	230	417	605	336	478	399	408	468	268	456
SF-270	738	277	558	456	418	485	419	470	610	428	425	459	353	458	263	450
DK-3868	813	111	653	419	505	526	363	494	678	408	485	461	415	454	273	458
MY-980	820	116	690	359	568	495	420	487	760	350	523	459	443	486	375	471
P-6451	828	117	658	379	525	476	398	453	778	357	523	483	465	491	370	497
C-187	838	131	693	362	530	457	428	442	780	304	545	432	488	453	408	449
T-571	835	92	720	369	578	459	458	471	785	298	558	478	468	500	378	486
K-8806	850	75	710	330	585	454	445	450	793	249	558	404	495	433	395	425
MEAN	760	198	617	392	487	490	327	461	697	328	491	434	408	452	303	447
ST DV	127	173	132	87	139	50	168	15	136	111	95	42	124	26	131	31

These results showed that seed moisture content confirmed accuracy of visual color observations. Sunflower hybrids in our experiment usually reached PM at 300 to 400 g /kg seed moisture (30 to 40 %) and one month after blooming 100 % (last anthesis). As previously were reported by Browne (1978). There were no differences among hybrids in the early group and among hybrids in the late group.

Similar results to seed moisture content were obtained from oil content analysis. Hybrids usually reached maximum oil content at the same date as PM for hybrids at each location (Table 4 and 5). Hybrids usually reached maximum seed oil content at second sampling date at Sidney, but reached at third sampling date in Scottsbluff (Table 4). However, due to unknown reasons, some hybrids decreased in oil content after they reached their maximum level, at last sampling dates especially at the dry land location. Although oil data support the results days and HU from planting date to PM, these data cannot be a characteristic largely to determine PM due to high cost and labor for collecting data and oil content analysis.

Table 5. Seed moisture (MC) and oil content (OC) (g / kg) of hybrids at Sidney.

HYBRID	EARLY PLANTING						LATE PLANTING					
	08-30		09-07		09-13		09-13		09-20		09-25	
	MC	OC	MC	OC	MC	OC	MC	OC	MC	OC	MC	OC
HS-311	718	363	503	444	253	435	540	422	330	427	250	435
IS-7000	710	331	510	410	155	394	545	429	350	396	278	410
IS-6111	735	385	508	435	243	436	533	432	340	441	285	455
P-6230	675	420	495	457	245	459	525	444	353	438	303	445
NK-231	740	380	493	438	220	415	543	443	410	443	313	423
SF-270	740	384	565	443	240	426	535	441	428	452	343	443
DK3868	795	356	575	460	343	474	593	441	478	441	398	438
M-980	813	330	650	445	465	481	628	420	488	455	443	344
P-6451	810	346	638	475	438	482	673	451	513	473	458	481
C-187	808	319	655	420	478	460	620	413	500	446	463	443
T-571	835	329	635	480	453	506	680	418	553	486	470	473
K-8806	840	340	673	469	473	491	688	400	513	435	450	444
MEAN	779	352	588	457	363	463	614	411	422	431	350	440
ST DV	86	16	120	18	156	40	105	16	129	6	141	6

Correlation Analysis

Correlation studies showed that it was possible to predict PM from earlier development stages especially using day summation data (Table 6). Similar correlations between days to PM and early growth stages were reported by Miller and Fick (1997) and between number of HU to PM and early stages were reported by Zimmerman and Zimmer (1978). Higher positive correlations were found between PM and early stages at the dryland site than in the irrigated site. Sunflower PM was more poorly correlated with earlier development stages (blooming, and petal drop) using HU than day accumulations.

Table 6. Correlation coefficients between PM and different growth stages.

VARIABLES	HU accumulation (R^2)			Days to maturity (R^2)		
	Overall	Dryland	Irrigated	Overall	Dryland	Irrigated
PM * BLOOM 50 %	0.34**	0.77**	0.42**	0.77**	0.83**	0.89**
PM * BLOOM100 %	0.50**	0.75**	0.60**	0.80**	0.81**	0.89**
PM * PETAL DROP	0.41**	0.84**	0.5**	0.79**	0.80**	0.90 **
PM * T.YELLOW	0.67**	0.86**	0.77**	0.9**	0.92**	0.95**
PM * BRACT FIRST	0.76**	0.86**	0.76**	0.93**	0.92**	0.94**
PM * BRACT 50 %	0.94**	0.97**	0.92**	0.97**	0.96**	0.95**
PM * BRACT 100 %	0.88**	0.91**	0.86**	0.95**	0.91**	0.93**
PM * HEAD 50 %	0.88**	0.91**	0.76**	0.96**	0.93**	0.83**
PM* HEAD100%(HM)	0.79**	0.66**	0.87**	0.93**	0.78**	0.86**
PM * STEM FIRST	0.82**	0.91**	0.66**	0.94**	0.92**	0.77**
PM * STEM 50 %	0.66**	0.75**	0.18 ns	0.89**	0.89**	0.21 ns
PM * STEM 100 %	0.58**	0.65**	-0.27 ns	0.86**	0.89**	-0.19 ns

*, ** refer to 0.05, 0.01 ns= non significant HM=Harvest maturity; PM=Physiological Maturity

There was a highly negative correlation between moisture and oil content at early dates and a less negative relationship later as oil content reached maximum and seed moisture loss slowed (Table 7). In contrast, there was a highly positive correlation among moisture sampling dates. Correlation results among sampling dates in the irrigated site was more consistent than the dryland site due to reduced temperature at the late dates and less drought stress.

Both HU and day correlation results showed that physiological maturity was positively correlated with seed moisture content (Table 7). In contrast, there was a highly negative correlation between PM and oil content at the first two sampling dates. Both correlations reflect maturity level on a given sampling date. Similar strongly negative correlation between PM and oil content in sunflower was reported by Qaizar et al. (1991). Sunflower PM was less or not correlated with oil content at the last two sampling dates due to hybrids reaching maximum oil content. There was also a highly linear relationship between HU and day accumulations at PM (r^2= 0.90, y = 552.94 + 8.9 x, where y= heat units, x = day summations).

Visual Evaluation

The easiest and most inexpensive way to observe and evaluate maturity in sunflower is from visual characteristics. Due to heliotropism, causing sunflower head to turn toward the sun usually in east-northeast direction during the day, planted rows should be in north-south direction for easy face and back of head observations in experimental plots (Anfinrud, 1997). Visual characteristics most commonly are used 50 % brown color at bract (Robinson, 1971, Robinson, 1983; Johnson and Jellum, 1972) and first (1-10 %) brown color at back of head (Anderson, 1975; Schneiter and Miller, 1981). Bract color observations could be observed looking at the front of sunflower heads. In contrast, head color observations could be observed by looking at the back of sunflower heads. Head first (1-10 %) observation was easier than bract 50 % brown color, because it was possible to look at back of heads faster and more accurately than looking at bract 50% color.

Table 7. Correlation coefficients between seed moisture and oil content.

VARIABLES	DRYLAND(R^2)	IRRIGATED(R^2)	OVERALL (R^2)
MOIST-1 * OIL-1	-0.72**	-0.77**	-0.69**
MOIST-2 * OIL-2	0.35**	-0.67**	-0.27**
MOIST-3 * OIL-3	0.62**	0.09 ns	0.46**
MOIST-4 * OIL-4	---	0.12 ns	0.12 ns
MOIST-1*MOIST-2	0.87**	0.77**	0.83**
MOIST-1*MOIST-3	0.29**	0.73**	0.51**
MOIST-1*MOIST-4	---	0.69**	0.69**
MOIST-2*MOIST-3	0.53**	0.80**	0.65**
		HEAT UNIT(R^2)	DAY (R^2)
MOIST-1 * PM		0.8**	0.67**
MOIST-2 * PM		0.8**	0.75**
MOIST-3 * PM		0.78**	0.78**
MOIST-4 * PM		0.64**	0.59**
MOIST-1*T. YELLOW		0.54**	0.57**
MOIST-1*BRACT 50%		0.73**	0.69**
MOIST-2*BRACT 50%		0.81**	0.76**
OIL -1 * PM		-0.75**	-0.80**
OIL -2 * PM		-0.35**	-0.37**
OIL -3 * PM		0.38**	0.36**
OIL -4 * PM		0.06 ns	0.09 ns

* ,** indicate significance level at 0.05, and 0.01, ns= non significant Moist-1= First seed moisture sampling date, Oil-1= First seed oil sampling date.

Seed moisture and oil content are more difficult and costly methods than visual determination of PM in sunflower due to labor required to take seed samples periodically. However, the value of moisture content, or maximum dry weight, oil and linoleic acid content would be to assure accuracy of the visual method. To protect loss of seed moisture from samples while removing seeds from the sunflower head, researchers should be fast and practical. Also, to get more accurate results, seed samples should be weighed with sensitive scales and collected at least every third day. Seed oil content is less expensive to measure than linoleic content and can use the seed moisture content sample for oil content analysis. However, a large seed sample should be taken when sampling, which could lead to greater seed moisture loss due to extra time needed for sampling.

Conclusions

The easiest and cheapest way to determine PM is visual color observations of the sunflower head. Head first stage (1-10 % brown color), when the back of the head starts to turn from yellow to brown, as described by Schneiter and Miller (1981), is a more practical and accurate visual observation than observations at other growth stages to identify PM. Most sunflower breeders and producers prefer this system to evaluate PM in experiments and fields (Blamey et al., 1997).

Seed moisture and maximum seed oil content could be used to provide more accuracy than visual determination of PM. However, these two parameters are more expensive and require more labor for sampling. Also, they need more practical and fast work during seed sampling due to loss of moisture from sunflower seeds. Using visual observation combined with seed moisture content or maximum seed oil content could be the most accurate way to determine sunflower PM.

Location by hybrid and location by planting date interactions at PM were evidence that the variability of hybrids and planting date depended on the site. The main effects of location, planting date and hybrids were found highly significant for both day and HU accumulations at PM and at all moisture and oil content sampling dates. The lack of planting date by hybrid interaction in day accumulations showed that temperature was the main environmental factor for determining of PM in sunflower. Consequently, genotype by environment interaction (L*D*H) was not found in both data sets at PM. The lack of genotype by hybrid interaction presented a convenient advantage to detect maturity differences among hybrids.

Hybrids reached flowering at an average of 62 to 70 days after planting date (DAP) and reached PM at 96 to 107 DAP. Consequently, hybrids reached flowering at 900 to 1000 HU and reached PM at an average of 1400 to 1510 HU after planting date. Seed moisture content of hybrids at PM were approximately 30 to 40 %, and maximum seed oil content occurred at this time. Later maturing hybrids at late plantings in both irrigated and dryland site could not accumulate enough HU to reach harvest maturity (about 1600 heat units) until after two week first average fall frost date when the last data collected. There was more variation in HU accumulation than days in different growth stages over location.

Sunflower PM was correlated with earlier growth stages with both HU and day accumulations, thus PM can be predicted at earlier growth stages. Blooming 50 % stage was the earliest plant growth stage to accurately predict PM especially using day summations data.

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