CARBON DIOXIDE EXCHANGE RATE AND NITROGEN PARTITIONING OF SPRING WHEAT GROWN UNDER DIFFERENT SOIL MOISTURE AND NITROGEN CONDITIONS

KARROU, M. *

INTRODUCTION

In dryland regions of Morocco, water stress can occur at any stage of development of wheat (Watts and El Mourid, 1988) . This stress can be followed by wet conditions under certain circumstances . Plants that are able to recover rapidly from this abiotic stress are researched (Amri, 1992) . This recovery depends on the degree of water stress and on time of occurrence and can be influenced by nitrogen nutrition. Under high N level conditions (Nilovskaya, 1987), the rate of photosynthesis decreases markedly at a soil moisture content of 14 % maximum water capacity ; whereas for plants under inadequate supply of N, the decrease in photosynthesis activity occurs more smoothly . The rapid drop in the rate of photosynthesis in the case of high levels of N, P and K in a drought situation has been regarded as an adaptive reaction of the plant to the effect of a water shortage (Yambao and O'Toole, 1984) allowing significant activation of the rate of photosynthesis in the reparation period . The rapid decrease of photosynthesis under water stress when high N is supplied can be an advantage only when this stress is followed by wet conditions. However, when water stress is permanent, low N plants have the ability to photosynthesize longer because their CER is less affected by decreases in leaf water potential (Morgan, 1986) .

---

* Chercheur au Centre Aridoculture, INRA Settat BP 589 .

Nitrogen uptake and partitioning of N among different parts of the plant are other parameters that can be affected by abiotic stresses . Nicolas et al. (1985) found that the uptake of N was reduced under drought by 50 and 94 % in two wheat cultivars . Moreover, N redistribtion from vegetative organs accounted for more than 60 % in the control and 70 % in water stressed plants of the N needed for ear growth .

The objectives of this study were to gain more understanding on the combined effect of water stress and N on CO2 exchange rate and on N partitioning among plant parts and to determine if N supply helps the water stressed plants recover better after rewatering .

MATERIALS AND METHODS

The experiment was conducted in the growth chamber using a split plot design with water regime (WR) as the main plot, nitrogen (N) as the split plot and wheat cultivar as the split split plot . Each treatment was replicated three times . Four water regimes were created by maintaining the soil mixture (1 : 1 soil/sand) in the pot at field capacity during the whole period of the experiment (WR1), by stressing plants, during early stem elongation (WR2), around anthesis (5 days before and 5 days after anthesis, WR3), and during milky-dough stage (WR4) . Stress was applied by withholding water for 10 days only during the periods mentioned before for each treatment . Before and after water stress period, soil moisture in the pots was kept around field capacity .

Nitrogen treatments (Nit) consisted of 2 levels . Low soil N concentration (LN), corresponding to 7 mg of NO^{-}_{3} - Nkg^{-1} of dry soil mixture and high soil N level (HN) which was around 15 mg of NO^{-}_{3} - Nkg^{-1} of dry soil mixture . These treatments were obtained by applying 200 ml of complete Hoagland nutrient solution, twice a week in the case of HN . Identical quantity of the same solution, but without N, was provided for NL. The bread wheat (**Triticum aestivum** L.) cultivars (Cult) chosen for this study were Nesma, a relatively older variety with wide adaptation , Merchouch 8, a newer cultivar that has some adaptation to the semi arid areas of Morocco and Saada, a higher tillering variety that appeared to be more sensitive to drought late in the growing season (during the grain filling).

Light was provided in the growth chamber with 1000-Watt metal halide lights placed one meter above the pots from 700 to 1900 hours . Day/night temperature and relative humidity were 27/18° C and 50/50 %, respectively.

Ten seeds were sown in each pot . At 2-leaf stage, seedlings were thinned to two plants pot^{-1} . Leaf CO2 exchange rate was measured at boot stage and on the last day of water withholding for WR3 and WR4 treatments with the infrared CO_2 analyzer (Model 6200, Li-Cor., Lincoln, NE) .

One plant pot^{-1} was harvested 5 days after anthesis (last day of water stress for WR3) and at physiological maturity . These plants were oven dried at 70° C for 48 hours . Leaves and stems were separated and then weighed and analyzed for N content using the Kjeldhal prodedure .

The ANOVA was performed using SAS statements .

RESULTS

Carbon exchange rate (CER)

Water stress imposed during early stem elongation (Table I) did not affect CER at boot stage . Plants rewatered after stress recovered and were able to photosynthesize as high as the nonstressed plants . High N increased CER at boot stage . Merchouch 8 tended to maintain its CER relatively higher than those of the other cultivars under most situations . However, this difference was statistically not significant .

At 5 days after anthesis (Table II), CER decreased for all water regime treatments . Water stress around anthesis decreased CER measured just before rewatering . This decrease was more severe under high than under low N. In the case of the nonstressed plants and the plants that were stressed during early stem elongation, N improved CER at 5 days after anthesis . Overall, the cultivar Merchouch 8 maintained its CER higher than other varieties . Saada however, had the lowest values .

Water stress during grain filling (Table III) reduced CER more under low than high N. All the cultivars recovered partially from stress imposed around anthesis under high N. However, the recovery was complete under low N. Nesma recovered better than the other cultivars . Stress imposed during early stem elongation improved CER during grainfilling especially under low N for Nesma and Merchouch 8 .

Nitrogen partitioning within the shoot

Table IV shows that 5 days after anthesis, leaf N content plant^{-1} was affected by water regime, nitrogen level and water regime x N interaction . In fact water stress imposed during elongation tended to improve leaf N content 5 days after anthesis . Water withholding around anthesis reduced N accumulation in the leaves . For all water regimes, N supply increased N content of the leaves . However, this effect was more pronounced when water was withheld during stem elongation than during other stages .

Stem N content plant^{-1}, 5 days after anthesis, is reported in Table V . The analysis of variance shows that this parameter was affected by N supply and the cultivar . Water regime and the interactions were not significant . Again N supply increased stem N content .

Although water stress during stem elongation tend to increase stem N content, this effect was statistically not significant . Nesma and Merchouch 8 absorbed more N than Saada .

At physiological maturity (Table VI), leaf N content plant^{-1} was affected

Tableau I : **CO2 exhange rate at boot stage of three bread wheat cultivars grown under different soil moisture regimes and soil N levels .**

		Nesma	Merchouch 8	Saada	Mean/N level	Mean/water regime
WR1	LN	13,96	18,25	17,08	16,43	17,10
	HN	17,92	19,61	15,78	17,77	
Mean		15,94	18,93	16,43		
WR2	LN	13,68	18,46	18,34	16,83	18,66
	HN	20,80	21,46	19,22	20,49	
Mean		17,24	19,96	18,78		
Overall Mean		16,59	19,45	17,60		
LSD at 0,05		Nit : 1,11				

Tableau II : **CO2 exhange rate 5-days after anthesis of three bread wheat cultivars grown under different soil moisture regimes and soil N levels .**

		Nesma	Merchouch 8	Saada	Mean/N level	Mean/water regime
WR1	LN	11,83	14,39	9,95	12,06	13,24
	HN	15,01	16,65	11,60	14,42	
Mean		13,42	15,52	10,77		
WR2	LN	11,75	15,77	11,91	13,14	14,93
	HN	16,88	17,78	15,47	16,71	
Mean		14,31	16,77	13,69		
WR3	LN	6,80	2,62	1,58	3,66	2,56
	HN	0,92	2,87	0,59	1,46	
Mean		3,86	2,74	1,08		
Overall Mean		10,53	11,68	8,52		
LSD at 0,05		WR : 2,41		cult. : 1,49		

Tableau III : **CO2 exhange rate at milky-dough stage of three bread wheat cultivars grown under different soil moisture regimes and soil N levels .**

		Nesma	Merchouch 8	Saada	Mean/N level	Mean/water regime
WR1	LN	9,81	8,18	9,89	9,29	11,90
	HN	14,77	14,07	14,68	14,50	
Mean		12,29	11,12	12,28		
WR2	LN	13,33	11,15	8,32	10,93	13,16
	HN	15,74	15,65	11,54	15,39	
Mean		14,53	13,40	12,54		
WR3	LN	11,47	8,92	8,51	9,63	7,77
	HN	9,47	5,36	2,90	5,91	
Mean		10,47	7,14	5,70		
WR4	LN	3,14	4,27	3,37	3,39	4,89
	HN	7,13	6,35	5,11	6,20	
Mean		5,13	5,31	4,24		
Overall Mean		10,60	9,24	8,44		
LSD at 0,05		WR : 1,09		Nit : 1,26	Cult : 1,05	

Tableau IV : **Leaf N content plant^{-1} at anthesis of three bread wheat cultivars grown under different soil moisture regimes and soil N levels .**

		Nesma	Merchouch 8	Saada	Mean/N level	Mean/water regime
WR1	LN	9,82	6,98	8,27	8,36	12,44
	HN	17,82	17,08	14,63	16,51	
Mean		13,82	12,03	11,45		
WR2	LN	7,76	9,96	6,41	8,04	14,01
	HN	17,96	20,82	21,12	19,97	
Mean		12,86	15,39	13,76		
WR3	LN	6,56	6,33	6,80	6,56	9,37
	HN	13,27	11,77	11,46	12,17	
Mean		9,91	9,05	9,13		
Overall Mean		12,20	12,16	11,45		
LSD at 0,05		WR : 1,17		Nit : 1,55		

only by N and cultivar . Water regime and interactions effects were not significant . In general, leaf N content was improved by N supply and the cultivar Nesma maintained more N in its leaves than Merchouch 8 and Saada .

Stem N content plant^{-1} at physiological maturity is reported in Table VII . Data shows that this parameter was affected by water regime, soil N concentration, cultivar and water regime x N. Overall, N supply improved stem N content and Merchouch 8 kept less N in its stems than Nesma and Saada . Water stress imposed during stem elongation and around anthesis tended to increase stem N content at physiological maturity . Under low N level, stem N content was similar for all water regimes . Under high N, water stress during stem elongation and around anthesis improved the quantity of N in the stems at physiological maturity .

Grain N (Table VIII) was affected by water regime variation, soil N level, and water regime x N interaction . Water regime during grain filling did not affect the accumulation of N in the grain . However, stress around anthesis reduced tremendously N translocation to the grain . Water stress during stem elongation increased, however, the level of N in the kernels .

DISCUSSION

The capacity of the plants to maintain growth and photosynthesis under water stress and to recover rapidly from this stress when the soil moisture regime becomes favorable is one of the mechanisms of plant adaptation to erratic conditions (Amri,1992) . This plant's response to water stress is a cultivar dependent phenomenon and is affected by time of stress occurence and by nitrogen avaibility in the soil . In fact, Blum et al. (1990) found that wheat plants were more sensitive to drought during early than late tillering stage and could, under these situations, recover better from the early stress . Our study showed that water stress applied early in the season, if it was not severe enough to kill the plants, seemed not to damage plant tissues . In fact wheat plants showed ability to recover and to photosynthesize at a similar rate to those non water stressed . It seems that, since N uptake was reduced during water withholding period, more N remained in the soil . During the recovery period, this portion of non used N under stress enhaced growth and N accumulation in the leaves and hence photosynthesis . Yambao and O'Toole (1984) showed that the rapid drop in the rate of photosynthesis due to nutrients supply under dry conditions could be regarded as a mechanism that allowed signifcant activation of the rate of photosynthesis during the reparation period .

The cultivars, like Merchouch 8, that produce less total dry matter tend to keep their CER higher than those that accumulate more . Moreover, as the plants become older their capacity of photosynthesis becomes lower . In fact, at 5 days after anthesis, CER decreased for all treatments when compared to CERs measured at boot stage . This phonomenon may have a negative effect on crop production . Peoples et al. (1980) showed that maintenance of active photosynthesis by the flag leaf throughout the period of cereal grain filling was a major requirement for production of adequate carbohydrates to give large grains

Tableau V : **Stem N content plant^{-1} at anthesis of three bread wheat cultivars grown under different soil moisture regimes and soil N levels .**

		Nesma	Merchouch 8	Saada	Mean/N level	Mean/water regime
WR1	LN	12,84	9,94	9,43	10,74	16,42
	HN	22,76	24,42	19,09	22,09	
Mean		17,80	17,18	14,26		
WR2	LN	12,81	16,63	11,74	13,72	20,60
	HN	26,37	28,16	27,87	27,47	
Mean		19,59	22,39	19,80		
WR3	LN	11,75	13,35	11,33	12,14	17,88
	HN	27,06	26,15	17,65	23,62	
Mean		19,40	19,75	14,49		
Overall Mean		18,93	19,78	16,19		
LSD at 0,05		WR : 2,16		Cult : 3,36		

Tableau VI : **Leaf N content plant^{-1} at physiological maturity of three bread wheat cultivars grown under different soil moisture regimes and soil N levels .**

		Nesma	Merchouch 8	Saada	Mean/N level	Mean/water regime
WR1	LN	5,35	3,40	3,62	4,12	5,19
	HN	8,96	4,56	5,24	6,25	
Mean		7,15	3,98	4,43		
WR2	LN	6,01	3,27	3,64	4,31	6,34
	HN	9,20	6,70	9,17	8,36	
Mean		7,60	4,98	6,40		
WR3	LN	4,49	3,20	3,57	3,75	6,09
	HN	9,96	8,57	6,77	8,43	
Mean		7,22	5,88	5,17		
WR4	LN	5,87	2,99	3,40	4,09	5,41
	HN	8,75	5,40	6,04	6,73	
Mean		7,31	4,19	4,72		
Overall Mean		7,32	4,76	5,18		
LSD at 0,05		WR : 0,85		Cult : 1,19		

.Tableau VII : **Stem N content plant^{-1} at physiological maturity of three bread wheat cultivars grown under different soil moisture regimes and soil N levels .**

		Nesma	Merchouch 8	Saada	Mean/N level	Mean/water regime
WR1	LN	4,22	2,87	3,55	3,55	4,54
	HN	5,47	5,61	5,50	5,53	
Mean		4,84	4,24	4,52		
WR2	LN	4,61	3,01	3,39	3,67	6,10
	HN	8,28	7,27	10,00	8,52	
Mean		6,44	5,14	6,69		
WR3	LN	3,42	2,73	3,03	3,06	5,04
	HN	6,70	8,09	6,27	7,02	
Mean		5,06	5,41	4,65		
WR4	LN	4,60	3,20	2,77	3,52	4,63
	HN	6,64	4,71	5,86	5,74	
Mean		5,62	3,95	4,31		
Overall Mean		5,49	4,69	5,05		
LSD at 0,05		WR : 1,39		Nilt : 0,94	Cult : 0,78	

Tableau VIII : **Grain N content plant^{-1} at physiological maturity of three bread wheat cultivars grown under different soil moisture regimes and soil levels .**

		Nesma	Merchouch 8	Saada	Mean/N level	Mean/water regime
WR1	LN	43,92	44,36	41,28	43,19	54,86
	HN	54,49	70,47	74,59	66,52	
Mean		49,20	57,41	57,94		
WR2	LN	40,24	39,05	38,17	39,15	62,23
	HN	92,55	85,31	78,04	85,30	
Mean		66,39	62,18	58,10		
WR3	LN	34,57	35,08	37,01	35,55	38,12
	HN	49,13	36,86	36,08	40,69	
Mean		41,85	35,97	36,54		
WR4	LN	53,93	36,05	39,42	43,13	54,14
	HN	67,51	60,08	61,87	63,15	
Mean		60,72	48,06	50,64		
Overall Mean		54,54	50,90	50,80		
LSD at 0,05		WR : 9,13		Nit : 9,46		

and high yields . In our study, the decrease in CER was more accentuated because of water stress imposed around anthesis . Moreover, although N supply improved CER early in the season (Morgan, 1986) its effect on this parameter was negative when stress was applied around anthesis . It seems that because of high biomass production due to N supply, the competition for water was high during the stress period ; consequently, the soil moisture was depleted earlier and hence stomata were closed more rapidly and CER measured at the end of water withholing period decreased . Morgan (1986) explained that apparent greater drought tolerance of low N wheat plants was related to a greater water retention at lowered leaf water potential, phenomenon that was due to lower tissue elasticity resulted from changes in leaf anatomy .

The effect of water withholding during grain filling was different than its effect when stress was imposed earlier . Under stressfull conditions, low N gave lower CER . This can be explained by the fact that because of lack of N, leaf senescence was accentuated by water stress . Moreover, if plants recovered completely from stress imposed during stem elongation, recovery was just partial when stress was imposed around anthesis . The difference between the two situations was that under early water stress, new leaves appeared and measurements were made on these leaves . When water stress was imposed around anthesis, CER measurements were taken on the flag leaf . The same leaf was chosen for the measurements made later on. Consequently, these measurements were influenced by the leaf age . Although all plants recovered partially from water stress imposed around anthesis, the degree of recovery during grain filling was a cultivar dependent phenomenon . In fact, Nesma recovered better than Merchouch 8 and Saada . The former variety and Merchouch 8, stressed during stem elongation, were able to maintain their CER higher than that of Saada under low N ; because Saada is known for its high and rapid senescence during grain filling period .

Even though nitrogen uptake is known to be reduced by water stress (Nicolas al., 1985) phenomenon observed when plants were stressed around anthesis and when N absorption was measured at the end of the stress period, plants that had been stressed during stem elongation recovered at 5 days after anthesis when they were rewatered and accumulated similar amounts of N in their leaves as the non stressed ones . It seems that these plants increased their rates of N uptake during the reparation period especially when they were supplied with N . Nitrogen accumulated in the stem, 5 days after anthesis, was neither affected by water stress applied during stem elongation nor by that imposed around anthesis.

Leaves and stems are the most important sources of N that accumulates in the grain during the grain filling period (Simpson et al., 1983) . Our data shows that during plant senescence, most of nitrogen accumulated in the leaves during the vegetative stages, except the structural N, was translocated to the grain, assuming that root activity and growth were negligeable during the grain filling period . Mereover, translocation of N from the leaves was not sensitive to water stress imposed during the vegetative and reproductive stages . However, the translocation of this nutrient from the stems to the grain was more affected by water stress especially under high N supply . The results show that the leaf was probably the first organ of the plant to provide N to the grains and that stress affected more the sink (grain production) than the source (N accumulated in the stem) . Nicolas et al. (1985a) found that drought reduced the sink size of grains measured by the number of endosperm cells and starch granules . In this study it seems that the sink was not strong enough to accumulate high quantities of N absorbed previously by the plant .

The cultivar Nesma performed better than Merchouch 8 and Saada . The former variety accumulated similar amounts of N in its grains but maintained higher quantities of this nutrient in the leaves and stems than the other cultivars ; consequently, the quality of its straw was better . The non difference in grain nitrogen yield at maturity was shown by Nicolas et al. (1985) . Straw quality was also increased by N supply .

The analysis of the relationship between CER and N concentration in the leaves and stems at boot stage and 5 days after anthesis showed that the correlation is high in the case of the young flag leaf (R2 =0.67) but becomes lower on older flag leaf (R2=0.33) . No relationship existed between CER and stem N concentration at anthesis .

From this study we can conclude that :

- the capacity of leaf photosynthesis recovery from previous water stress became smaller as the occurrence of this stress was delayed in time . The cultivar Nesma, however, tended to recover better from late stress . Nitrogen supply accentuated the effect on CER of water stress applied during anthesis .

- plants that had been subjected to water stress during stem elongation recovered completely from this stress after rewatering and accumulated similar amounts of N in their leaves and stems as those non stressed . The cultivar, Nesma, performed better than the other cultivars . The quality of its straw was better because it contained higher quantities of N at harvest . Its grain nitrogen yield was similar to that of Merchouch 8 and Saada .

- high correlation was shown between N concentration and CER only in the case of the young leaves .

RESUME

Peu d'informations existent actuellement dans la litterature sur la reprise des plantes après un stress hydrique survenant à différents stades de développement et sous différentes conditions d'alimentation azotée .

L'objectif de cette étude est d'investiguer comment le taux d'échange de CO2 et la répartition de l'azote dans la plante sont affectés par le niveau d'azote dans le sol et par la variation du régime hydrique au cours du cycle de croissance .

Pour atteindre cet objectif, trois variétés de blé tendre, Nesma, Merchouch 8 et Saada ont été cultivées dans des pots sous des conditions de la chambre de croissance . Au cours de la montaison, à l'anthèse et au cours du remplissage du grain, des plantes ont été stréssées par arrêt d'irrigation pour une durée de 10 jours puis réirriguées jusqu'à la maturité physiologique.

Un régime hydrique, consistant en une irrigation continue des plantes durant tout le cycle végétatif a été considéré comme "témoin" . Les deux niveaux d'azote ont été crées par addition de la solution de Hoagland avec et sans azote chaque semaine . Au stade gonflement, 5-jours après l'anthèse et au stade laiteux-pâteux, le taux d'échange du CO2 a été mesuré. La quantité d'azote accumulée dans les différentes parties de la plante a été déterminée 5-jours après l'anthèse et à la maturité physiologique .

Les résultats obtenus montrent que le taux d'échange du CO2 a chuté avec l'âge de la plante . Les plantes qui ont été stréssées au cours de la montaison étaient capables de reprendre à l'anthèse, d'accumuler l'azote et de photosynthétiser normalement comme celles qui n'ont pas été stréssées . L'apport d'azote a augmenté la production de biomasse totale et a accentué l'effet depressif du stress hydrique appliqué à l'anthèse . Les stresses hydriques de la montaison et de l'anthèse ont réduit la translocation de l'azote des tiges vers le grain sous des conditions de sol riche en azote . Cependant seul le stress appliqué à l'anthèse a réduit le rendement azoté du grain . De cette étude on peut conclure que le stress précoce n'avait pas d'effet depressif sur le taux d'échange du CO2 et sur l'accumulation de l'azote dans la plante . L'apport d'azote a stimulé la croissance et le stress hydrique appliqué à l'anthèse a réduit la photosynthèse . Les variétés Nesma et Merchouch 8 ont mieux repris lorsqu'elles étaient réirriguées après avoir subi des stresses hydriques à la montaison et à l'anthèse .

ABSTRACT

Little is known about wheat recovery from water stress applied at different stages of development under different soil N conditions . The objective of this study was to investigate how CO2 exchange rate (CER) and nitrogen (N) partitioning within the shoot are affected by soil N level and soil moisture regime variation during the growing season . To reach this objective, three bread wheat cultivars, Nesma, Merchouch 8 and Saada were grown in pots in the growth chamber . During stem elongation, around anthesis and during the grainfilling period, plants were stressed by withholding water for 10 days . After each stress, plants were rewatered until physiological maturity . Moreover, one water regime treatment was continuously watered during the whole growing season as a check . Nitrogen levels were created by adding Hoagland solution with and without N to the pots each week . At boot stage, 5-days after anthesis and at milky-dough stage, CER was measured. At 5-days after anthesis and at physiological maturity, nitrogen concentration was measured in different parts of the plants and N contents of these organs were calculated . Data showed that CER decreased with plant age . Plants that were water stressed during stem elongation were able to recover at anthesis and to accumulate N and photosynthesize normally like the non stressed ones . Nitrogen supply increased biomass production and hence accentuated the depressive effect of water stress applied around anthesis. Water stress during stem elongation and around anthesis reduced nitrogen translocation from the stems to the grains under high N supply . However, only stress around anthesis reduced grain N yield . From this study we can conclude that early stress did not have any depressive effect on CER and N accumulation in the plants . Nitrogen supply stimulated growth and hence water stress around anthesis reduced photosynthesis . Nesma and Merchouch 8 recovered better from water stress applied during stem elongation and around anthesis .

بتكوين الحب . لهذا كان هذا الحب غير قادر على استعمال كميات كبيرة من النيتروجين الموجودة في ساق النبات في حالة كثرة هذه المادة في التربة . إن الضغط المائي في طور الإزهار هو الوحيد الذي سبب في تخفيض الإنتاج النيتروجيني في الحبوب . ومن خلال هذه الدراسة يمكن أن نستخلص أن الضغط المائي المبكر ليست له أي فعالية على نسبة تبادلات ثاني أكسيد الكربون وعلى امتصاص النيتروجين من طرف النبات ، وأن التسميد بالنيتروجين قد ساعد على النمو .

ونستنتج كذلك من هذه التجربة على أن الجفاف وقلة الماء غداة الإزهار يُسَبِّبان النقص في التركيب الضوئي وأن الصنفين النسمة ومرشوش 8 أكثر قدرة على استرجاع نموهما بعد ضغط مائي أجبرنا عليه في وقت نمو الساق وفي طور الإزهار.

ملخص

يعرف القليل عن استطاعة القمح لاسترجاع قدرة النمو بعد تعرضه للضغط المائي (stress hydrique) و لتغير كميات مادة النتروجين الموجودة في التربة .

والهدف من هذه الدراسة هو تحقيق فعالية مستوى النيتروجين في التربة و تغير أنظمة الماء على نسبة تبادلات ثاني أكسيد الكربون و على توزيع مادة النيتروجين بين أعضاء نبات القمح خلال دورة النمو . للوصول إلى هذا الهدف زرعت ثلاثة أصناف من القمح الطري في أواني (pots) و وضعت في غرفة النمو (chambre de croissance) . تعرضت هذه الأصناف المزروعة إلى ضغط مائي خلال نمو ساق نبات القمح (montaison)، وقت الإزهار و غداة امتلاء الحب ، وذلك بإيقاف السقي ، بصفة نهائية لمدة عشرة أيام في كل مرحلة . وفي اليوم الآخر من كل مدة الإمساك عن السقي قمنا مرة أخرى بسقي هذا النبات إلى غاية نضج الحبوب .

وهكذا اعتبر النظام المائي الذي لم يعرض لأي ضغط مائي طيلة الدورة النباتية كشاهد في هذه التجربة . أنشئت مستويات مادة النيتروجين بسبب إضافة محلول «هوكلاند» (hoagland) المحتوية و الغير المحتوية على مادة النيتروجين

وفي طور انتفاخ السنبلة (gonflement)، بعد مرحلة الإزهار بخمسة أيام وخلال الطور الحليبي -العجيني (laiteux - pateux) للحبة قمنا بقياس نسبة تبادلات ثاني أكسيد الكربون في أوراق القمح . كما حللت كذلك كثافة و كمية مادة النيتروجين في أعضاء مختلفة للنبات بعد الإزهار بخمسة أيام و في مرحلة نضج الحبوب . حيث أبانت النتائج المحصل عليها أن نسبة تبادلات ثاني أكسيد الكربون قد انخفضت كلما تقدم نبات القمح في العمر . إن النباتات التي تعرضت لضغط مائي غداة نمو ساق النبات كانت قادرة على استرجاع نموها في وقت الإزهار ، على مص مادة النيتروجين و على مواصلة الترتيب الضوئي . في هذه المرحلة صارت هذه النباتات لا تختلف عن الأخرى التي لم تعرض لأي جفاف . لقد سبب التسميد بمادة النيتروجين في ارتفاع إنتاج كل المادة اليابسة و في تشديد فعالية الضغط المائي المسلط على النبات في وقت الإزهار . قد يكون أن من المحتمل أن يكون الضغط المائي الذي تعرض له القمح في طور نمو الساق و عند الإزهار قد ضر

REFERENCES BIBLIOGRAPHIQUES

AMRI, A. 1992 . Caractérisation de l'environnement et stratégies d'amélioration génétique de l'orge . Mémoire pour le concours d'ingénieur en Chef - INRA .

BLUM, A.,.S. RAMAIAH, E. T. KANEMASU and G. M. PANKEN . 1990 . Wheat recovery form drought stress at the tillering stage of development . Field Crops Research 24 : 67-85 .

MORGAN, J. 1986 . The effects of N nutrition on the water relations and gas exchange characteristics of wheat (**Triticum aestivum** L.). Plant Physiol. 80 : 52-58.

MORGAN, J. 1988 . Growth and canopy carbon dioxide exchange rate of spring wheat as affected by nitrogen status . Crop Sci . 28 : 95-100 .

NICOLAS, M. E., R. M. GLEADOW and M. J. DALLING . 1985a . Effect of post-anthesis drought on cell division and starch accumulation in developing wheat grains . An. of Botany 54 : 433-444 .

NICOLAS, M. E., R. J. SIMPSON, H. LAMBERS and M. J. DALLING . 1985 . Effects of drought on partitioning of nitrogen in two wheat varieties differing in drought tolerance . An. of Botany 54 : 743-754 .

NILOVSKAYA, N. T., E. V. MOROZOVA, T. V. MOISEEVA and A. D. MOISEEV . 1988 . Doklady vsesoyuznoi akademii sel'skokhozyaistvennykh Nauk . Im. Lenina, n°4, pp 7-10 .

PEOPLES, M. B., V. C. BEILHARZ, S. P. WALTERS, R. J. SIMPSON and M. J. Dalling . 1980 . Nitrogen redistribution during grain growth in wheat (**Triticum aestivum** L.) . II . Chloroplast senescence and the degradation of ribulose - 1,5 - bisphosphate carboxylase. Planta 149 : 241-251 .

SIMPSON, R. J., H. LAMBERS and M. J. DALLING . 1983 . Nitrogen redistribution during grain growth in wheat (**Triticum aestivum** L.) . Plant Physiol . 71 : 7-14.

WATTS, D. G. and M. EL MOURID . 1988 . Rainfall patterns and probabilities in the semi-arid cereal production region of Morocco . USAID Project n° 608-0136 . Aridoculture Center, INRA, Morocco .

YAMBAO, E. B., J. C. O' TOOLE . 1984 . Effects of nitrogen nutrition and root medium water potential on growth, nitrogen uptake and osmotic adjustment of rice. Plant Physiol . 60 : 507-515 .