EVALUATION THE EFFECTS OF ORGANIC FERTILIZER AND IRRIGATION INTERVAL ON WATER NEED, WATER USE EFFICIENCY, AND QUALITY AND QUANTITY OF MAIZE YIELD

EVALUATION DES EFFETS D'ENGRAIS ORGANIQUE ET D'INTERVALLE D'IRRIGATION SUR LES BESOINS EN EAU, L'EFFICIENCE D'UTILISATION DE L'EAU, LA QUALITE ET LA QUANTITE DU RENDEMENT DU MAIS

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ABSTRACT

Water use efficiency (WUE) is grately influenced by soil water holding capacity, irrigation interval and also by soil organic matter, especially in draught condition. An experiment was conducted to study the effects of manure application and irrigation interval on growth properties, water need and WUE of maize (Zea mays L.), in Lorestan Province, west of Iran. Experimental design was split plot in randomized complete blocks with three replications in two years. Irrigation treatments were assigned to the main plots and four levels of manure application were assigned to the subplots (0, 20, 40, 60 ton/ha). Irrigation treatment levels were control or what is locally precticed (I_c), and irrigation after 50 (I_{50}), 75 (I_{75}) and 100 (I_{100}) mm evaporation from A class evaporation pan. The required irrigation amount was estimated from soil moisture depletion from field capacity by formula and the estimated quantity was applied. Result from the first and second years experiment indicated that the effect of irrigation treatment and manure application on the grain yields was significant at α =1%. Significant decrease in seed protein (%) at α =1% was observed under the application of 60 Mg ha^{-1} of manure. Seed protein percent significantly increased in water stressed treatment. WUE range in different treatments was about 0.60 to 0.87 kg m^{-3}. Minimum WUE was in I_{100} treatment without manure application. For optimum irrigation management and increasing yield and WUE, the suggested irrigation interval is 6 days

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during the last vegetation growth stage and initial tussling stage, and 8 days in the other growth stages.

Keywords: *Water Use Efficiency, Irrigation Management, Maize (Zea mays L.), and Manure.*

RESUME ET CONCLUSIONS

La bonne gestion de l'eau combinée à une gestion appropriée des sols est nécessaire pour l'efficacité d'utilisation de l'eau imprvement et la production agricole durable dans un état aride et semi aride. Efficacité de l'utilisation de l'eau dominante affectée par la capacité en eau du sol le long de l'intervalle d'irrigation. Cette capacité en particulier dans l'état le projet peut améliorer la productivité des cultures. L'indicateur principal du sol pour une capacité de rétention d'eau est la matière organique du sol. En raison des conditions arides et semi-arides en Iran, la quantité de matière organique du sol est particulièrement réduite. Cette expérience a été menée pour étudier les effets de l'épandage d'engrais organiques comme le fumier et l'intervalle d'irrigation sur le besoin de croissance et de l'eau du maïs (Zea mays L.), dans la province de Lorestan, à l'ouest de l'Iran. Conception expérimentale a été divisée complot en blocs aléatoires complets avec trois répétitions en deux ans. Traitements affectés à l'irrigation des parcelles principales et quatre niveaux de l'épandage de fumier attribué à sous-parcelles (0, 20, 40, 60 Mg ha^{-1}). Les niveaux de traitement d'irrigation ont été Ic (conrol ou d'irrigation dans le temps la mode locale), I_{50}, I_{75} et I_{100} que le temps d'irrigation après 50, 75 et 100 mm d'évaporation d'une plaque d'évaporation de classe. Quantité d'eau d'irrigation mesurée à partir de pour cent FC appauvrissement de l'humidité du sol et par la formule appliquée.

Résultat de première et deuxième années ont indiqué que l'effet du traitement d'irrigation et l'épandage de fumier sur le rendement en grain est significatif à α = 1%. Le rendement en grain maximum a été atteint d'un traitement par I_{50} montant de 12,879 tonnes / ha . Le rendement en grain minimum a été appartenir à un traitement I_{100}. Augmentation significative du poids de mille graines (gr) a été créé par l'appauvrissement de la période d'irrigation ou à la baisse de l'eau appliquée, et l'application de 60 tones / ha de fumier a diminué significativement protéines de la graine (%) à α 1% =.. pour cent de protéines de semences considérablement augmenté dans de l'eau a souligné traitement. l'eau d'irrigation maximale a été utilisée dans I_{50} avec zéro épandage de fumier et était égal à 17670 m^3 . l'eau d'irrigation minimale a été utilisé dans I_{100} avec 60 tonnes / ha de fumier et d'application a été égal à 11380 m^3. Volume d'eau a diminué appliquée à tous les niveaux de fumier épandu. Efficacité de l'utilisation de l'eau a été maximale dans les traitements I_{75} par le montant de 0,81 kg m^{-3} d'eau d'irrigation. L'efficacité minimale utilisation de l'eau a été dans le traitement de I_{100} par le montant de 0,73 kg m^{-3} d'eau d'irrigation. Canopy en matière sèche à α = 5% a augmenté significativement avec le fumier et les applications croissantes de l'eau et la période d'irrigation diminuent.

Les résultats indiquent que pour la gestion de l'irrigation optimale et augmenter le rendement et l'efficience d'utilisation de l'eau, a suggéré l'intervalle d'irrigation doit être régulé dans 6 jours au stade de la végétation et la croissance dernière floraison mâle initiale et 8 jours en phase de croissance d'autres. Ces temps basé sur le système de propriété et la valeur économique peut être changé. De plus, cette période peut être augmentée dans *la phase initiale de croissance et de l'eau appliquée diminué, par la suite, de sorte que le développement des racines dans cette étape est inférieur à d'autres stades.*

Mots clés: *Efficience d'utilisation de l'eau, gestion d'irrigation, Maïs (Zea mays L.), fumier.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

Maize has a specific ability to respond to applied inputs (e.g. water, fertilizer, etc.). This plant can be used for various usage as human and domestic feeding as well as in the industry. According to Zhang et al. (2004), 0.6 litter of water is needed to produce one gram of dry matter for maize cropo. Tussling and early flowering are the sensitive maize growing stages to water stresses (Panda et al. 2004). Water use efficiency (WUE) has been the most widely used parameter to describe irrigation effectiveness in terms of crop yield. Irrigation management by use of appropriate irrigation scheduling should be an effective approach for WUE enhancement. Irrigation scheduling can be accomplished by different methods including soil moisture budgeting at root zone, plant appearance, soil moisture tension, leaf turgidity, neutron meter instrument, satellite images etc. Milani and Neyshabouri (2001) showed that root depth Moisture budgeting method was the best method to determine maize irrigation scheduling and irrigation when 50 per cent of the available water has depleted from the root zone is the best irrigation time.

In an experimental research on maize irrigation scheduling with soil water budgeting method, Panda et al (2004) found that at any stage of maize growth not more than 45 per cent of available soil moisture should depleted. Wu et al. (2009) indicated that the average maize yield and dry matter increase was 18.0% and 28.8% for organic manure application, and 20.4% and 32.4% for the combined organic manure application and irrigation scheduling based on soil water depletion method. Research results (Aspasia et al. 2010) showed that manure application as amendments increased the level of soil organic matter and total nitrogen, height, dry weight and leaf area index, significantly ($P< 0.05$). Their results indicated that application of cow and poultry manure doubled maize yield as comparied to the control treatment.

Ould et al (2010) indicated that farmyard manure application resulted in 78 and 21% higher soil water retention and dry matter yield, respectively, compared to the control treatments. Cvetkov and Tajnsek (2009) mentioned that application of 30Mg ha^{-1} farmyard manure increased the soil organic carbon content by an average of 3.3 Mg ha^{-1} to 4.7 Mg ha^{-1} in different crop types, compared to the control treatment. Mentler et al. (2002) investigated the impact of two manure sources on maize. They found that application of manure significantly increased grain yield and dry matter by about 426 and 380 per cent, respectively, compared to the control treatment. The study reported in this paper was done to investigate the effect of different irrigation amount and time and different levels of manure application on yield, growth indices and water needs and water use efficiency of maize.

2. MATERIALS AND METHODS

The experimental design was split plot in randomized complete blocks with three replications. Irrigation treatments were assigned to main plots and four levels of manure application were assigned to subplots (0, 20, 40, 60 Mg ha^{-1}). Irrigation treatment levels were I_c (control, i.e., local practice), I_{50}, I_{75} and I_{100} as irrigation time after 50, 75 and 100 mm evaporation from A class evaporation plate. Irrigation water depth was estimated from per cent depletion of soil moisture from Field Capacity moisture content by using the the following formula:

$$IW = \frac{D \times (Fc - P_m)}{100} \times B_d$$

IW: irrigation water depth (cm), D: root zone depth, Fc: volumetric soil moisture percent at field capacity, P_m: volumetric soil moisture content (%) in the root zone, B_d: mean soil bulk density in the root zone (g cm^{-3}).

Finally, plant growth variables including grain yield, shoot dry matter, grain protein and weight of thousand seed (WTS) were measured. In addition, irrigation management variables, including used water volume, irrigation interval, and water use efficiency was calculated. Water use efficiency was calculated as grain yield divided by total used water during the growth season. Mean irrigation interval was measured by averaging irrigation interval in different growth stages. Results were analyzed by SPSS and MSTATC software.

3. RESULTS AND DISCUSION

Results indicated that all measured variables were affected by irrigation treatment. Amounts of grain yield and WTS ($P \leq 0.01$) and WUE ($P \leq 0.05$) were significantly reduced by long irrigation interval and under water stress condition. But, protein percent significantly increased ($P \leq 0.05$). Manure application influence on seed protein percent was significant in $P \leq 0.01$ level (Table 1). Interaction effect between irrigation and manure treatment was not significant.

Table 1. Summary of analysis of variance for variables mean square (Résumé de l'analyse de la variance pour les variables quadratique moyenne)

Variation sources	df	Grain yield	Protein percent	WTS	WUE	Shoot dry matter
Rep.	2	21.073*	0.431*	135.25^{ns}	0.105*	1.326 ^{ns}
Irrigation	3	44.86**	0.873*	641.67**	0.106 ^{ns}	13.547*
Manure	3	0.102^{ns}	2.548**	71.367 ^{ns}	0.002 ^{ns}	7.413*
Irrigation × Manure	9	3.575 ^{ns}	0.252*	107.21 ^{ns}	0.022 ^{ns}	3.028 ^{ns}
Error	24	5.696	0.159	111.57	0.031	2.220

ns: no significant, *: significant at $P \leq 0.01$ and **: significant at $P \leq 0.05$

3.1 Plant growth variables

Maximum grain yield was at I_{50} treatment that showed an increase of about 54% comparing I_{100} treatment (with minimum grain yield: Table 2). Manure application @ 20 Mg ha^{-1} significantly increased shoot dry weight of maize, but its further application had no effect. The results are similar to those obtained by Mubonderi et al (1999). Ould et al (2010) found that farmyard manure application resulted in 21% higher dry matter yield compared to the control treatments. Findings from Wu et al. (2009) indicated that the average maize yield and dry matter increase was 20.4% and 32.4% for the combined organic manure application and irrigation scheduling based on soil water depletion method.

Table 2. Effects of irrigation and manure treatments on grain yield and shoot dry weight of maize (Effets de l'irrigation et des traitements de fumier sur le rendement en grains et poids sec des pousses de maïs)

Manure treatment (Mg ha^{-1})	Irrigation treatment				Mean
	Ic	I_{50}	I_{75}	I_{100}	
grain yield (ton ha^{-1})					
0	12.482	12.571	11.596	7.082	10.933a†
20	12.603	11.915	10.610	9.039	11.042a
40	12.097	14.352	10.089	7.991	11.133a
60	10.478	12.675	11.211	9.431	10.949a
mean	11.91ab	12.789a	10.877b	8.386c	____
shoot dry weight (ton ha^{-1})					
0	16.202	28.911	26.728	16.469	17.084b
20	17.583	21.27	18.889	16.806	18.637a
40	18.378	19.472	18.656	17.567	18.518a
60	16.006	17.202	19.050	17.294	17.388ab
mean	17.042b	19.214a	18.311a	17.041b	____

† Difference among means, in each row or column that have a similar letter, with the Duncan test at P=0.01 are not significant

Experimental results indicated that irrigation treatment had significant effect on WTS at $P \leq 0.01$ level (Table 1). In other words, with increasing water stress, especially if irrigation interval exceeded 10 days, WTS was significantly decreased. But, there was no significant effect on WTS by manure application (Table 3). Decreasing irrigation interval caused significant decrease in seed protein percentage. In other words, seed protein increased under water stressed treatments. The maximum amount of seed protein was found in I_{100} treatment (Table 3). Also, heavy manure application significantly decreased seed protein percent ($P \leq 0.01$). This result can be evaluated in subsequent study.

Table 3. Effects of irrigation and manure treatments on Weight of thousand seed and seed protein of maize (Effets de l'irrigation et des traitements du fumier sur le poids de mille graines et en protéines des graines de maïs)

Manure treatment (Mg ha^{-1})	Irrigation treatment				Mean
	Ic	I_{50}	I_{75}	I_{100}	
Weight of thousand seed (gr)					
0	312.2	305	323	301.2	310.4a†
20	315.5	318.6	316.9	308	314.7a
40	320.5	316.7	306.7	297.9	310.5a
60	318.1	318	322.5	299.6	314.5a
mean	316.5a	314.6a	317.3a	301.7b	----
seed protein (%)					
0	11.0	11.8	11.4	12.3	11.6a†
20	11.9	11.2	11.5	11.8	11.6a
40	11.5	11.6	11.6	12.0	11.7a
60	10.4	10.9	10.5	11.0	10.7b
mean	11.2b	11.4b	11.3b	11.8a	____

† Difference among means, in each row or column that have a simlcar letter, are not significant with the Duncan test at P=0.01

3.2 Irrigation water Indices

WUE was affected by irrigation treatment significantly at P≤0.05 (table 1). The maximum WUE was observed in I_{75} treatment that showed 10% increase in comparison to I_{100} treatment (Table 4). Average irrigation interval for Ic (local practice or control), I_{50}, I_{75} and I_{100} irrigation treatment was 8, 6, 8, and 10 days, respectively. But, these times were variable in different growth stage. In I_{75}, treatment, average applied water was decreased by about 24% in comparison to I_{50} treatment (Table 4). Maximum irrigation water and dry matter production was under the I_{50} treatment. In this treatment, application of water up to about 17292 m^{-3} ha^{-1} could increase dry matter production. This result was in contrast to Farshi et al. (1998) findings. They calculated maize water need of about 8520 m^{-3} ha^{-1} for Khorram Abad area using different models.

Results from table 4 indicated that Application of manure significantly decreased irrigation water need. This can be an indication of the effects of manure application on soil organic matter enhancement and water retention capacity of soil. Ould et al (2010) had indicated that farmyard manure application resulted in 78% higher soil water retention compared to the control treatments.

Table 4. Effects of irrigation and manure treatments on WUE and irrigation water used (Effets des traitements d'irrigation et de fumier sur l'efficacité d'utilisation de l'eau et l'irrigation de l'eau utilisée)

Manure treatment (Mg ha^{-1})	Irrigation treatment				Mean
	Ic	I_{50}	I_{75}	I_{100}	
Water use efficiency (kg m^{-3})					
0	0.83	0.69	0.87	0.60	0.75a
20	0.81	0.67	0.87	0.87	0.76a
40	0.80	0.84	0.77	0.70	0.78a
60	0.67	0.76	0.81	0.84	0.77a
mean	0.78ab	0.74b	0.81a	0.73b	____
Water used (m^3 ha^{-1})					
0	13211.75	17614.58	13218.2	11993.75	14009.57ab
20	13903.5	17848	13268.5	11809	14207.25a
40	13554	16994	12925	11589.2	13765.55b
60	13662.5	16709.35	13217.5	11380.4	13742.44b
mean	13582.94b	17291.48a	13157.3b	11693.1c	____

† Difference among means, in each row or column that have a similar letter, are not significant with the Duncan test at P=0.01

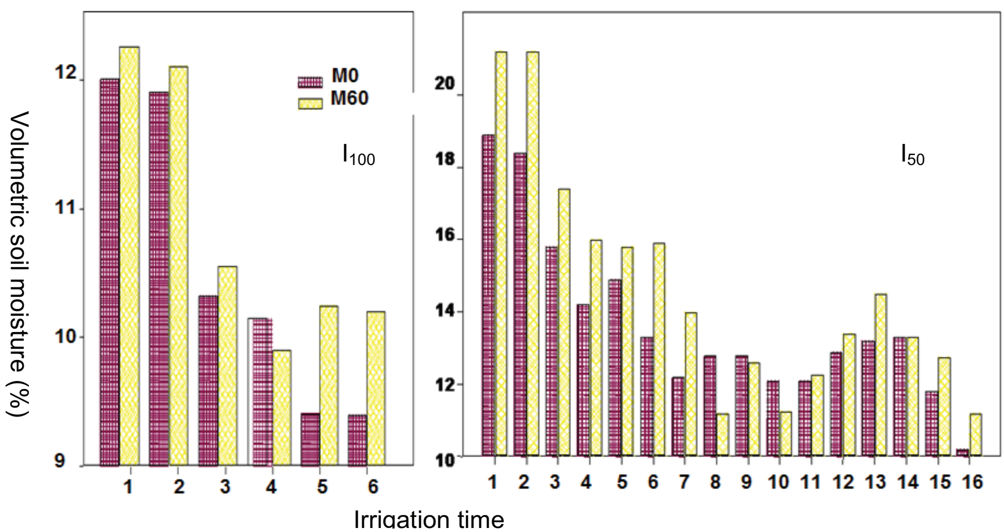

Fig. 1. Effect of manure application (0 and 60 Mg ha^{-1}) on average soil moisture content before irrigation in two irrigation treatment (Effet de l'épandage de fumier (0 et 60 Mg ha^{-1}) sur la teneur moyenne en eau d'irrigation avant des sols dans deux irrigation traitement).

An overall evaluation of volumetric soil moisture content, immediately before irrigation, indicated that there was no simultaneous trend in depletion of soil moisture and evaporation from A class evaporation plate. Because of evapotranspiration surface increasing, in the last growth stage soil moisture depletion was higher than the first one. Application of manure fertilizer increased soil moisture retention capacity, which decreased the needs for irrigation water. As showed in Fig. 1, application of 60 Mg ha^{-1} manure, in about 80% of irrigation cases, increased measured soil moisture immediately before irrigation, while irrigation water depth decreased.

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