WATER USE AND WATER USE EFFICIENCY OF WEEDS AND WHEAT IN SEMI - ARID MOROCCO

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INTRODUCTION

In Morocco, wheat constitutes the basic diet of the population. More than half of the wheat in the country is planted in semi-arid areas under rainfed conditions where annual precipitation is between 250 and 450 mm. Rainfall in these areas is unpredictable, and its distribution is variable within each year and among years. Most precipitation occurs in winter months while summer months are hot and dry. Wheat is usually planted in November-December, and harvested in May-June. Wheat growth is often hampered by periodic drought, Hessian fly (**Mayetiola destructor** SAY) and weed infestations (Regehr et al., 1988).

Water availability is a factor limiting crop productivity. Weeds compete with crops and reduce the amount of water available to crops. Weed competition for water is considered to be severe under conditions of dryland agriculture

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(Radosevich and Holt, 1984).

Water use efficiency (WUE) is commonly defined as the ratio of dry matter produced by plants to the water volume absorbed during their growth. Water use efficiency is frequently used to evaluate the impact of crop management in rainfed farming systems (Cooper et al., 1987).

Water use efficiency is affected by management practices (Hsiao and Acevedo, 1974 ; Gregory, 1984). In a previous study in semi-arid Morocco, Tanji et al. (1987) found that weed control did not affect water use in wheat but increased WUE by increasing production of grain and straw.

Fallowing for approximately 16 months is widely practiced in semi-arid Morocco. The purpose of this fallow period is to accumulate herbage for grazing. Chemical fallow has improved weed control and water conservation (Mazhar, 1987 ; Bouzza, 1990). Thus, there is a need for improved water storage in soil during the fallow period. In harsh and variable environments where moisture supply is limited, an understanding of soil water dynamics and paterns for crop water use is essential in identifying management strategies for consistent and stable yields.

This study was undertaken to determine the effects of weeds on water use (WU) and water use efficiency of wheat ; the effects of nitrogen fertilization on herbage production, water use, and WUE in weedy fallows ; and the effects of chemical fallow on soil moisture conservation.

MATERIAL AND METHODS

Field experiments were conducted in 1986/87 and 1987/88 on a deep vertisol (Chromoxerert) at the Sidi El Aidi experiment station located in semi-arid Morocco. They were conducted on adjacent sites each year. Procedures were the same for both years.

Wheat (**Triticum aestivum** L. cv. "Nesma 149") was sown with a drill in 30 cm row spacing at a rate of 80 kg ha-1 . The seedbed was prepared by an offset tandem disk. Amnonium nitrate at 10 kg N ha^{-1} and P at 14 kg ha^{-1} were applied in bands the first year on previously fallow land. The second year, P was applied at the rate of 20 kg ha^{-1} at planting on a site previously cropped with barley. Sixty kg N ha^{-1} from urea were added at wheat tillering stage in the second year. Planting dates were 16 November 1986 and 9 November 1987. Broadleaf weeds were controlled at early wheat tillering with a mixture of ioxynil (4-hydroxy- 3,5-diiodobenzonitrile) at 360 g ha $^{-1}$ and mecoprop [(-)-2-(4-chloro-2-methylphenoxy) propanoic acid] at 1080 g ha $^{-1}$. No grassy weeds were present on the experiment sites, except volunteer barley plants which were removed by hand pulling shortly after crop emergence. Carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) was applied in furrow at planting at a rate of 1120 g ha^{-1} to limit Hessian fly damage. The 5 treatments were :

1) Weed-free wheat. Weeds were sprayed at early wheat tillering.

2) Weedy weat. Wheat was planted and managed in the same way as in treatment 1 except that weeds were not controlled.

3) Fertilized weedy fallow. Wheat was not planted and weeds were allowed to grow ; fertilizers were applied at similar rates and times as in treatments 1 and 2.

4) Non fertilized weedy fallow. Wheat was not planted and weeds were allowed to grow.

5) Chemical fallow. Plots were kept weed-free by two applications of a mixture of glyphosate [N (phosphonomethyl) glycine] at 540 g/100 1 water and 2,4-D [(2,4-dichlorophenoxy) acetic acid] at 720 g/100 1 water.

Treatments, in 7.2 x 10 m plots, were arranged in a randomized complete block design and replicated four times. Neutron probe access tubes were placed in the center of each plot soon after wheat emergence. Neutron probe readings were taken at depths of 15, 30, 60, 90, and 120 cm in each plot at early wheat tillering, wheat anthesis, and maturity. Water use was calculated using calibration curve (Watts and Troeh, 1984) and water balance procedure. It was calculated based on the average moisture from all readings at different depths. Water use was underestimated since soil moisture measurements were not started until early wheat tillering. Weed density, weed dry weight, and above-ground biomass of wheat were measured from 1m2 areas within each plot at wheat anthesis. Weight of above-ground biomass was determined after drying plant samples or subsamples at 60 C for 72 hours. At wheat physiological maturity, an area of 3 m2 from the middle rows was cut at ground level to determine grain and straw yields. Threshing was done with a stationary thresher and grain was cleaned with a commercial seed cleaner. Water use efficiency of wheat was determined for treatments having this crop. Rainfall and temperatures were recorded daily at the Sidi El Aidi experiment station and monthly means are shown in Table 1. The 1986/87 growing season had a shortage of precipitation combined with unusually warm conditions that resulted in drought stress on all crops (Watts, 1988). Rain in mid-March and early April 1987 prevented crops from being a total loss, although yields were low. The cropping year 1987/88 was wetter than the average year.

RESULTS AND DISCUSSION

Weed biomass

The predominant weed species during the two-year study were : blue pimpernel (**Anagallis foemina** Miller), centaury (**Centaurea diluta** Aiton), common poppy (**Papaver rhoeas** L.), field bindweed (**Convolvulus arvensis** L.), field marigold (**Calendula arvensis** L.), and wild mustard (**Sinapis arvensis** L.). These species are early winter germinating dicotyledonous weeds. Weed densities in the weedy wheat treatment at anthesis were 38 plants m-2 in 1986/87 and 34.5 plants m-2 in 1987/88 (Table 2).

Weed populations in fertized weedy wheat were 26.6 and 46.3% lower than fertilized and non-fertilized weedy fallow plots, respectively, in 1986/87, and 61.0 and 66.3% respectively, in 1987/88. Weed dry matter reductions due to competition from wheat compared with fertilized and non-fertilized weedy fallow averaged about 93% in 1986/87 and 80% in 1987/88. Tanji and Jlibene (1989) found that 'Nesma 149' wheat planted at 120 kg ha^{-1} reduced weed density and dry matter by 49 and 84%, respectively.

Herbicide treatment resulted in reduction of 86.8 and 96.4% in weed density and dry matter, respectively, compared to weedy wheat in 1986/87 (Table 2). Complete weed control was achieved the second year. Ioxynil with Mecoprop applied at early wheat tillering gave consistent control of a large spectrum of dicotyledonous weeds, confirming previous results from Morocco (Tanji and Regehr, 1988b) and Tunisia (CYMMIT, 1973).

The addition of fertilizer did not affect density and biomass of weeds in weedy fallow. Soil fertility probably was not limiting weed growth at the Sidi El Aidi experimental sites.

Absence of wheat in weedy fallows allowed more weeds to emerge and grow.

Table I : **Monthly rainfall and mean maximum (Max) and minimum (Min) air temperatures at Sidi El Aidi experiment station during the growing seasons 1986/87 and 1987/88.**

	1986/87			1987/88		
	Temperature		Rain	Temperature		Rain
	Max.	Min.		Max.	Min.	
	.... C		mm	.... C		mm
Sep.	29.8	13.8	0.0	35.6	17.1	13.4
Oct.	26.9	12.0	0.0	25.6	12.7	29.3
Nov.	23.5	7.9	38.5	21.5	9.0	62.2
Dec.	19.5	4.8	5.0	20.9	8.9	139.8
jan.	20.4	7.0	45.0	17.4	5.6	113.6
Feb.	20.0	7.3	57.1	18.4	5.8	73.5
Mar.	23.7	7.3	38.1	22.9	5.6	14.8
Apr.	26.9	10.2	12.8	23.5	7.5	5.9
May.	27.5	11.6	7.0	24.7	10.5	16.7
Total			203.5			469.2

Table II: **Density and dry matter of weeds at wheat anthesis in 1986/87 and 1987/88.**

Treatments	1986/87		1987/88	
	Density	Biomass	Density	Biomass
	Plans m^{-2}	kg ha^{-1}	Plants m^{-2}	kg ha^{-1}
Weed-free wheat	5.0	5.8	0.0	0.0
Weedy wheat	38.0	160.0	34.5	1686.0
Weedy fallow				
fertilized	51.8	2142.3	88.5	8611.0
non-fertilized	70.8	2395.8	102.5	8756.5
LSD (0.05)	20.1	708.0	31.9	2594.6

Table III : **Wheat grain and straw yield in 1986/87 and 1987/88.**

Treatments	1986/87		1987/88	
	Grain	Straw	Grain	Straw
	.... kg ha^{-1}			
Weed-free wheat	1085	2227	3021	7980
Weedy wheat	994	2029	931	6066
LSD (0.05)	NS	NS	763	NS

High and well distributed rainfall in 1987/88 resulted in increased weed biomass in weedy wheat and weedy fallows compared to the first year. Average productivity of weeds in fallows was 2269 kg ha^{-1} in 1986/87 and 8684 kg ha^{-1} in 1987/88. Greater weed densities and dry matter production in 1987/88 compared with 1986/87 were most likely due to more available water.

Wheat yields

Reductions of total wheat biomass (grain plus straw) due to weed interference were 8.7 and 36.4% in 1986/87 and 1987/88, respectively (Table 3).

Grain yield losses due to weeds were 8.4 and 69.2%, and straw was decreased by 8.9 and 24.0%, respectively. These data indicate that interference between wheat and weeds was influenced by rainfall and the degree of weed infestation.

Competition between weeds and wheat plants was probably very high during the reproductive and grain filling periods, since available soil water was low at that time. The limited amount of water available for the wheat from anthesis to maturity might affect grain set and fill. Tanji and Regehr (1988a) reported that weeds caused wheat grain yield losses as high as 63% in semi-arid areas of Morocco. Allowing weeds to grow beyond the full - tiller stage of wheat caused intense competition for water, and wheat grain yield was reduced (Zimdahl, 1980 ; Wiese, 1983).

Water use

Since 1986/87 was drier than 1987/88, the quantity of water used during the first growing season was lower than that used in the second season (Table 4). For both years, weedy wheat and weedy fallows had greater evapotranspiration (ET) than weed-free wheat, but the difference in ET between weed-free and weedy wheat was not significant in 1986/87. The highest differences between weed-free and weedy wheat were found during the period from anthesis to harvest of wheat.

Weed control in wheat resulted in soil moisture conservation. The difference found in water use between weed-free and weedy wheat in this experiment is in agreement with results from Northeastern Victoria, (Australia), where Reeves (1976) found that the soil moisture level was lower in ryegrass (**Lolium rigidum** Gaud.) Infestation wheat than in weed-free wheat under rainfed conditions.

Weed species and infestation levels affect water use under dryland farming conditions (Brengle, 1982).

Fertilizer applied to weedy fallow plots did not significantly affect the amount of water used during both seasons. The lowest evapotranspiration values were observed in the chemical fallow treatment in both years. (Table 4).

In this study, soil water measurements were made during approximately six months (December to May). In a 3-year crop rotation study in semi-arid Morocco, Mazhar (1987) found that available soil moisture measured before planting (November) for rainfed wheat averaged 6.7 cm for the rotation wheat/tilled fallow and 2,0 cm for wheat/weedy fallow.

Water use efficiency

Water use efficiency for total weed-free wheat biomass was 207.9 kg ha^{-1} cm^{-1} in 1986/87 and 348.3 kg^{-1} cm^{-1} in 1987/88 compared with 176.6 and 196.0 in weedy wheat (Table 5). Differences between WUE for total above ground biomass (grain plus straw) in weed-free wheat and weedy wheat were not significant the first year, but were significantly different the second year. Cooper et al. (1983) found that WUE of fertilized weed-free 'Mexipak' wheat in semi-arid Syria averaged 291 kg ha^{-1} cm^{-1}, while that of nonfertilized weed-free wheat was 265 kg ha^{-1} cm^{-1}. Tanaka et al. (1990) found no significant effect of fertilizer rate and placement on WUE of spring wheat in Montana, USA. They reported that WUE of total biomass of wheat at harvest (straw + grain) varied from 195 to 210 kg ha^{-1} cm^{-1} in a normal year and 103 to 114 kg ha^{-1} cm^{-1} in a dry year. WUE of grain varied from 96 to 105 kg ha^{-1} cm^{-1} in a normal year and 39 to 42 kg ha^{-1} cm^{-1} in a dry year. In both years, herbicide use reduced water use and significantly increased WUE in wheat, as compared with weedy wheat. Cooper et al. (1987) reported that any management factor which reduces evapotranspiration and increases the crop's ability to extract moisture will result in greater WUE and increased crop production. In contrast, there were no differences in the WUE between fertilized and nonfertilized weedy fallow.

Table IV : **Water use (evaportranspiration) in different treatments in 1986/87 and 1987/88.**

Treatments	1986/87			1987/88		
	T-F[1]	F-H[2]	Total	T-F[1]	F-H[2]	Total
	cm					
Weed-free wheat	11.6	4.5	16.1	22.8	8.8	31.6
Weedy wheat	11.6	6.6	18.2	23.8	12.8	36.6
Weedy fallow						
fertilized	11.8	8.6	20.4	23.2	15.9	39.1
non- fertilized	12.3	8.4	20.7	19.6	17.3	36.9
Chemical fallow	9.3	0.9	10.2	19.4	7.0	26.4
LSD (0.05)	1.6	2.9	3.3	3.7	4.4	4.5

[1] T-F: Period from wheat tillering (20 January 1987 and 11 December 1987, respectively) to anthesis (5 April 1987 and 15 March 1988, respectively). Water use is precipitation recorded from tillering to anthesis of wheat plus soil water at tillering minus soil water at anthesis of wheat.

[2] F-H : Period from wheat anthesis to harvesy (19 May 1987 and 28 May 1988, respectively). Water use is precipitation recorded from anthesis to maturity of wheat plus soil water at anthesis minus soil water at maturity of wheat.

Table V : **Water use effeciency (WUE) of wheat and weeds at harvest in 1986/87 and 1987/88.**

WUE	Wheat		Weedy fallow		LSD (0.05)
	weed-free	weedy	fertilized	non fertilized	
	..............Kg.ha $^{-1}$ cm $^{-1}$				
1986/87					
WUE grain	68.0	55.1	-	-	3.8
WUE total	207.9	176.6	104.8	116.9	56.2
1987/88					
WUE grain	95.8	26.6	-	-	25.9
WUE total	348.3	196.0	220.3	240.1	81.4

CONCLUSION

The presence of wheat and chemical weed control reduced both density and biomass of weeds. The herbicide, Certrol H, gave good control of broadleaf weeds that were dominant at the experimental sites. Weedy fallow permitted high dry matter production of weeds that can be used as forage. However, weeds reduced the amount of water stored in weedy fallow ; thus, the yield of the following crop may be reduced. Grain and straw yields were more affected by weeds during a wet croping season than a drier one. Weed control in wheat is more justified during wet seasons because the effect of weeds is more significant during wet seasons.

The presence of weeds in wheat and weedy fallow caused higher evapotranspiration than in weed-free wheat. Consequently, it is necessary to control weeds in both situations in order to reduce the competition for water during the wheat growing season, and to conserve moisture under fallow for the following crop. The efficiency of water use for wheat production is decreased when weeds are not controlled.

This study demonstrated the benefit of herbicidal weed control in dryland wheat. Economic studies should be made comparing biomass and quality of herbage produced in weedy fallow, and the impact of soil moisture conservation on the yield of the following crop after chemical fallow.

SUMMARY

Fluctuations and low annual amount of rainfall during the growing season of wheat in semi-arid Morocco are the most limiting factors for grain production. Under these conditions, soil moisture deficit is usually accentuated if weeds are present and not controlled. In this study, water use (WU)and water use efficiency (WUE) of rainfed bread wheat (**Triticum aestivum** L.) cv. 'Nesma 149' and weeds were measured in a two-year field trial in a semi-arid environment at the Sidi El Aidi experiment station. Experiments were conducted during consecutive seasons with rainfall of 203 mm in 1986/87 and 469 m in 1987/88. Treatments were : 1) weed-free wheat ; 2) weedy wheat ; 3) fertilized weedy fallow ; 4) non-fertilized weedy fallow ; and 5) chemical fallow. Soil moisture was measured three times each growing season with a neutron probe from early wheat tillering to maturity. For both years, weed control reduced the total WU and increased total WUE (grain plus straw yield/total WU and grain/yield/total WU) compared to unweeded wheat. The highest WU values occurred in weedy fallows and weedy wheat ; thus, weeds extracted more soil moisture than wheat. Fertilizer application did not affect weed density, weed biomass, water use, and WUE in weedy fallow. Fallow productivity averaged 2.3 and 8.7 tons ha^{-1} of above-ground dry matter in 1986/87 and 1987/88, respectively. Weed control in dryland wheat is then necessary to produce high yields.

RESUME

Les fluctuations et les faibles quantités de précipitations pendant le cycle du blé sont les facteurs les plus limitants de la production en milieu semi-aride Marocain. Dans ces conditions, le déficit hydrique est généralement accentué en présence des adventices. Dans cette étude, l'évapotranspiration (ET) et l'efficience d'utilisation de l'eau (EUE) par le blé tendre (**Triticum aestivum** L.) cv. 'Nesma 149' et les adventices ont été mesurées. Ces essais ont été conduits en sec au domaine expérimental de Sidi El Aidi pendant deux campagnes agricoles consécutives dont les pluvimétries étaient de 203 mm en 1986/87 et 469 mm en 1987/88. Les traitements retenus sont : 1) blé désherbé, 2) blé non désherbé, 3) jachère non travaillée fertilisée, 4) jachère non travaillée et non fertilisée, et 5) jachère chimique. Au cours de chaque campagne agricole, l'humidité du sol a été mesurée à l'aide de la sonde à neutron, du stade début tallage jusqu'à maturité du blé. Le désherbage du blé a réduit l'ET et augmenté l'EUE (rendement grain + paille/ET et rendement grain/ET) en comparaison avec le blé non désherbé. Les valeurs d'ET les plus élevées ont été obtenues dans les deux jachères suivies du blé non désherbé, ce qui démontre que les adventices ont absorbé plus d'eau que le blé. La fertilisation azotée de la jachère n'a pas affecté la densité, la biomasse, l'ET et l'EUE de la végétation. La productivité moyenne des deux jachères a été 2,3 et 8,7 tonnes/ha de matière sèche respectivement en 1986/87 et 1987/88. Le désherbage du blé est nécessaire pour améliorer les rendements en milieu semi-aride non irrigué.

Mots clés : Identification-Blé dur-Protéines- Gliadines-Eléctrophorégramme.

فعالية استعمال الماء من طرف الأعشاب والقمح في المناطق شبه الجافة بالمغرب

تعتبر تقلبات المناخ وقلة الأمطار خلال فترة نموالقمح في المناطق ا لشبه الجافة بالمغرب من أهم أسباب نقص إنتاج الحبوب. وفي هذه الظروف، تزداد قلة رطوبة التربة حدة إذا لم تتم محاربة الأعشاب. في هذا البحث، تم قياس التبخروفعالية استعمال الماء بالنسبة للقمح الطري (TRITICUM AESTIVUM L,) "نسمة 149" والأعشاب لمدة سنتين وذلك في محطة التجارب بسيدي العايدي ذات المناخ الشبه الجاف. بلغت كمية الأمطار203 م م في الموسم الفلاحي 86- 1987 و 469 م م في 87 - 1988. تضمنت التجربة خمس معادلات هي:

1) قمح بدون أعشاب، 2) قمح بدون مكافحة الأعشاب، 3) حقل مرتاح (JACHERE) مسمد، 4) حقل مرتاح غير مسمد، و 5) حقل مرتاح مع محاربة الأعشاب بالمبيدات. وقد تم قياس رطوبة التربة بواسطة آلة نوترونية -SONDE A NEU) (TRONS 3 مرات من بداية التفريخ إلى نضج القمح.

أظهرت النتائج أن محاربة الأعشاب قللت من التبخر وزادت فعالية استعمال الماء (حب + تبن/ تبخرأو حب/ تبخر) بالمقارنة مع قمح بدون مكافحة الأعشاب. أعلى مقادير التبخر كانت بالحقل المرتاح وبالقمح المعشوشب مما تبين أن الأعشاب ساهمت في ارتفاع مستوى التبخر. كما بينت النتائج أن تسميد الحقل المرتاح لم يؤثرعلى عدد الأعشاب ووزن مادتها الجافة وعلى التبخر وفعالية استعمال الماء. معدل منتوجية الحقل المرتاح كانت 2.3 و 8.7 طن /هـ من الوزن الجاف خلال موسمي 86 - 1987 و 87 - 1988. نستخلص من هذا البحث أن محاربة الأعشاب في المناطق الشبه الجافة ضرورية للحصول على منتوج مرتفع.

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