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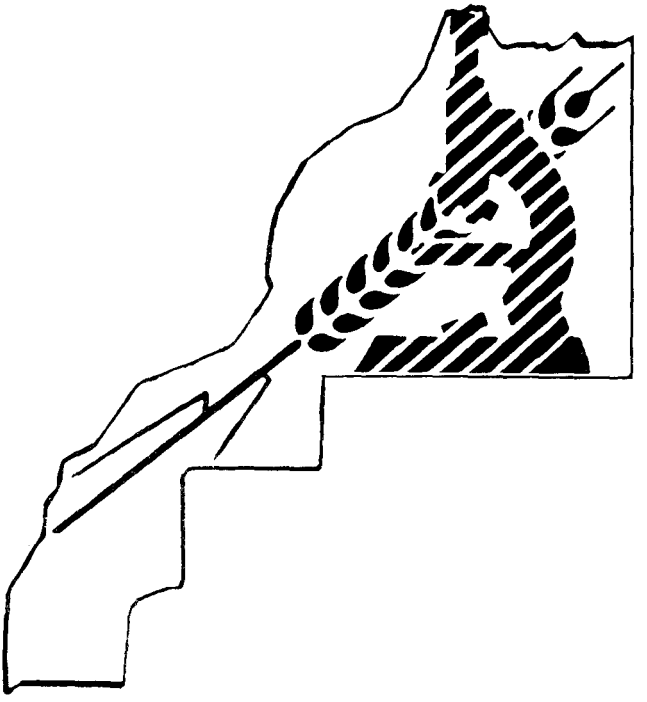

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WATER USE EFFICIENCY, GROWTH AND DEVELOPMENT RESPONSE OF MAIZE TO PLANT POPULATIONS IN SEMI-ARID MOROCCO

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INTRODUCTION

In semi-arid areas of the world, soil water deficits and excessively high temperatures are probably the most common yield - limiting factors in crops. Among these crops, maize yield is limited most by drought that occurs during its reproductive period. To improve yield, many scientists are seeking means of reducing the drought effect and hence making corn more water use efficient. Controlling plant population is one of the important practices to match water use to anticipated availability of soil moisture (Waldren, 1983). Timmons et al. (1966) demonstrated that when precipitation was below average from planting through silking, different stand depleted availabele soil moisture to near the wilting point at later stage and evapotranspiration remained about the same for each population so the efficiency of water use varied with yield. However, no definite relationship was found by Bababola and Oputa (1981) between water

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use efficiency and population necessary for optimum grain yields since optimum corn stands were related to growing seasons.

Increasing plant population from about 30,000 to 70,000 plants/ha in adverse soil wateddr seasons decreased grain yields of corn (Babadbola and Oputa, 1981) and reduced effective filling period duration by 2.5 days at high plant density (Poneleit and Egli, 1979). Claassen and Shaw (1970) postulated that reductions in yields were due to reductions in kernel numbers when stress occured before or during silking and pollination, and to reduction in kernel weights when stress occurred after silking. However, Harden et al., (1982) concluded that moisture stress within two weeks after silking reduced the number of kernels /plant by about 15% with little influence on final kernek weight. Later stress cycles had only minor effects on kernel number.

In semi-arid Morocco, one of the techniques used by farmers to reduce plant competition for water during grain filling and to feed their livestock is the thinning of less vigorous plants at tasseling. The objective of this study was to determine if plant population level obtained either by seeding rate ot by thinning plants at tasseling (practice of Moroccan farmers) can reduce the competition among plants and conserve water in the soil for use during the reproductive and grain felling periods when moisture deficiency usually occurs.

MATERIALS AND METHODS

Experiments were conducted at Sidi El Aydi and Jemaa Shaim experiment stations, located in Chaouoia and Abda plains (Morocco), respectively. Soils on which experiments were located are alkaline vertisols (pH7.5-8.0). Mean annual precipitation was 388 and 318 mm at Sidi El Aydi and Jemaa Shaim, respectively. The hybrid used was a moroccan double cross DRA 400 planted Feb 1, 1985 in Sidi El Aydi and 7 Feb 12, 1985 in Jemaa Shaim. Treatments consisted of four expected plant populations or densities : low -20,000 (d1); medium -40,000 (d2); high -80,000 plants / ha thinned at tasseling to 40,000 plants / ha (d4). Data collected were, total dry matter, grain yield, yield components, midday leaf water potential, leaf diffusive resistance, leaf transpiration, and soil moisture. Seeds were planted at 3 seeds / hill and then plants were thinned to 1 per hill at the 4 leaf stage. Row spacing was 75 cm. The experimental design was a rondomized complete block design with 4 replications.

RESULTS AND DISCUSSION

Water status

Total water used from emergence to physiological maturity was not affected by plant population (Table 1). Increaing plant population apparently hastened soil water depletion. Leaf transpiration (Fig.1) decreased earlier for the high plant population than for the lower ones. Leaf water potentiel (Fg.2) declined over time as the season progressed in 1985. Curves were parallel in the case of the low and medium plant populations. For the high plant population, early the cuve was parallel to the other curves, then the rate of decrease was very fast after day 100 (29 May, silking stage). The lowest leaf water potentials were -1.9, -2.2 and -3.3 MPa for d1, d2 and d3, respectively, when the plants were at the dent stage. The critical value of the leaf water potential for which leaves could not recover at night was around -2.2 MPa in this study, but was never reached by the low plant population.

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

Treatment	Cropping Season and Location			
Plants/ha	SEA 85	JS 85	SEA 86	JS 86
	Total Water cm			
d1 : 20.000	14.70	10.71	10.14	13.88
d2 : 40.000	15.36	11.27	10.07	15.24
d3 : 80.000	15.26	12.64	11.38	15.88
d4 : 80.000 + Thinning	14.46	11.14	10.07	13.87
LSD (0.05)	n.s.	n.s.	n.s.	n.s.
LSD (0.01)	n.s.	n.s.	---	---
CV (%)	8.90	19.37	11.30	12.41

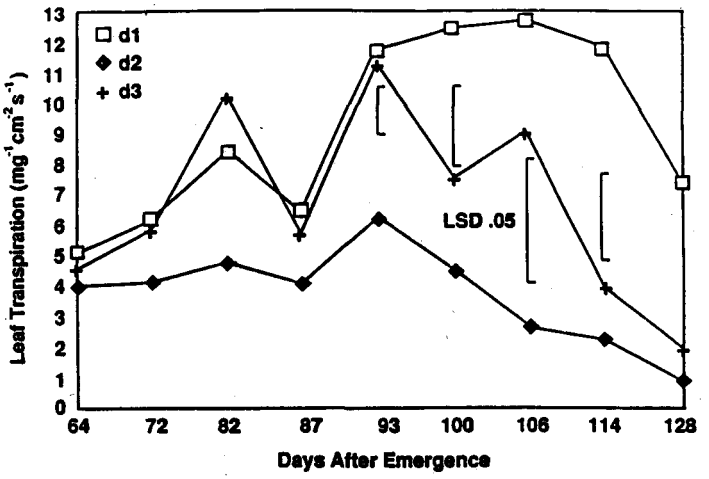

Fig. 1 : **Leaf transpiration versus time at Sidi El Aydi.**

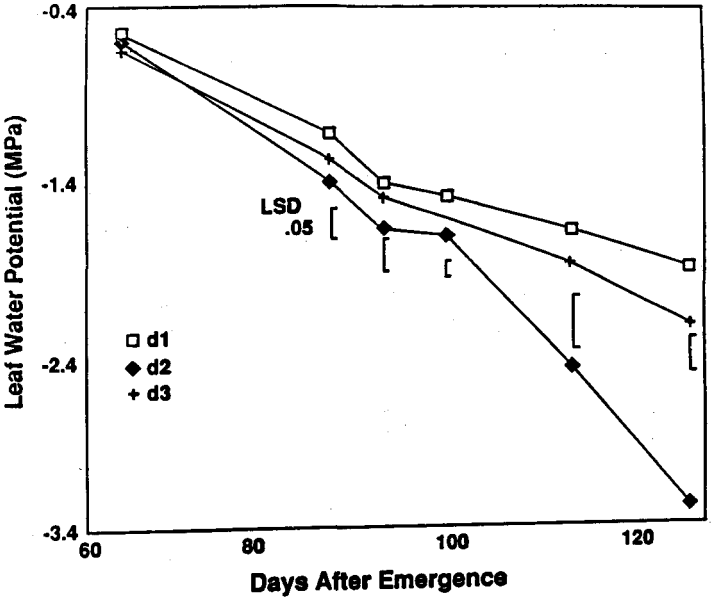

Fig. 2 : **Leaf water potential versus time at Sidi El Aydi**

The low plant population (d1) did not induce variation in total leaf diffusive resistance until the end of the growing season, where a small increase was measured (Fig.3). Leaf diffusive resistance remained constant until silking stage (100 days after emergence) for the other two plant populations (d2 and d3) and then increased rapidly. This increase was faster for d3 than d2 and corresponded to the rapid decrease of leaf water potential.

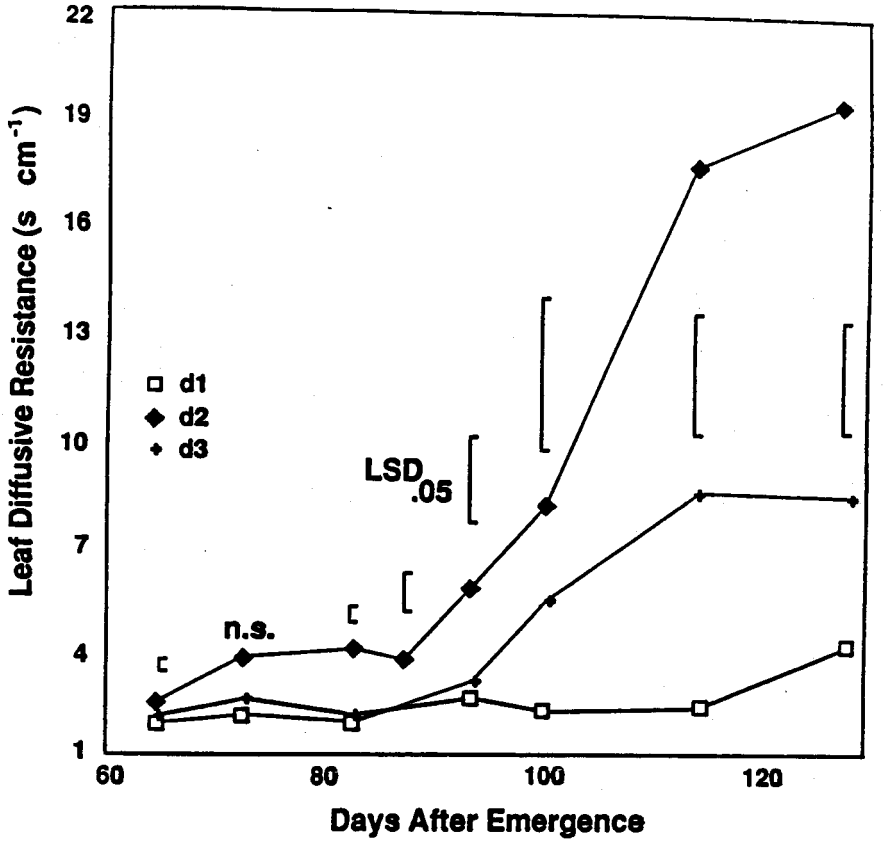

Fig. 3 : **Leaf diffusive Resistance versus time at Sidi El Aydi**

To gain an understanding of the relationship of stomata closure and leaf water potential, leaf diffusive resistance was plotted against leaf water potential (Fig. 4). The lack of increase of leaf diffusive resistance when leaf water potential decreased from -0.3 to -1.6 MPa can be explained by drought that occurred during March and April of 1985. This drought probably hardened plants and made them less sensitive to leaf water potential variation. Nevertheless, values of -1.6 to -2.0 MPa and 4 s cm-1 correspond to the beginning of stomatal closure. These values are similar to those reported in the literature (Boyer, 1970)

Yields

Grain yield and its components are presented in Tables 2, 3 and 4, respectively. Numbers of kernels / ear decreased with the increase of plant

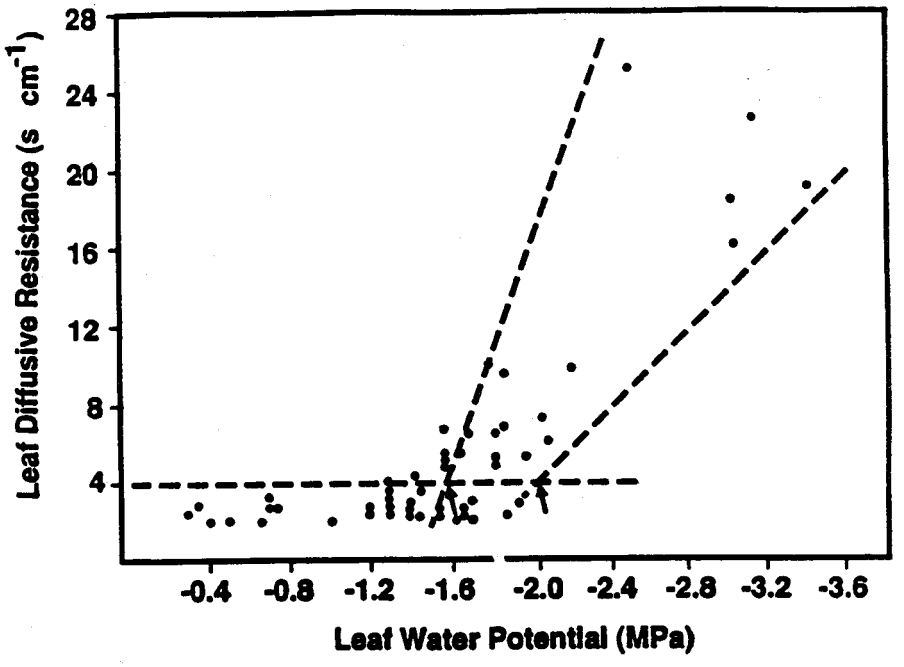

Fig. 4 : **Relationship between diffusive resistance (L.D.R.) and leaf water potential (L.W.P.) were independent until L.D.R. increased to near 4 sec/cm, then L.D.R. was related to L.W.P. Data are bracketed because of the scatter at low L.W. Ps (stomatal closure).**

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

Treatment Plants/ha	Cropping Season and Location			
	SEA 85	JS 85	SEA 86	JS 86
	Qx/ha			
d1 : 20.000	13.98	8.85	3.85	4.15
d2 : 40.000	16.98	12.46	1.97	5.91
d3 : 80.000	16.78	14.16	1.48	5.27
d4 : 80.000 + Thinning	19.64	11.73	1.92	4.42
LSD (0.05)	2.67	3.10	0.83	n.s.
LSD (0.01)	3.83	4.46	1.26	n.s.
CV (%)	9.90	16.44	18.14	17.18

Table III : **Number of kernels/ear at Sidi El Aydi (SEA) and Jemaa Shaim (JS) in 1985 and 1986.**

Treatment	Cropping Season and Location			
	SEA 85	JS 85	SEA 86	JS 86
	# Kernels / Ear			
d1 : 20.000	450	454	312	338
d2 : 40.000	415	435	304	377
d3 : 80.000	365	405	222	302
d4 : 80.000 + Thinning	413	455	254	318
LSD (0.05)	32	n.s.	n.s.	n.s.
LSD (0.01)	46	n.s.	---	---
CV (%)	5	9	15	14

Table IV : **Seed weight at Sidi El Aydi (SEA) and Jemaa Shaim (JS) in 1985 ans 1986**

Treatment	Cropping Season and Location			
	SEA 85	JS 85	SEA 86	JS 86
	mg / Kernel			
d1 : 20.000	21.4	24.4	13.1	13.7
d2 : 40.000	18.2	20.9	12.4	13.4
d3 : 80.000	15.5	19.3	12.8	12.5
d4 : 80.000 + Thinning	17.1	19.6	12.7	12.5
LSD (0.05)	2.0	3.2	n.s.	0.8
LSD (0.01)	2.8	4.5	n.s.	1.2
CV (%)	6.8	9.4	6.5	3.1

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

Treatment	Cropping Season and Location			
	SEA 85	JS 85	SEA 86	JS 86
	Qx / ha			
d1 : 20.000	32.04	16.60	21.11	20.83
d2 : 40.000	41.81	21.96	24.55	36.61
d3 : 80.000	45.98	27.39	22.33	45.50
d4 : 80.000 + Thinning	45.07	25.49	21.45	29.06
LSD (0.05)	9.90	---	n.s.	14.60
LSD (0.01)	15.00	---	n.s.	22.12
CV (%)	12.01	---	9.24	16.51

population. However, these decreases remained statistically not significant in 1985 at Jemaa Shaim and in 1986 at both sites. Nevertheless, seed weight decreased roughly with the increase of plant population in all conditions. Meanwhile, the differences were highly significant in 1985 at Sidi el Aydi. The reason was that 1986 was too dry at the end of the cycle and affected all plant populations.However, in 1985 the cropping season was relatively wet and only the highest plant population was affected. Leaf transpiration was very low in the case of the high plant population after silking (Fig. 1). In 1985, the highest yields obtained by the medium and high plant population were not statistically different. However, high seed weight and number of kernels/ear obtained with the low plant polpulation were unable to compensate for the lower plant population. So the yields remained low. In 1986, these components of yield were too low; and consequently, yields were also very low.

Thinning of plants at tasseling did not improve yields and its components during a dry year (1986) because most of the water stored in the soil was depleted at thinnig time. In a relatively wet cropping season (1985), thinning improved the yield and its components, especially at Sidi El Aydi.

Aboveground yield and harvest indices are presented in Tables 5 ans 6. These parameters increased and decreased respectively with the increase of plant population in the two locations during the two-year experiment. Data on harvest index show that more dry matter is accumulated in the grain as plant population becomes smaller. However, the harvest indices obtained in 1986 are very low because of the rapid growth before tasseling that induced a rapid depletion of soil moisture. Consequently, the reproductive period was very dry and grain yield was very low.

Water Use Efficiency

Water use efficiency is the ratio of dry matter produced to the amount of water used. Because the amount of water used by different plant populations was similar, the efficieny of water use varied with yield. In fact, the low and medium (d2) plant populations used water more efficiently during dry and wet cropping seasons, respectively (Table 7).

From this study we can conclude that optimum plant population is 20,000 plants/ha and 40,000 plants/ha in a dry and wet year, respectively. However, thinnig should be done earlier during a dry year.

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

Treatment	Cropping Season and Location			
	SEA 85	JS 85	SEA 86	JS 86
	Harvest Index, %			
d1 : 20.000	43.63	53.29	18.13	19.71
d2 : 40.000	40.61	45.44	8.04	16.00
d3 : 80.000	36.49	43.80	6.80	11.37
d4 : 80.000 + Thinning	43.58	47.38	9.03	15.17
LSD (0.05)	3.48	---	2.99	4.25
LSD (0.01)	5.26	---	4.54	6.43
CV (%)	4.11	---	14.28	13.66

Table VII : **Water use efficiency at Sidi El Aydi (SEA) and Jemaa Shaim (JS) in 1985 and 1986.**

Treatment	Cropping Season and Location			
	SEA 85	JS 85	SEA 86	JS 86
	Kg Grain/cm Water Used			
d1 : 20.000	95.33	82.02	39.01	39.96
d2 : 40.000	110.63	110.88	20.46	39.50
d3 : 80.000	110.11	115.48	12.54	33.28
d4 : 80.000 + Thinning	132.75	107.46	19.47	32.11
LSD (0.05)	13.37	26.89	6.13	n.s.
LSD (0.01)	19.21	38.63	9.29	n.s.
CV (%)	7.45	16.17	13.43	16.50

ABSTRACT

The objective of this study was to determine if plant population reduction obtained either by seeding rate or by thinning plants at tasseling (practice of Moroccan farmers) can reduce the competition among plants during the reproductive and grain filling periods when moisture deficiency usually occurs. To reach this objectif experiments were conducted at Sidi El Aydi and Jemaa Shaim, Morocco, on alkaline vertisols under mean precipitation of 388 and 318 mm, respectively. Treatments consisted of four expected plant populations or densities: low -20,000 (d1), medium -40,000 (d2), high -80,000 (d3) and 80,000 plants / ha thinned at tasseling to 40,000 plants / ha (d4). Data collected were total dry matter; grain yield; yield components; midday leaf water potential; leaf diffusive resistance;leaf transpiration; and soil moisture. Increasing plant population hastened soil water depletion, but total water used was not affected by population levels. Leaf diffusive resistance increased after silking. At the dent stage, the lowest leaf water potentials were -1.9, -2.2 and -3.3 MPa for the low, medium and high plant population, respectively. Critical value of leaf water potentiel for which leaves could not recover at night was -2.2 MPa. This value was never reached by the low plant population.

Drought during March and April probably hardened plants in 1985 and made them less sensitive to leaf water potential variation. Yield components, number of kernels/ear and seed weight tended to decrease with the increase of plant population. However, during a wet cropping season, high seed weight and number of kernels / ear obtained with the low plant population, were unable to compensate for the low plant population, consequently, yields remained low in this case. In a dry year, the two components mentioned above were relatively low, and yields were also very low. Thinning of plants at tasseling did not improve yields when the year was dry. In a relatively wet year thinnig improved yield (by 286 kg/ha) and its components.

From this study we can conclude tha thinning at tasseling is probably too late for saving water for the grain filling period and that 20,000 plants/ha in dry years and 40,000 plants/ha in wet years can be considered as optimum. Further investigation of plant populations is needed under these conditions.

RESUME

L'objectif de cette étude est de déterminer si la diminution de la densité de peuplement, en jouant sur la dose de semis ou sur l'éclaircissage des plantes de maïs au stade panicule (pratique des agriculteurs marocains), peut réduire la compétition entre plantes au cours des périodes de reproduction et de remplissage de grain où le déficit hydrique est souvent observé.

Pour atteindre cet objectif, des essais sont conduits aux domaines expérimentaux de Sidi El Aydi et de Jamaa Shain (Maroc) sur des vertisols alcalins où les précipitations moyennes annuelles sont respectivement de 388 et 318 mm. Les densités de peuplement choisies pour cette étude sont : faible -20.000 (d1), intermédiaire -40.000 (d2), élevée -80.000 (d3) et 80.000 réduite à 40.000 pieds /ha (d4) par éclaircissage au stade panicule. Les données relevées sont, la matière sèche totale, le rendement grains, les principales composantes de rendement, le potentiel hydrique de la feuille, sa résistance stomatique, et sa transpiration ainsi que l'humidité du sol.

L'augmentation de la densité de peuplement a accélérée l'épuisement de l'eau du sol, mais la quantité d'eau totale utilisée n'a cependant pas été affectée par la variation de la densité de peuplement. Après floraison, la transpiration et le potentiel hydrique de la feuille ont chuté; cependant la résistance stomatique a augmenté au stade pateux. Les potentiels hydriques les plus bas sont respectivement -1.9, -2.2 et -3.3 MPa pour la faible, la moyenne et la plus forte densité de peuplement. La valeur critique du potentiel hydrique qui semble correspondre au point de flétrissement des feuilles est d'environ -2.2 MPa. Cette valeur n'est jamais atteinte par la faible densité de peuplement. Le manque de pluie en Mars et en Avril a probablement induit une certaine tolérance à la dessiccation chez le maïs en 1985 et a rendu les stomates des feuilles moins sensibles au variations du potentiel hydrique. Les composantes de rendement, nombre de grains/épi et le poids du grain ont tendance à chuter lorsque la densité de peuplement - pieds augmente. Cependant en année pluvieuse des niveaux élevés du poids du grain et du nombre de grains/épi chez la plus faible densité ne sont pas suffisants pour compenser le niveau bas du nombre de plantes/ha ; par conséquent les rendements dans ce cas sont restés faibles. En année sèche, les deux composantes mentionnées ci-dessus ainsi que le rendement grains sont généralement faibles surtout dans le cas de la plus forte densité de peuplement. De même l'éclaircissage au stade panicule ne semble pas améliorer les rendements. Néanmoins en année relativement plus arrosée, cet éclaircissage a amélioré le rendement grains (par 286 kg /ha) et ses composantes.

De cette étude, on peut conclure que la réduction du peuplement pieds par arrachage des plantes au stade panicule ne permet pas d'économiser de l'eau pour la période ultérieure du remplissage du grain et que les densités de 20.000 plantes/ha en année sèche et 40.000 en année pluvieuse peuvent être considérées comme optimales. Plus d'investigations sur les densités le peuplement sont nécessaires en zones semis-arides

ملخص

إن الهدف من هذه الدراسة هو معرفة ما إذا كان تخفيض كثافة نباتات الذرة عن طريق التقليل من كمية البذور أو التخفيف من عدد النباتات تؤدي إلى نقص التزاحم بين النباتات غداة التناسل ووقت إمتلاء الحب.

ولتحقيق هذا الهدف، أجريت تجارب بمحطتى التجارب بسيدي العايدي بالشاوية وجمعة السحايم بعبدة، استعملت فيها أربع كثافات هي 20.000 (d1)، 40.000 (d2)، 80.000 (d3) و80.000 في الهكتار التي خففت في موعد التناسل من أجل الحصول على 40.000 نبتة في الهكتار (d4)، وقد أنجزت هذه التجارب خلال الموسمين الفلاحيين 86-1985، 87-1986 حيث كان أحدهما (87-86) جافا والآخر أكثر رطوبة.

وقد تم قياس المردود البيولوجي (المادة اليابسة)، مردود الحبوب ومكوناته، جهد الماء الورقي، مناعة التغت، نتخ النباتات ورطوبة التربة.

وتبين النتائج بأن الزيادة التدريجية في كثافة النباتات أسرعت في طرح مشكل الماء. لكن الكمية المستهلكة من الماء لم تتأثر بتغير الكثافة.و لوحظ انخفاض نتخ النباتات بعد موعد التناسل وارتفاع جهد الماء الورقي ومناعة التغت عند مرحلة نضج البذور. في أواخر مرحلة إمتلاء الحب كان أعلى جهد الماء الورقي 1.3 ميكابامكال بالنسبة لأقل كثافة، 2.26 بالنسبة للكثافة المتوسطة و3.3 لأعلى كثافة، وقد لوحظت حالة الذبول عند الذرة حين كانت قيمة جهد الماء الورقي 2.2 ميكابامكال تقريبا.وهذه القيمة لم تسجل أبدا في حالة الكثافة القليلة.

بالنسبة للسنة الجافة. مكنت قلة الأمطار خلال شهري مارس وأبريل النبات من التكيف مع الحالة التي عرفتها آخر الدورة الزراعية. أما مكونات المردود (عدد الحبوب في السنبلة ووزن الحبة) فقد سجلت نقصا ملحوظا حينما صارت الكثافة عالية. لكن خلال السنة الممطرة، فإن كثرة الحب في السنبلة نتيجة التقليل من كمية البذور(أقل كثافة) لم تواز النقص في الكثافة، ولهذا بقي المردود منخفضا، ويمكن القول بأن تخفيف النباتات في مرحلة الإخصاب لم يحسن المردود خلال السنة الجافة عكس ما وقع خلال السنة الممطرة.

الخلاصة من هذه الدراسة هي أن تخفيف الكثافة بالعملية اليدوية في مرحلة الإخصاب لا تمكن من اقتصاد الماء وخزنه من أجل إستعماله عند وقت إمتلاء الحب. ويمكن الإرشاد ب 20.000 نبتة في الهكتار في السنة الجافة و40.000 نبتة في السنة الممطرة.

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