MAIZE HYBRID YIELD AND WATER USE EFFICIENCY UNDER LIMITED RAINFALL

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INTRODUCTION

Chaoui and Abda are two plains of the semi-arid areas of Morocco. Average rainfall per year is below 400 mm. The wet period is usually December through February. During March and April, rainfall is scarce and spring crops are usually dependent on stored soil moisture while exposed to high temperatures and soil moisture deficit during the reproductive period. In these areas farmers grow corn for different reasons : 1) It is a good preceeding crop for wheat (weeds, insects and disease control). 2) It is used for grain and forage production. In fact plants are usually thinned at tasseling and fed to the livestock. The degree of thinning depends on the rainfall regime of winter and the beginning of spring. 3) No alternative crop is available. Sorghum was tried in experiments but did not succeed because of low temperatures during February (planting period of corn) and lack of rainfall during March (problem of emergence). One way of improving yields in these areas is the use of drought resistant plants that can

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avoid drought because of their deep rooting systems, their capacity for controlling transpiration loss, or can escape drought because of their short life cycle. Drought-tolerance refers to the ability of plant tissues to withstand water loss. Lowering of osmotic potential, which is termed osmoregulation or osmotic adjustment, is a physiological mechanism that enables plants to tolerate water stress (Clarke and Durley, 1981). Loomis (1983) postulated that little was to be gained from research aimed at increasing the tolerance of crop species to drought because a doubling of the limiting soil water potentials to which plants were tolerant, for example, would add little to seasonal moisture supplies. So unless tolerance included an improved water use efficiency, little was gained in terms of production`. Variation in growth duration is one of the most obvious means for matching seasonal transpiration to moisture supply. Laing and Fisher (1977) suggested that early maturing varieties rarely had a strong advantage in yield. However, Loomis (1983) proposed that the choice of early varieties would assure a low risk and high efficiency for water actually used by the crop. Moreover, Waldren (1983) reported that early-maturing corn hybrids were more efficient in using water for grain production while the later-maturing ones used water more efficiently for forage production.

The objective of this study was to determine if early corn hybrids can improve the probability for obtaining yield during dry years and insure high yields during wet cropping seasons.

MATERIALS AND METHODS

Experiments were conducted at Sidi El Aydi and Jemaa Shaim experiment stations located in the Chaouia and Abda plains (Morocco), respectively. The planting periods were early February in 1985 and 1986. The soil type of these stations is an alkaline vertisol. The mean annual precipitation is 388 mm at Sidi EL Aydi and 318 mm at Jemaa Shaim.

Treatments consisted of seven hybrids: H1=DRA 400 (Late); H2=TX21 (late);H3=HT 308 (late); H4=PAG SX111 (medium); H5=Funks 4065 (medium); H6 = Pioneer 3969 (early); and H7 = Pioneer 3994 (early). Maturity classification was based in this study on the heat units which is a more reliable critertion than the number of days.

Plant population was 40,000 plants/ha. Plants were sown at 3 plants/hill and thinned to 1 per hill at 4 leaf stage. The distance between the rows was 0.75 m. Data collected were total dry matter, leaf area using the leaf area meter and grain

yields. Midday leaf water potential was monitored with the pressure bomb. Leaf diffusive resistance and leaf transpiration were measured with the steady state porometer (Licor 1600). Neutron probe was used for soil moisture measurements and water use was calculated using the water balance equation. Run off and drainage were neglected. The soil depth chosen for these measurements was 120cm.

RESULTATS AND DISCUSSION

Water Status

Table 1 shows total water used by different hybrids tested. In 1985, late hybrid (H1, H2, and H3) tended to use more water than the earlier ones. The earliest variety, H6 used less water than all other genotypes at Sidi El Aydi in 1985 and 1986. No difference among hybrids was registered in 1986 at Jamaa Shaim. The early hybrids, especially H6, kept their leaf diffusive resistance low (Fig. 1) and their leaf water potential high (Fig.2) in 1985. During all their reproductive periods, leaf water potentials were higher than the critical value (-1.8 to -2.0 MPa) suggested by Boyer (1970) and by this study. This threshold value corresponds to leaf diffusive resistance of 4 Scm^{-1} and probably to the beginning of stomatal closure (Fig. 3). Consequently,photosynthesis of these hybrids was probably not affected. In the case of the other hybrids (late and medium), leaf water potentials decreased and leaf diffusive resistance increased drastically after anthesis.

Growth and development

Development: The hybrids studied have different growth cycle lengths. H1, H2, and H3 are relatively late; H6 and H7 are early and H4 and H5 are medium in maturity. The first, second, and third classes reached physiological maturity between 3-5 July, 13-23 June, and 29 June - 1 July, respectively. The heat units received from planting to physiological maturity were 952 to 1049; 1120 to 1141; and 1158 to 1176 for early, medium, and late hybrids, respectively. Yields: Grain yield, above-ground yield, and harvest index are presented in tables 2,3, and 4, respectively. Statictical analyses show that grain yields were affected by the hybrids. During a wet cropping season (1985), the highest grain yields were produced by H3, H4, H6, and then H1. So, there was no tendency of a maturing class to have higher yields than others during a west season. However, in 1986 (dry year), the late varieties gave the lowest yield. However, the medium and early hybrids partially escaped drought. These hybrids are

Table I : **Total water used from emergence to physiological maturity at Sidi El Aydi (SEA) and Jemaa Shaim (JS) in 1985 and 1986.**

Hybrid	Cropping Season and Location		
	SEA 85	SEA 86 Total water cm	JS 86
H1 - DRA 400	15.63	14.32	----
H2 - TX 21	17.18	14.36	17.49
H3 - HT 308	16.42	13.31	17.23
H4 - PAG SX111	15.89	13.32	16.14
H5 - Funks 4065	14.89	15.43	18.16
H6 - P. 3969	15.01	12.60	17.24
H7 - P. 3994	15.27	14.34	17.06
LSD (0.05)	2.38	1.37	n.s.
LSD (0.01)	3.24	1.89	--
CV (%)	10.54	5.69	12.54

Table II : **Grain yield at Sidi El Aydi (SEA) and Jemaa Shaim (JS)) IN 1985 and 1986.**

Hybrid	Cropping Season and Location		
	SEA 85	SEA 86 Qx / ha	JS 86
H1 - DRA 400	25.16	2.89	4.31
H2 - TX 21	22.45	2.16	9.52
H3 - HT 308	26.87	3.25	5.75
H4 - PAG SX111	26.75	5.67	7.72
H5 - Funks 4065	23.41	6.38	10.67
H6 - P. 3969	26.48	6.48	10.87
H7 - P. 3994	24.15	6.27	12.32
LSD (0.05)	3.81	2.41	3.67
LSD (0.01)	5.18	3.33	5.06
CV (%)	10.58	16.01	14.03

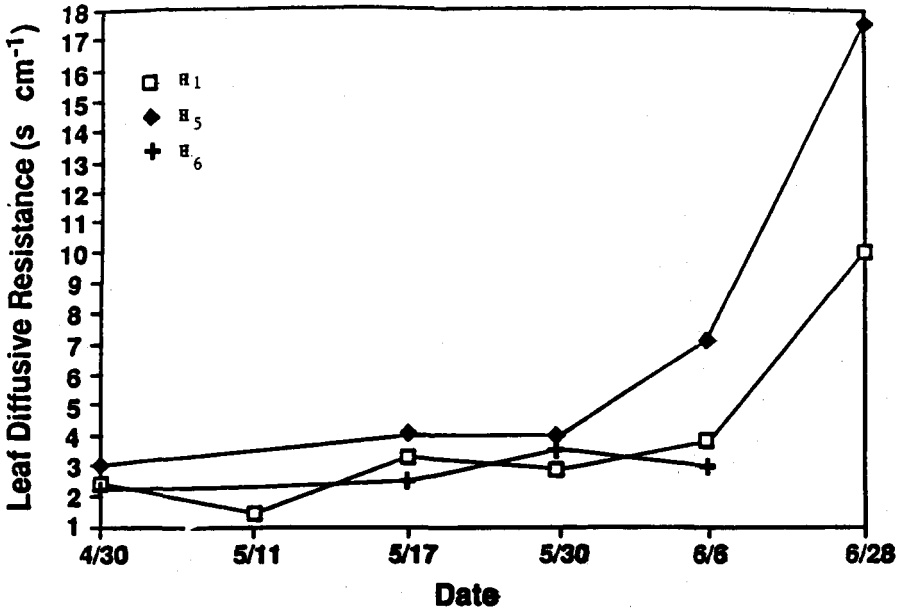

Fig. 1 : Leaf diffusive resistance versus time for H1, H5 and H6

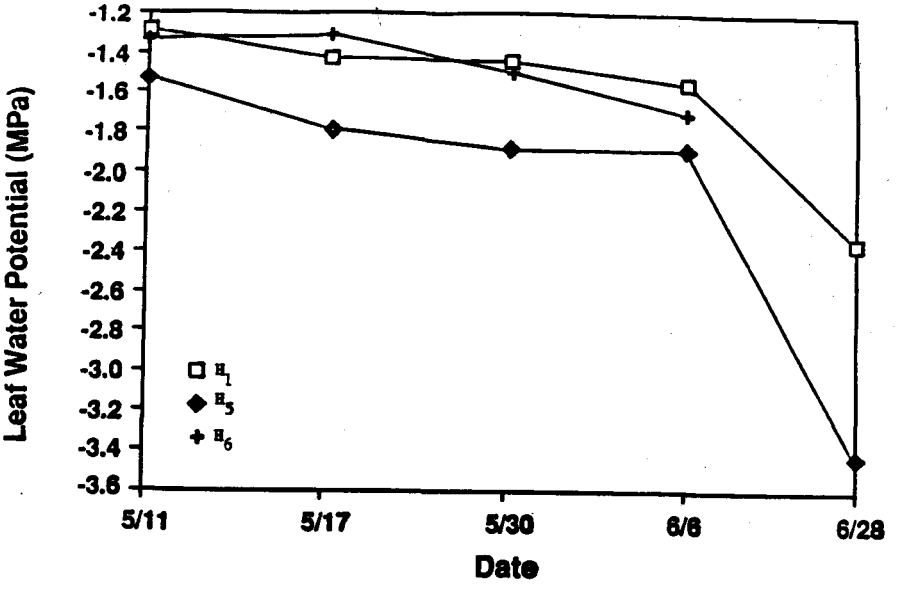

Fig. 2 : Leaf water potential versus time for H1, H5 and H6

promising because they can yield well during a wet year and insure some yield during a dry year.

Aboveground yield tended to be high in the case of the latest hybrids, especially at Sidi El Aydi in 1985 and at Jemaa Shaim in 1986. However, the highest harvest indices were given by the early and medium hybrids. These hybrids were more efficient in accumulating dry matter in kernels than in the other parts of plants (Waldren, 1983).

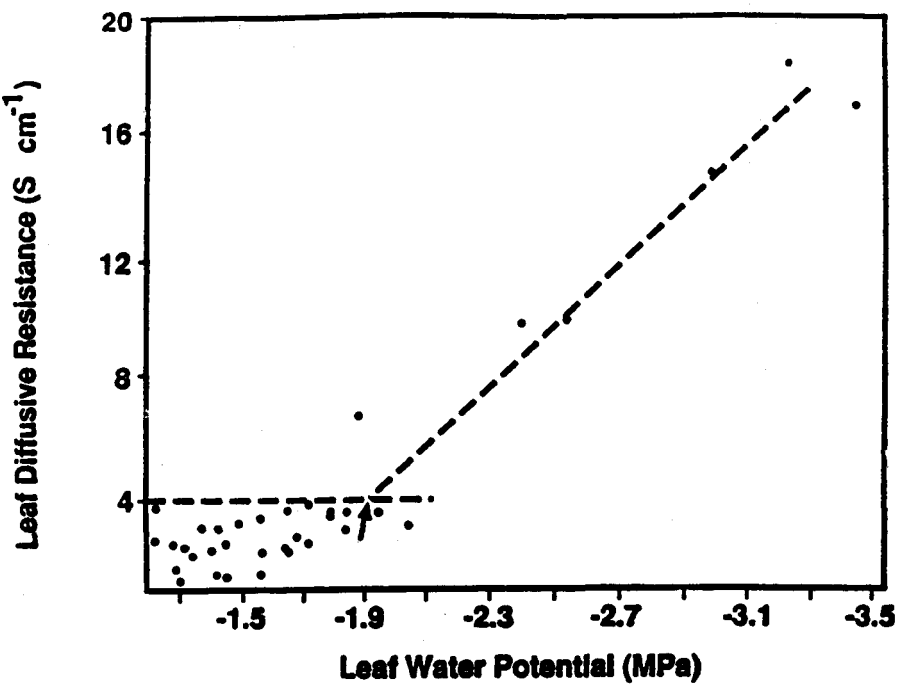

Fig. 3 : **Relationship between leaf diffusive resistance and leaf water potential (stomatal closure)**

Table III : **Aboveground yield at Sidi El Aydi (SEA) and Jemaa Shaim (JS), Morocco in 1985 and 1986.**

Hybrid	Cropping Season and Location		
	SEA 85	SEA 86 Qx / ha	JS 86 (1 Rep)
H1 - DRA 400	63.20	23.78	45.05
H2 - T x 21	58.65	26.80	50.61
H3 - HT 308	70.36	22.78	47.61
H4 - PAG S x 111	59.51	20.55	48.00
H5 - Funks 4065	48.71	23.89	37.38
H6 - P. 3969	55.59	21.78	35.17
H7 - P. 3994	45.32	20.11	39.72
LSD (0.05)	10.56	n.s.	---
LSD (0.01)	14.38	---	---
CV (%)	13.10	12.97	---

Table IV : **Harvest index at Sidi El Aydi (SEA) and Jemaa Shaim (JS) in 1985 and 1986.**

Hybrid	Cropping Season and Location		
	SEA 85	SEA 86	JS 86 (1 Rep)
H1 - DRA 400	39.72	12.18	9.73
H2 - T x 21	38.31	8.06	18.90
H3 - HT 308	38.63	14.36	11.86
H4 - PAG S x 111	44.92	27.10	21.86
H5 - Funks 4065	48.32	26.20	28.44
H6 - P. 3969	47.99	29.69	30.33
H7 - P. 3994	53.43	31.18	31.40
LSD (0.05)	3.57	9.27	---
LSD (0.01)	4.86	12.77	---
CV (%)	5.30	13.00	---

Table V : **Leaf Area Index at Sidi El Aydi in 1985 and 1986.**

Hybrid	Cropping Season and Location	
	SEA 85	SEA 86
H1 - DRA 400	1.54	0.81
H2 - T x 21	1.57	1.08
H3 - HT 308	1.48	0.94
H4 - PAG S x 111	1.33	0.97
H5 - Funks 4065	1.48	1.11
H6 - P. 3969	1.07	0.68
H7 - P. 3994	0.68	0.48

Leaf area indices obtained (Table 5) were very low for all hybrids, especially in 1986 at Sidi El Aydi. The lowest numbers were given by the earliest hybrids H6 and H7. The leaf area indices of the late hybrids were also lower than the optimum (2 to 2.6) proposed by Major et al. (1972). Low levels of the harvest index and leaf area index given by early varieties can be a disadvantage, because corn is also used as forage.

Water use efficiency, which is the ratio of dry matter produced (grain yield in this case) to the amount of water used is presented in table 6. Statistical analyses show that this parameter was similar for all hybrids in 1985 (wet year) at Sidi El Aydi. This result indicated that hybrids that used more water gave better grain yields and vice versa. However, in 1986 (dry year), water use efficiency was more related to yield than to the amount of water used. So water use efficiency was higher in the case of the early and medium genotypes. This result agrees with that of waldren (1983).

From this study we can conclude that no differences were observed among maturity classes in a west year (1985). Early and medium hybrids escaped drought and gave roughly similar grain yields and higher harvest indices than those of late hybrids in a dry year. Early hybrids produced small quantities of dry matter, low leaf areas and less forage than medium hybrids under dry conditions and thus are less desirable. It seems that medium hybrids have some merit in the region.

Table VI : **Water Use Efficiency (kg grain/cm water used) at Sidi El Aydi (SEA) and Jemaa Shaim (JS) in 1985 and 1986.**

Hybrid	Cropping Season and Location		
	SEA 85 kg grain/cm	SEA 86	JS 86)
H1 - DRA 400	160.89	20.18	---
H2 - T x 21	144.70	15.04	54.61
H3 - HT 308	165.02	24.42	33.21
H4 - PAG S x 111	168.85	42.57	48.03
H5 - Funks 4065	157.52	40.60	59.08
H6 - P. 3969	176.16	51.29	63.05
H7 - P. 3994	158.12	43.72	75.16
LSD (0.05)	n.s.	16.11	23.40
LSD (0.01)	n.s.	22.14	32.47
CV (%)	11.54	17.02	17.07

ABSTRACT

The objective was to determine if early corn hybrids could improve the probability of obtaining grain yield during dry years and insure high yields during wet cropping seasons in a semi-arid environment. To reach this objective, experiments were conducted at Sidi El Aydi and Jemaa Shaim experiment stations, Morocco, on alkaline vertisol under mean annual precipitations of 388 and 318 mm, respectively. Treatments consisted of seven hybrids : H1 = DRA 400 (late); H2 = TX21 (late); H3 = HT 308 (late) ; H4 = PAG SX111 (medium); H5 = Funks 4065 (medium); H6 = Pioneer 3969 (early); and H7 = Pioneer 3994 (early). Plant population was 40,000 plants/ha and data collected were total dry matter, leaf area, grain yield, yield component, midday leaf water potential, leaf diffusive resistance, leaf transpiration, and soil moisture. Late hybrids (H1 H2, and H3) and one early hybrid (H6) tented to use more and less water, respectively, than the other hybrides at Sidi El Aydi. Early hybrids, especially H6, kept their leaf water potential higher than the threshold values (-1.8 to - 2.0 MPa) which corresponds to leaf diffusive resistance of 4 S cm^{-1} during all their reproductive periods. However, leaf water potentials decreased and leaf diffusive resistances of the other hybrids in creased drastically after anthesis. Consequently, their photosynthesis was probably affected.

In a wet year (1985), no differences in grain yields were registered among maturity classes. But the hybrids that used more water produced more yield. In a dry year, early and medium hybrids escaped drought somewhat and gave higher grain yields and harvest indices than late hybrids. The disadvantage of early hybrids is that they produce small quantities of dry matter, low leaf areas, and less forage. Under these climatic conditions water use efficiency was more related to yield than to the amount of water used.

RESUME

L'objectif de cette étude est de déterminer, dans les zones semi-arides, si le recours aux hybrides précoces de mais peut améliorer la probabilité de production de grains au cours des années sèches et assurer des rendements élevés de cette culture en années pluvieuses. Pour atteindre cet objectif, des essais ont été conduits aux domaines expérimentaux de Sidi El Aydi (Chaouia) et Jamaa Shaim (Abda), où les sols sont des vertisols alcalins et où les précipitations moyennes annuelles sont respectivement de 388 et 318 mm. Les hybrides testés dans cette étude sont, les hybrides tardifs DRA400 (H1), TX21 (H2) et HT308 (H3), les hybrides semi précoces PAG SX H1 (H4), funks 4065 (H5) et les hybrides précoces Pioneer 3969 (H6) et Pioneer 3994 (H7). La densité de peuplement utilisée est de 40 000 pieds/ha. Les données relevées concernent la matière sèche totale, la surface foliaire, le rendement grain, les principales composantes de rendement, la potentiel hydrique de la feuille, sa résistance stomatique et sa transpiration et enfin l'humidité du sol. Les hybrides tardifs (H1, H2 et H3) et l'hybride précoce (H6) ont tendance à utiliser respectivement plus et moins d'eaux que les autres hybrides à Sidi El Aydi. Cependant à Jemaâ Shaim la différence n'était pas significative. Les hybrides précoces et plus particulièrement H6, ont maintenu leurs potentiels hydriques supérieurs à - 2.0 MPa au cours de toute la période où les mesures sont effectuées. Le potentiel hydrique d'environ - 2.0MPa correspond à la résistance stomatique d'environ 4 scm-1. Dans les cas des autres hybrides, les potentiels hydriques ont diminué et les résistances stomatiques ont augmenté rapidement après floraison. Par conséquent leur photosynthèse a probablement chutée. En année pluvieuse (1985), les rendements grains n'étaient pas significativement différents d'un type de précocité à un autre. Les hybrides ayant utilisé plus d'eau ont pu produire plus de grains. En année sèche, les hybrides précoces et semi précoces ont échappé à la sécheresse de la fin du cycle et ont abouti à des rendements grains et indices de récolte meilleurs que ceux des hybrides plus tardifs. L'inconvénient des hybrides précoces est qu'ils produisent moins de matière sèche totale, des surfaces foliaires plus faibles et par conséquent moins de fourrage. Sous ces conditions, l'efficience d'utilisation de l'eau est plus liée au rendement qu'à la quantité d'eau utilisée.

ملخص

إن الهدف من هذه التجربة هو معرفة ما إذا كان اللجوء إلى أصناف الذرة الصفراء المبكرة يمكن من رفع مردود الحبوب في السنوات الجافة ويضمن الوصول إلى محاصيل عالية في السنوات الممطرة في المناطق الشبه الجافة بالمغرب. لتحقيق هذا الهدف، أقيمت تجارب بمحطتي سيدي العايدي بالشاوية وجمعة اسحايم بعبدة خلال الموسمين الفلاحيين 86 ـ1985، 87 ـ 1986،

وتربة هذه المحطات من نوع التيرس ، ومعدل كمية الأمطار هو 388 ملمتر بسيدي العايدي و 318 مليمتر بجمعة اسحايم ، وقد استعملت الأصناف المتأخرة :

الشبه المبكرة : (FUNRS 4065 = H5, PAGS x 111 = H4)

والمبكرة, (PIONNER 3994, PIONNER 3969 = H6) = H7

كما أن كثافة النباتات كانت 40.000 نبتة في الهكتار.وقد تم قياس المادة اليابسة (أوالمردود البيولوجي)، المساحة الورقية ، مردود الحبوب ومكوناته ، جهد الماء الورقي في وسط النهار مناعة التغت ، نتح النبات ، ورطوبة التربة ،

لقد أوضحت النتائج أن الأصناف المتاخرة استهلكت أكبر كمية من الماء ،أما الأصناف المبكرة فقد استهلكت أقل كمية بمحطة سيدي العايدي ، احتفضت الأصناف المبكرة وبالأخص H6 طوال فترة امتلاءالحب على أقل من 1.8 ـ و 2.0 ـ ميكابا صكال كعهد مائي في الورقة وأقل من 4 ثانية في السنتميتر كمناعة تغتية ، لكن جهد الماء الورقي ومناعة التغت ارتفعا عند الأصناف الأخرى بعد فترة الإخصاب ، ولهذا فمن الممكن أن يكون الترتيب الضوئيphotosgnthis قد تأثر بالجفاف .

وفي السنة الممطرة (1985) لم نحصل على أي فرق في المردود بين أنواع الأصناف ، لكن في السنة الجافة (1986) تجنبت الأصناف المبكرة والشبه المبكرة الجفاف وأعطت أعلى مردود وأعلى مؤشر للمحصول . إن مشكل الأصناف المبكرة هو أنها تنتج أقل مساحة ورقية وأقل مردود بيولوجي وبالتالي أقل كمية من الكلأ في السنة الممطرة ، إن الأصناف التي استهلكت أكبر كمية من الماء هي التي أعطت أكبر محصول، وقد كان مؤشر استعمال الماء مرتبطا بالمردود أكثر من ارتباطه بكمية الماء المستهلكة خلال السنة الجافة .

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