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Maize Photosynthesis and Productivity in Relation to Sowing Time in a Mediterranean Environment, Çukurova

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Abstract: Under Mediterranean conditions, maize *Zea mays* L.) grain yield is generally reduced by delayed sowing. Pioneer 31G98 was grown as early and late crop to evaluate the grain yield relations with agronomic and physiological differences between two sowing time in the Seyhan Plain in Çukurova, Turkey, which represents agroclimatic conditions, typical of those prevailing in the Mediterranean region. Maximum values for Leaf Area Index (LAI) and leaf net photosynthesis (A_n) did not differ between two sowing dates. The duration of LAI, A_n and Dry Matter (DM) accumulation decreased considerably when sowing took place late. There was a consistent decrease in the Intercepted Photosynthetically Active Radiation (IPAR) in the late sowing crop, compared with the early crop. Biomass and grain yield were significantly decreased when maize was grown as a late crop. Grain yield decrease of the late crop was resulted in lower grain weight, possible due to lower total energy and lower IPAR during the grain growth. Number of grains of both crops were similar. Thus, higher radiation use efficiencies during the grain filling must be considered to overcome maize yield decreases in the late season and under changing climate in the future in Mediterranean environments.

Key words: Temperate cereal, cropping time, yield components, leaf area index, leaf net photosynthesis

INTRODUCTION

In Çukurova, which represents agroclimatic conditions, typical of those prevailing in the Mediterranean region, maize (*Zea mays* L.) is grown from April to October as first (early) and second (late) crop by using long- and short season maize hybrids, respectively. Due to longer growing period and favorable conditions of the early crop, higher grain yields are achieved for this crop than for the late crop, although agronomic measures are similar for both crops.

Both yield potential of hybrids and climatic conditions are likely to be involved in grain yield difference between early and late crop maize. The sowing date influenced the rate and duration of dry matter accumulation (and therefore grain yield) in different growth stages[1-3]. In maize, grain yield is determined by grain number and individual grain weight, which were affected by pre- and post-silking environmental conditions, respectively. Earlier studies with different sowing date showed that grain number was not affected by photoperiod[4], but was related to the amount of intercepted PAR during the grain set[5]. On the other hand, delays in sowing date reduced individual grain weight because of low daily incident radiation[6]. But, the understanding of morpho-physiological determinants of maize performance under the different conditions still needs improvement[6-8].

In this study it was tried to identify possible causes of yield differences between early and late crop maize in Çukurova, to contribute to the sustainability of late sowing crops yields. The relationships obtained in this study will help to explain the effects of environment and crop management on the yield variation not only in the present also in the future under changing global environments.

MATERIALS AND METHODS

Cultural practices: Field experiments were conducted at a private Farm (Özekici) in Seyhan Plain in Çukurova (36°46.905′N and 35°20.542′E, 6 m above sea level) near Adana, Turkey, maize growing season in 2003. The soil was coarse sandy clay, mixed montmorillonitic,

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Table 1: Biomass, grain yield, harvest index and grain yield components of early and late crop maize during 2003 growing season in Çukurova

	Biomass (g m^{-2})	Grain yield (g m^{-2})	Harvest index (%)	Grain weight (mg)	No. of grains (m^{-2})
Early crop	3817	1865	48.3	326	5720
Late crop	2982	1612	54.1	276	5840
Mean	3340	1739	51.2	301	5780
Change (%)	-%23	-%14	+%12	-%15	+%2
P-value	0.029	0.074	0.006	0.023	0.858
CV (%)	8.86	7.64	1.94	5.49	11.26

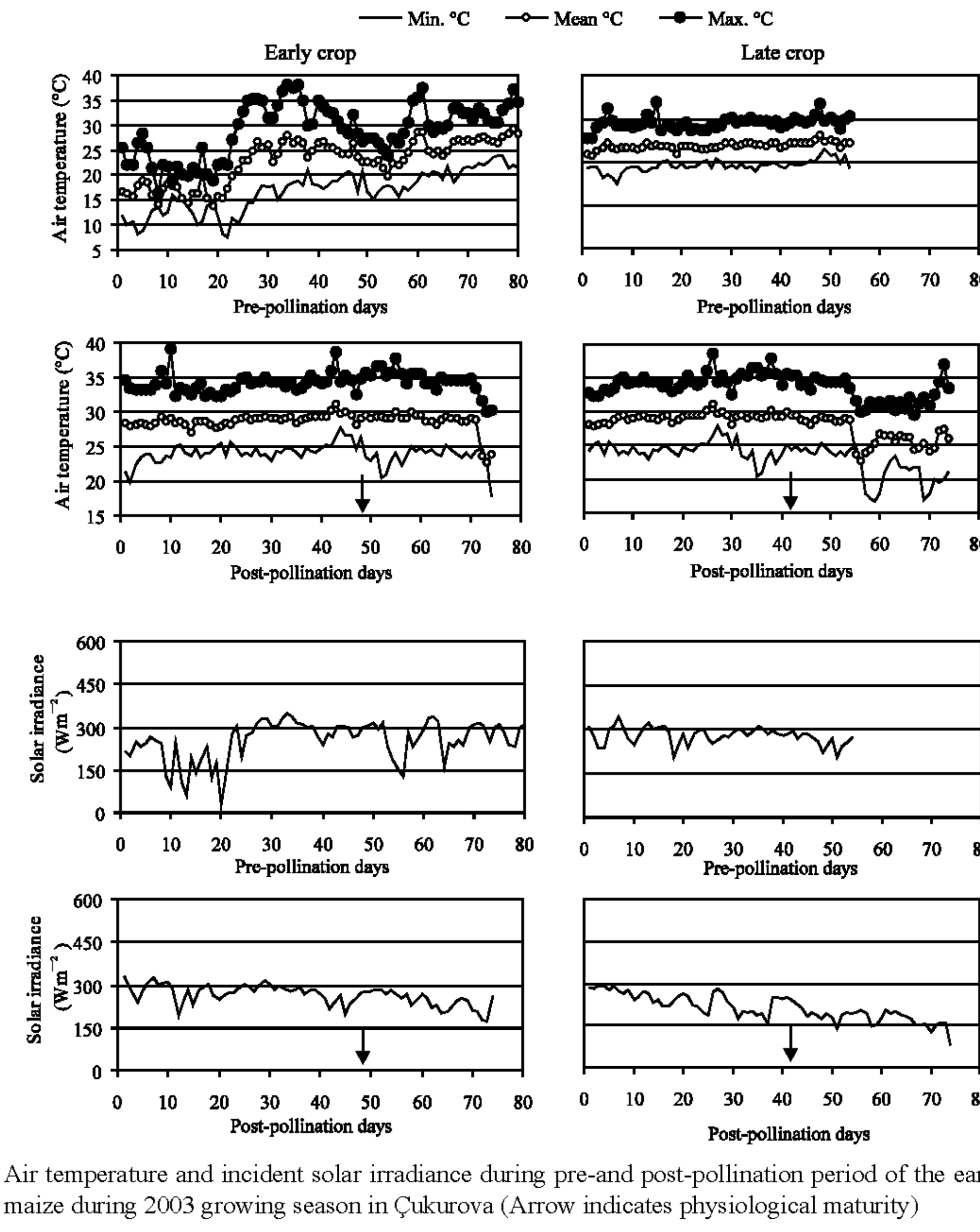

Fig. 1: Air temperature and incident solar irradiance during pre-and post-pollination period of the early and late crop maize during 2003 growing season in Çukurova (Arrow indicates physiological maturity)

thermic, Lithic Rhodoxeralf, low in organic matter and slightly alkaline. Previous crop was wheat (*Triticum aestivum* L.).

A well known high yielding single-cross Hybrid, Pioneer 31G98 was machine-planted on 06.04.2003 (Early sowing date, Early crop) and 19.06.2003 (Late sowing date, Late crop). Established plant population was 10 plants m^{-2}. In both sowing time maize was grown in large fields. The plots were arranged in completely randomized design with four replications. Each plot consisted of 14 rows, 0.7 m apart by 50 m length. The fields were fertilized at planting with 75 kg P ha^{-1}; 75 kg K ha^{-1} and 75 kg N ha^{-1} and at the seven leaf stage (stem elongation) with 225 kg N ha^{-1}.

Both, early and late crops were irrigated bi-weekly by furrow irrigation following the emergence. Weeds and insects were controlled with chemical agents.

Sampling procedures: Phenology, plant height, leaf area and dry matter were measured bi-weekly on 5-10 target plants. Plants were taken from the inner rows of each plot, starting at 5 m from the end of each plot and leaving 1-1.5 m between consecutive sampling.

At maturity, numbers of grains per ear and grain weight were determined on sampled ears and grain yield was calculated.

Measurements of leaf CO_2 exchange rates, leaf area and light interception: Photosynthetic leaf CO_2 exchange rates (A_n) measurements of both crops were made on the youngest fully expanded leaves in the period between four leaf stage and the onset of last leaf senescence. A_n of individual leaves were measured with a portable infrared gas-analyzer using an open system (LCA-3, Analytical Development Corp., Hoddeston, UK). Readings were taken with the leaf chamber (PLC-N) positioned relative to the sun to provide similar photosynthetic photon flux densities within each measurement date. Data were collected on clear days between 1000 and 1600 h. For each measurement, a leaf was placed across the leaf chamber, with the adaxial surface of the leaf facing up to sun to get 1500 μM m^{-2} sec^{-1} Photosynthetic Active Radiation (PAR). Area of green leaves was measured with an area meter (Li-3100, Li-Cor, USA). Leaf Area Index (LAI) was calculated. Interception of the Photosynthetic Active Radiation (IPAR) in the canopy was measured during the development with a portable PAR measurement system (SunScan Canopy Analysis System, Delta-T, Devices, Cambridge, England).

Data analysis: Data collected fully randomized within a sampling or measurement date were subjected to separate or combined analysis for the sowing date was performed using the Minitab program[9]. Exponential models were calculated between changes of investigated traits and time (x, days).

RESULTS

Growing conditions: Experiments were carried out under well irrigated conditions with similar fertiliser supplies. Weather conditions differed markedly between two crops

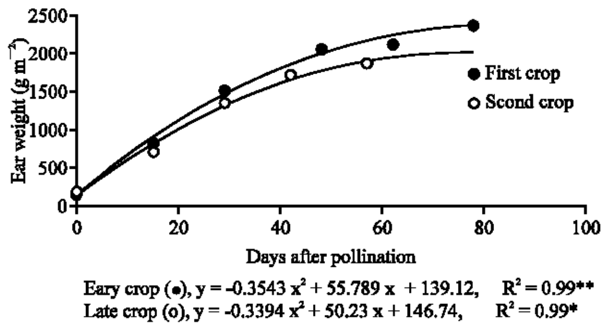

Fig. 2: Ear weight of the early and the late crop maize during 2003 growing season in Çukurova

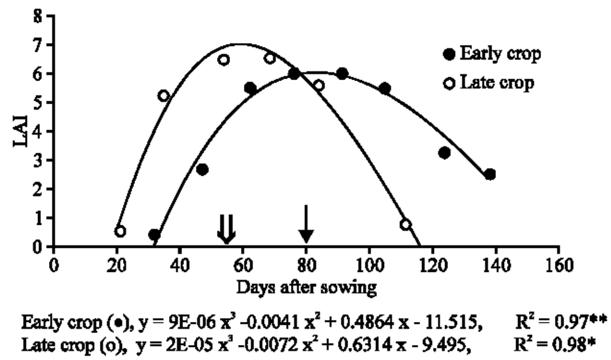

Fig. 3: Changes of leaf area index of early and late crop maize during 2003 growing season in Çukurova (Bold and light arrows indicate pollination of the early and late crop maize, respectively)

(Fig. 1). Late crop was characterized by higher temperatures during vegetative period and by lower incident solar radiation during effective grain filling.

Days from sowing to pollination differed substantially between two crops (80 and 54 days in early and late crop, respectively), but thermal times for this interval were more consistent. The lack of photoperiod response may be due to lack of sensitivity of the cultivar used. Physiological maturity was reached 48 and 42 days after silking in early and late crop, respectively.

Biomass, grain yield, harvest index and yield components: Biomass and grain yield in the early crop were 23 and 14% higher than that in the late crop, with values of 3817 and of 1865 kg ha^{-1}, respectively greater than in late crop (Table 1). Harvest index was increased from 48.3% in the early crop to 54.1% in the late crop. Number of grains per m^2 showed no significant difference between early and late crop. Number of grains averaged over crops was 5780 m^{-2}. Grain weight was reduced from

326 mg in the early crop to 276 mg in the late crop by a ratio of 15%, which is very similar to the grain yield reduction (Table 1).

Ear growth after pollination: Dry matter accumulation in the ears followed a different pattern in both crops (Fig. 2). Both the rate and duration of dry matter accumulation was smaller in the late crop than that in the early crop. As the number of grains per ear was not significantly different between two crops, these curves can be considered also as growth curves for the individual grains. Thus, both the rate and duration of grain growth was also smaller in the late crop than that in the early crop.

Changes of LAI, A_n and IPAR: Both, leaf area expansion and the onset of senescence accelerated in the late crop (Fig. 3). The rate of Leaf Area Index (LAI) expansion was 6.26 and 11.1 dm^2 day^{-1} in the early crop and in the late crop, respectively. Maximal LAI values around pollination of early crop (5.1) and late crop (6.5) differed not significantly. LAI in the early crop showed a longer duration than that in the late crop. Leaf area declined linearly with a rate in the late crop, approximately two times greater than that in the early crop.

At the earlier stages of development, there were no significant differences in A_n rates between early and late crop (Fig. 4). But after pollination, A_n of the crops followed different patterns of decline. Leaf net photosynthesis rate in late crop began to decline earlier and rapidly.

IPAR of the early and the late crop were similar at the beginning of the grain filling (Fig. 5). After that, canopy light interception of the late crop was consistently lower than that of the early crop.

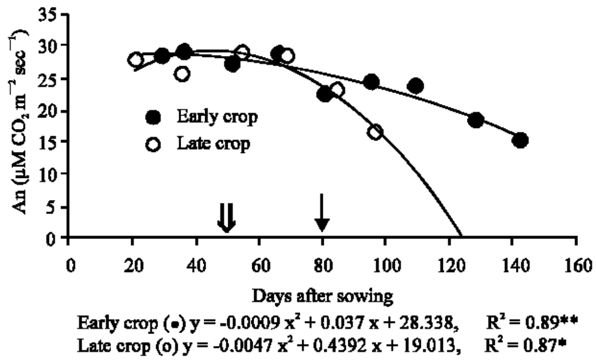

Fig. 4: Changes in leaf CO_2 exchange rates (A_n) of early and late crop maize during 2003 growing season in Çukurova (Bold and light arrows indicate pollination of the early and late crop maize, respectively)

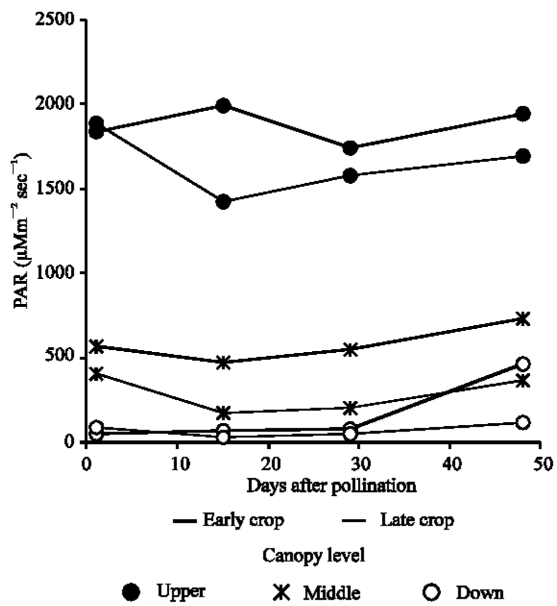

Fig. 5: Canopy light interception of early and late crop maize after pollination during 2003 growing season in Çukurova

DISCUSSION

As shown, reduced grain yield of the late crop was related to the lower grain weight obtained in this crop. Grain weight of maize is the result of grain growth during two stages of grain filling, the lag phase (formation of grain sink capacity) and the effective grain filling phase[10]. Environmental conditions may effect grain growth in each period. Numerous factors influence grain weight of maize. Grain sink capacity, the potential of grains to achieve maximal mass is established during early stages of grain development and is a function of endosperm cells and starch granules formed. However, whether the number of endosperm cells or starch granules is the more important determinant of mature grain mass is genotype dependent[11]. In this study, the same hybrid, Pioneer 31G98 was used in both crops. Early grain growth of both crops occurred under comparable environmental conditions such as temperatures and incident and attenuated light quantities. LAI and rate of leaf net photosynthesis of crops were also similar during this period. Thus a reduction of grain sink capacity seems not to be involved here.

As mentioned before, both the rate and duration of effective grain growth was smaller in the late crop that in the early crop. Rapid decreases in leaf net photosynthesis rate and in leaf area may have reduce grain growth, through limited supply of assimilate per grain (grain number differed not significantly). Losses of straw dry weight observed only in the late crop (data not shown) supports this suggestion. Source limitation is repeatedly reported for late sown maize in temperate regions[6,10,12]. Accelerated senescence in the late crop may have been effected by lower light energy supplies during the grain filling, which can cause the remobilization of photo-assimilates and nitrogen to sustain grain growth. Leaf area duration in maize has always been shown to depend on source/sink ratio[8,13,14].

In summary, late crop maize yield appears to be source limited, which restricts final grain weight. Unfavorable radiative conditions seem to be involved in reducing grain weight, hence grain yield. The implication of these results for the future maize yields is very important, if we take expected changes in solar energy into consideration. A reduction of solar radiation reaching the Earth's surface have occurred already during past 5 decades[15]. Further research is needed to increase radiation use efficiencies during the grain filling to overcome maize yield decreases in the late season and in the future in Mediterranean environments.

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REFERENCES

1. Berzsenyi, Z., A.Y. Ragab and D.Q. Lap, 1998. Effect of sowing date on the dynamics of reproductive growth and the grain yield components of maize hybrids. Novenytermeles, 47: 423-437.
2. Mudrik, V.A., P. Stoyanov and B.N. Ivanov, 2000. Evaluation of maize productivity considering solar energy use limitation by environmental factors. Photosynthesis Res., 66: 177-187.
3. Linquist, J.L., T.J. Arkebauer, D.T. Walters, K.G. Cassman and A. Dobermann, 2005. Maize radiation use efficiency under optimal growth conditions. Agron. J., 97: 72-78.
4. Tollenaar, M., 1999. Duration of the grain-filling period in maize is not affected by photoperiod and incident PPFD during the vegetative phase. Field Crop Res., 62: 15-21.
5. Otegui, M.E. and R. Bonhomme, 1998. Grain yield components in maize.I: Ear growth and kernel set. Field Crops Res., 56: 247-256.
6. Cirilo, A.G. and F.H. Andrade, 1996. Sowing date and kernel weight in maize. Crop Sci., 36: 325-330.
7. Cirilo, A.G. and F.H. Andrade, 1994. Sowing date and maize productivity: I. Crop growth and dry matter partitioning. Crop Sci., 34: 1039-1043.
8. Rajcan, I. and M. Tollenaar, 1999. Source:sink ratio and leaf senescence in maize. I. Dry matter accumulation and partitioning during grain filling. Field Crops Res., 60: 245-253.
9. Minitab, 1995. Minitab for Windows Release 10.51 Xtra, 1995. Statistical software. Minitab Inc., State College. USA.
10. Maddonni, G.A., M.E. Otegui and R. Bonhomme, 1998. Grain yield components in maize II. Postsilking growth and kernel weight. Field Crops Res., 56: 257-264.
11. Jones, R.J. and B.M.N. Schreiber and J.A. Roessler, 1996. Kernel sink capacity in maize: Genotypic and maternal regulation. Crop Sci., 36: 301-306.
12. Ruget, F., 1993. Contribution of storage reserves during grain filling of maize in northern European conditions. Maydica, 38: 51-59.
13. Rajcan, I. and M. Tollenaar, 1999. Source: Sink ratio and leaf senescence in maize. II. Nitrogen metabolism during grain filling. Field Crops Res., 60: 255-265.
14. Sadras, V.O., L. Echarte and F. Andrade, 2000. Profile of leaf senescence during reproductive growth of sunflower and maize. Ann. Bot., 85: 187-195.
15. Stanhill, G. and S. Cohen, 2001. Global dimming: A review of the evidence for a widespread and significant reduction in global radiation with discussion of its probable causes and possible agricultural consequences. Agric. For. Meteor., 107: 255-278.