Comparative yield performance and adaptation of some barley and triticale genotypes under rainfed conditions

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Abstract

The production of a new species such as triticale, requires the delimitation of the agroecological environments where its cultivation is expected to compete favorably with traditionally grown crops. Previous work has shown that triticales offer a superior resistance to frost, a better initial growth at low temperatures, a higher resistance to diseases mainly during grain filling and ripening, and an improved amino-acid composition over wheat and barley. Moreover, the triticales show a distinct yield advantage over wheat mainly when grown in acidic soils. However, under low rainfall areas, their relative merits in comparison with barley are not clearly assessed. A preliminary assessment of the yield potential of triticale in the drier areas of West Asia and North Africa has been carried out over six years (1978-1983). Although selection has improved their yielding ability over the study period, the yields of triticale were constantly below the mean yields obtained when averaging over sites. When the testing sites were grouped into the four broad geographical regions of North Africa, Mediterranean West-Asia, Non-Mediterranenan West-Asia, and the rest of the world, grain yields of triticale overs six seasons, were constantly higher in the "rest of the world" group. Stability analysis, using the regression technique of Finlay and Wilkinson showed that triticales were generally similar to barley in low yield environments but were less responsive to improved conditions. However, locations characterized by long vegetative periods of growth, high rainfall and high incidence of diseases, favored triticales. Finally, environments where triticales outyielded locally grown barley cultivars for two to three season were identified.

Key words : *Hordeum vulgare*, triticale, adaptability, stability, agro-ecological zoning, semi-arid conditions

Résumé

Comparaison des performances de rendement et de l'adaptation de génotypes d'orge et de triticale en conditions d'agriculture pluviale.

Le développement d'une espèce nouvelle telle que le triticale, nécessite la détermination des conditions agro-écologiques dans lesquelles sa culture devra se montrer plus avantageuse que les cultures traditionnelles. Le triticale présente par rapport aux autres céréales dans la région méditerranéenne, une bonne vigueur initiale associée à une faible sensibilité au froid au stade plantule, une meilleure résistance aux maladies pendant la maturation ainsi qu'une meilleure qualité des protéines. Toutefois, si ses avantages du point de vue rendement, en dépit d'un léger échaudage des grains, restent nets par rapport aux blés, particulièrement en sols acides, sa compétitivité par rapport à l'orge en zone à faible pluviométrie est incertaine. Un travail préliminaire ayant pour objectif d'évaluer le potentiel des triticales et leur adaptation aux zones sèches du Moyen-Orient et de l'Afrique du Nord, a été mené pendant six ans. Les triticales sont comparés aux orges. Malgré une nette amélioration par la sélection, les triticales ont donné des rendements inférieurs à la moyenne générale des essais. Toutefois, lorsque les environnements ont été groupés en quatre zones géographiques : une nord-africaine, une moyen-orientale méditerranéenne, une moyen-orientale continentale et le reste du monde, les triticales ont donné de meilleurs rendements dans le reste du monde. L'analyse de la stabilité par la méthode de Finlay et Wilkinson a montré que les triticales ont une réponse généralement similaire à celle de l'orge dans des conditions de faible pluviomètrie, mais n'augmentent pas sensiblement leur rendement lorsque les conditions redeviennent favorables. La performance des triticales a été, toutefois, supérieure à celle des orges lorsque les conditions climatiques ont favorisé le développement des maladies et des génotypes à longue période végétative. Des localités ont été identifiées dans lesquelles les triticales se sont montrés plus performants que les orges locales pendant 2 ou 3 saisons.

Mots-clés : *Hordeum vulgare*, triticale, adaptabilité, stabilité, zones agro-écologiques, zones semi-arides

ملخص

مقارنة إنتاج و ملائمة أصناف من الشعير والتريتكال في ظروف الزراعة المطرية

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يتطلب تطوير نوع جديد من المزروعات مثل التريتيكال معرفة الضروف الفلاحية والبيئية التي يكون فيها هذا النوع الجديد متميزا عن المزروعات التقليدية. يتميز التريتيكال عن باقي الحبوب في منطقة البحر الأبيض المتوسط بنمو قوي في البداية مع مقاومة البرد في مرحلة النبتة، ومناعة ضد الأمراض في مرحلة النضج وبجودة عالية للبروتينات. وإذا كان التريتيكال يمتاز على القمح بمردودية عالية خاصة في الأراضي الحامضة، فإن منافسته للشعير تظل غير مؤكدة. أقيمت تجارب لمدة ست سنوات لتقييم طاقة التريتيكال وملائمته للمناطق الجافة في الشرق الأوسط وشمال إفريقيا بالمقارنة مع الشعير. رغم التحسين بالإنتخاب، كان مردود التريتيكال أقل من معدل المردود العام للتجارب. لكن عندما قسمت البيئات إلى أربعة أصناف : شمال إفريقية، شرق أوسطية متوسطية، شرق أدنوية داخلية وباقي العالم، كانت مردودية التريتيكال هي أعلى في باقي العالم. وبين تحليل الإستقرارية بطريقة فينلي وويلكنسون أن مردودية التريتيكال تشابه مردودية الشعير في المناطق القليلة الأمطار ولا تزداد مردوديته إذا زادت كمية الأمطار. لكن مردودية التريتكال كانت أعلى من مردودية الشعير كلما سمحت الظروف المناخية بنمو الأمراض والأصناف المتأخرة. وقد تم التعرف على مناطق كانت فيها مردودية التريتيكال أحسن من مردودية الشعير خلال سنتين إلى ثلاث سنوات.

الكلمات المفتاحية : الشعير، التريتيكال، ملائمة، استقرارية، المناطق البيئية، المناطق شبه الجافة

Introduction

Barley is a species well adapted to the drier areas of West Asia and North Africa, where it has been cultivated for a long time (Harlan 1976). Though for economic and food availability reasons it has been surpassed by wheat, it still covers 10 millions hectares. In the drier Mediterranean areas (350mm or less rainfall), it predominates over wheat, being more dependable under low soil fertility and drought conditions (Srivastava 1981).

Triticale, on the other hand, is a new man made cereal, unfamiliar to the cereal growers of the region. It has been characterized as tolerant to environmental stresses and to perform better than wheat in areas where cool temperatures prevail early in the season, as well as on sandy and low fertility soils (Zillinsky 1974).

Research carried out at ICARDA has also shown that it has higher disease resistance and yield potential than both durum and bread wheat. However, its performance in the drier, barley growing areas of West Asia and North Africa, and its relative merits and disadvantages in comparison with barely are not clearly assessed.

The main objective of this paper is to make a preliminary assessment of the potential of triticale in the drier areas of West Asia and North Africa (henceforth referred to as WANA), and to present results over six seasons (1977/78 to 1982/83) of the relative yield performance and yield stability of barley and triticale in the Regional Barley Trial (RBYT) when tested over a wide range of environments.

Materials and methods

The results presented in this paper are extracted from data of the Regional Yield Trial, collected by ICARDA or by cooperating national institutions, and covering the six years period 1977/1978 to 1982/1983. The original trials data, excluding those dealing with barley *versus* triticale comparisons reported here, are published and distributed annually in the Cereal International Nursery Report, ICARDA, where the performance and adaptability of all the genotypes studies are included. The RBYT is an international nursery, sent out every season from ICARDA to cooperating research programs; it tests ICARDA and cooperating national programs' best genotypes which have already been identified as promising and widely adapted in the region when grown over a wide range of environments in a non-replicated Barley Observation Nursery. The RBYT comprises 24 entries (except the 1977/1978 RBYT which had 25 entries) including 19 to 20 elite barley lines, one long term barley check (cv Beecher), one national barley check, one or two triticale checks and zero to one durum wheat check. The purpose of including triticale and durum is to compare the relative performance and adaptation of the three cereal species to the different agroecological niches of the region. The triticale genotypes included in the RBYT were constantly the newest and highest yielding lines identified and selected by ICARDA for the region from CIMMYT developed germplasm. In this paper, whenever two triticale lines are included in the trial, the results considered for comparison are those of the better lines. The triticale lines included in the RBYT were:

77/78 season:	M2A (x2802-41n-1M-2M-1Y-1M-OM-OY)
79/80 and 80/81 season:	Beagle
81/82 and 82/83 season:	Drira/M2A (x15893/PDBC-361)

The testing sites were arbitrarily grouped into four classes, on the basis of the mean grain yield. The objective is to allow for the comparison of the responsiveness of barley and triticale to high risk and stress environments, and to degrees of improving conditions. The four yield groups identified were :

1. Low yield environment: site mean yield less than 1500 kg/ha.
2. Moderate yield environment: site mean grain yield between 1500 and 3000 kg/ha.

3. High yield environment: site mean grain yield between 3000 and 5000 kg/ha.
4. Very high yield environment: site mean grain yield exceeding 5000 kg/ha.

Additionally the regression technique of Finlay and Wilkinson (1963) was used to compare the stability of the genotypes.

Results

Performance over all environments

Selection improved the yielding ability of triticale over the six seasons. Figure 1 shows the mean grain yield and the ranking of the triticale lines and those of Beecher, the long term check. Triticale performed lower than Beecher initially (a

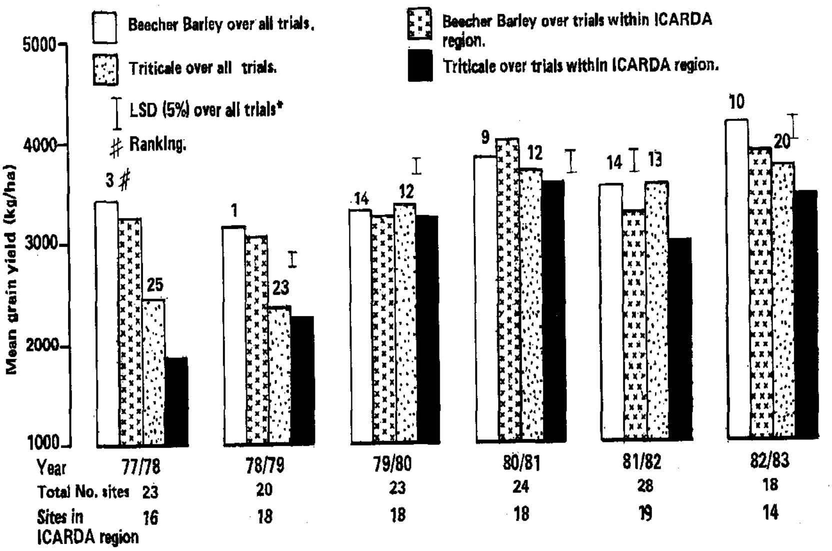

Figure 1. Comparison of the mean yield and ranking triticale with Beecher Barley in the Regional Barley yield Trial from 1977-78 to 1982-83 seasons. Averaged over all trials and within the ICARDA region. * LSD calculated from data of 21 locations only for 1977/78. A fixed model was considered.

difference of 800 kg/ha or more) but in the following three seasons (79/80, 80/81 and 81/82) its grain yield increased and attained the yield of the long term check.

The ranking of triticale among the barley genotypes improved over the years in parallel with its mean grain yield (Figure 1). It should be noted that as the triticale improved sharply its ranking, the ranking of Beecher dropped also sharply from Ist to 14th and then remained relatively stable afterwards (9th to 14th). The triticale, however, showed a new drop to 20th in the 1982/1983 season.

The yielding performance, agronomic characteristics, and diseases resistance of Beecher barley and triticale over the six seasons in the RBYT are presented in table 1. The number of locations at which triticale was among the top yielding entries doubled between 1978/79 and 1979/80 seasons (Table a). Triticale had similar heading time to Beecher in the first three seasons, but tended to be 4 to 5 days later heading in the following three seasons, and it was 5 to 12 days later maturing than Beecher except in 1977/78 and 1979/80 seasons. Triticale was also 10 to 17 cm taller than Beecher in the last four seasons. Therefore, after the first cycle of selection, the triticale tended to become taller, later heading and maturing than the barley check. Table 1. shows that triticale is resistant to most barley diseases. Triticale is resistant to yellow rust (*Puccinia striiformis*), stem rust (*Puccinia graminis*), net blotch (*Pyrenophora teres*), and spot blotch (*Cochliobolus sativus*), and has better disease resistance than Beecher to leaf rust (*Puccinia hordei*) and powdery mildew (*Erysiphe graminis*).

Performance within the ICARDA region

The ICARDA region covers West Asia and North Africa (WANA) and extends from Morocco West to Pakistan in East and from Turkey North to Sudan and Ethiopia South. Within this region a trend of improvement through selection, similar to that obtained when considering the overall performance over all environments was discernible (Figure 1). However, in spite of the improvements in their yield levels over years, the grain yields of triticale within the region, were constantly lower than the mean grain yields of Beecher, with the exception of 1979/80 season. Moreover, the performance of triticale in the region, has been poorer than their performance when averaging over all test environments.

Performance Within geographical regions

When the testing sites were grouped into the four broad geographical regions of North Africa, Mediterranean Western Asia, Continental Western Asia, and the rest of the world or non ICARDA region, grain yields of triticale over the six seasons were constantly higher in the non-ICARDA region (Ib). This difference in yield between regions was large in the first three seasons but narrowed down in the second half of the test period. Incidentally, the higher grain yields of Beecher were also, in four out of six seasons, obtained in the non-ICARDA region (not shown in figure 2), indicating that barley is grown in the ICARDA region, under harsher environments than those generally encountered in most of the other barley growing areas of the world. It also indicates that the ICARDA region allows effective selection pressure for drought tolerance. For all the regions, grain yield of triticale relative to that of Beecher improved after 1978/79 as shown in figure 2. Triticale yielded poorly in all regions before 1978/79 season, but outyielded Beecher in some regions afterwards. However, it should be noted that in each of the six seasons, Beecher still outyielded triticale in the Mediterranean West Asia region.

Table 1. Comparison of yielding performance, agronomic characters and disease resistance of Beecher barley with triticale in the Regional Barley Yield Trial over six seasons (1977/78 to 1982/83)

Characters	C	77/78	78/79	79/80	80/81	81/82	82/83
No. of locations where the line	B	13	15	11	11	14	9
national check is outyielded	T	5	5	11	8	13	7
No. of sites where the	B	17	13	10	12	10	10
ranking is among the top 10	T	3	4	10	11	12	8
Days to heading	B	116	104	113	109	110	115
	T	115	105	114	114	115	119
Days to maturity	B	156	143	155	151	149	143
	T	157	150l+	156	156l+	161l+	163
Plant height (cm)	B	91	95	93	90	91	
	T	88	80	112t	110t	100t	106t
Yellow rust (ACI)	B	15	17	0	16	2	
	T	0	0	0	0	1	
Yellow rust (ACI)	B	0	4	33	22	12	
	T	2	0	18	0	1	
Stem rust (ACI)	B	10	5	-	30	9	
	T	0	0	-	1	0	
Powdery mildew	B	3		6	4	5	
	T	0		2	1	0	
Scald	B	0		0	1	1	1
	T	0		3	0	0	0
Nech Blotch	B	0		1	1	9	9
	T	0		0	0	0	0
Spot Blotch	B				2	0	
	T				0	1	

C=Crop : B=barley; T=Triticale. l=later than all barley entries in the trial. t = taller than all barley entries in the trial. ACI = Average Coefficient of Infection. Except for the rusts where ACI were used, all the diseases were scored on a scale of 0 (resistance)-9 (susceptible). The number of locations at which disease data were taken varied between years and between diseases.

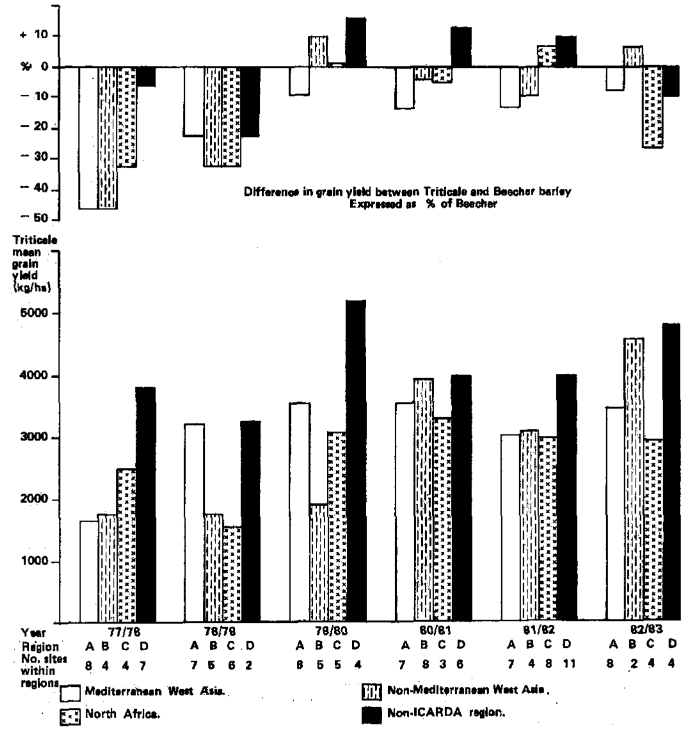

Figure 2. Averaged within each geographical region

Performance Within different yielding categories

The relative performance of triticale in comparison with Beecher barley was very different at the low and the very high yielding sites (Figure 3). Triticale yielded as well as and in some situations better than Beecher at the low yielding sites except in the first season. On the contrary, its grain yield was lower than that of Beecher in the good environments except for the 1979/80. However, it should be pointed out that there was a relatively small number of low yielding sites during the test period, and that there were very high yielding sites in the initial three seasons. For moderate and high yielding sites, triticale yielded less than Beecher in the first three seasons, but its performance improved over the second half of the period. By comparing the results of the initial season (1977/1978) with those of the last season (1982/1983), again it can be seen that selection improved the yielding ability of triticale over the study period.

Individual sites and countries

The adaptability of triticale relative to barley for different countries, for different locations within one country and the consistency of its performance in a given location over seasons was highly variable (Table 2). Sites at which triticale yielded relatively well were: Beja (Tunisia), Terbol (Lebanon), Taiz (Yemen),

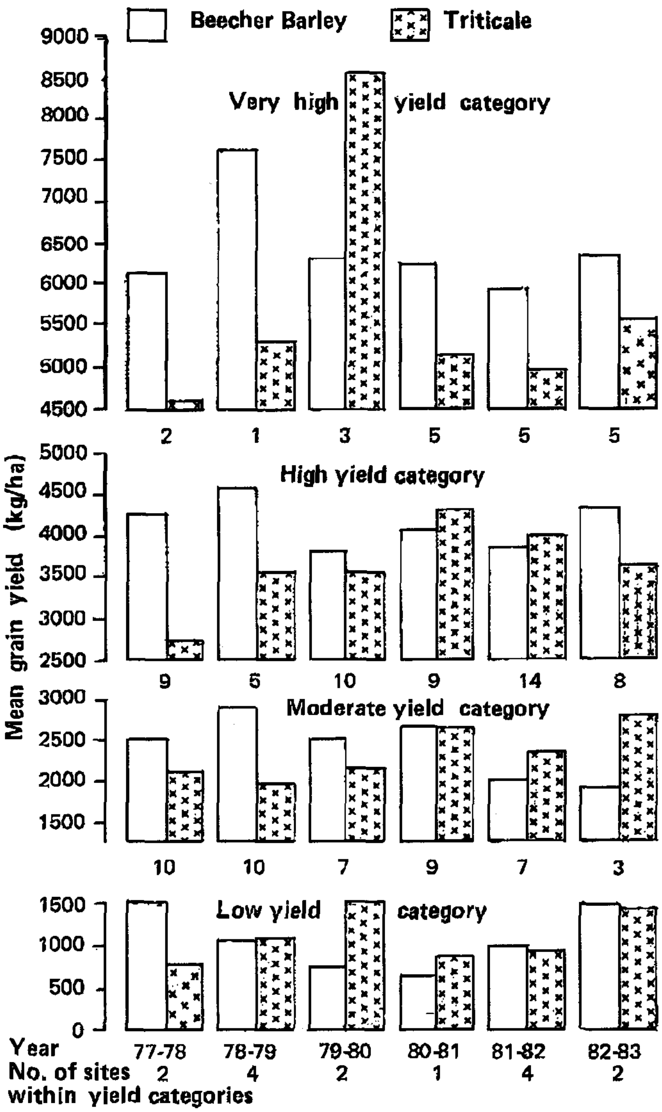

Figure 3. Averaged within each yielding category

Bulkh (Afghanistan), Islamabad (Pakistan), Muan (Korea) and Montpellier (France). It should be noted that all these locations are characterized by long vegetative periods of growth, high rainfall and high incidence of diseases mainly the rusts to which Beecher barley is poorly resistant, whereas triticale has good resistance or immunity. Sites at which triticale yielded relatively poorly were those characterized by high seasonal variations such as Tel Hadya and Izraa in Syria; Ramtha, Rabba, Deir Alla and Jubeiha in Jordan; and le Kef and Hindi Zitoun in Tunisia.

Table 2. Performance of triticale relative to barley at different locations, within different countries in the Regional Barley Yield Trial over six seasons (1977/78 to 1982/83)

Country	Site	77/78	78/79	79/80	80/81	81/82	82/83
Cyprus	Laxia, Athalassa	0.55	0.59	1.03	0.95	0.77	0.96
Turkey	Ankara, Dyarbakir				0.99		
	Adana					0.52	
Syria	Izraa	0.57	1.07	0.77	0.98		
	T.Hadya	0.34	0.57	0.94	0.97	0.89	0.82
Lebanon	Tel Amara, Kfardan	0.54	0.60	1.14	0.84	0.90	1.17
	Terbol		1,79	1,82			
Jordan	Ramtha, Jubeina	0.58	0.70	0.50	0.30	0.38	0.51
	Rabba, Deir Alla	0.53	0.61		0.58	1.36	
Iraq	Sulamaymania,Erbil	0.96	0.98		1.28		
	Dohuk				0,88		
Iran	Karaj, Darab	0.70	0.55		0.76		0.95
	Kelarda						
Arabia	Dirab, Riadh		0.43	3.23	1.52		
	Al Gassim			6.94			
Quatar	Rawdat Harma					0.79	1.00
	Wadi Al Araij						0.72
Oman	Wadi-Qurayat	0.32	0.79	0.53			
Yemen	Taiz	0.46			1.01		
Afgh.	Bulkh, Kabul		0.20	1.15	0.88	1.56	1.13
Paki.	Islamabad				1.54	1.54	
	Faisalabad,				0.73	0.68	
Morocco	Rabat, Merchouch		0.27	1.25		1.19	
Algeria.	Setif	0.54	0.90		1.32	0.86	
Tunisia	Beja			1.70	1.03	1.24	0.74
	Le Kef, Mateur			0.33		0.83	0.69
	H.Zitoun, Barouta			0.97	0.77	0.93	0.66
Libya	Al Marj, Janduba	0.75	0.23				
	Sebha, Tajoura		0.92			1.18	
Egypt	Giza, Gemmiza	0.95	0.62	0.58		0.82	
	Sakha, Sids	0.60	1.06	0.92		0.62	0.84

Table 2. continued

Greece	Thessaloniki	1.86	1.14	0.53	0.52	0.87	1.36
Italy	Cassaccia					1.16	
France	Montpellier			1.27		1.17	1.06
Spain	Mahissa, Gozullata	0.87	0.57	1.12	2.91		
	El Encin					1,63	
Portugal	Elvas	1.65		0.91	1.95	1.02	0.92
Finland	Hankkija					0.98	
USA	Merril (Oregon)			1.38			
Kenya	Njoro					0.90	
Benglad.	Kajbar, Dacca	1.27			1.44		
Korea	Muran				1.25	1.15	

Stability analysis

Stability analysis of the two species using the regression technique following Finlay and Wilkinson (1963) was carried out (Table 3). Triticale genotypes had lower regression coefficients than Beecher, except for 1979/80 season, when it reached its highest yields and outyielded Beecher in good environments. These lower regression coefficients indicate that it is generally less responsive to good conditions. However, triticale had lower correlation coefficients and deviations from the regressions which were generally larger. These results can be explained by the yield performance of the two species. In spite of diseases and lodging, Beecher average yields were constantly higher than the overall site mean yields, while those of triticale, though generally lower than the site mean yields, showed greater variability with locations and seasons. Additionally, triticale ranking showed wide fluctuations between years and locations. Triticale ranked either among the five highest yielding lines or among the five poorest lines most of the time.

Kernel weight and protein content

Throughout the test period, triticale had shrivelled seed, and lower 1000 kernel weight than Beecher barley (Table 4). Shrivelled triticale seeds were however large. The resulting grain as expected, had higher protein percentage than those of normally developed, plump barley grains, except for the 1980/81 season when Beecher had heavier but also higher protein content seed. The protein content of triticale remained relatively stable, while the 1000 kernel weight showed noticeable improvements with the newer triticale genotypes.

Table 3. Linear regression coefficients (b) and correlation coefficients (r) between grain yield of Beetcher and triticale with site mean yield (kg/ha)

Season (1)	b	r	Mean yield	b	r	Mean yield	Mean yield over sites
	Beecher			Triticale			
77/78 (23)	1.09*	.92	3466	.78	.76	2450	3075
78/79 (20)	1.14*	.83	3175	.83	.77	2345	2767
79/80 (22)	1.05	.96	3455	1.34	.87	3584	3440
80/81 (24)	.94	.89	3857	.73	.79	3705	3601
81/82 (30)	1.05	.89	3391	.85	.84	3371	3378
82/83 (20)	1.10*	.96	4577	.81	.87	4079	4296
Mean	1.06	.94	3654	.89	.82	3256	3426

(1) number of trials in brackets
* Significant difference at P= .05 (One tailed test)

Table 4. Average kernel weight and protein percentage of Beecher barley and triticale at Tel Hadya, Syria, from 1977/78 to 1982/83 season

Season	Crop	K.W. (g/100)	Protein (%)
77/78	Barley	40.4	9.8
	Triticale	----	12.8
78/79	Barley	42.1	7.4
	Triticale	----	10.8
79/80	Barley		10.3
	Triticale	34.0	
80-81	Barley	44.0	12.8
	Triticale	35.0	12.2
81/82	Barley	47.7	9.9
	Triticale	36.5	12.6
82/83	Barley	52.6	10.6
	Triticale	48.4	11.6

Table 5. Ranking of the highest yielding barley entries in the Regional Barley yield trial over six seasons (1977/78 to 1982/83)

Season	1st	2nd	3rd	4th	5th
77/78	Cr 366-13-2	Comp. Cr.	Beecheret	Cr.366-16-2	H251-34-
78/79	Beecheret	Cr. 368-4-1	WI 2291	Com.Gr.89	Cr.366-13-2
79/80	Faiz +	WI 2198	CM67/Sv.	M126/CM67	Comp. 29
80/81	Rihane +++	Ky 63-1294	Carina	M126/CM67	
81/82	Rihane	Faiz	Khouzama	Rihane 'S'-	Emir/nordga
82/83	Rihane"S"-	Rihane	Mari/CM67	Khouzama	Faiz +

& Long term barley check
+ ICARDA selected germplasm from introduced segregating populations
++ ICARDA crosses and selection,
+ Faiz : formerly ER/Apam. released in Tunisia in 1984.
+++ Rhinane : released in Spain, Morocco, Algeria, Tunisia and Iraq

Discussion

Yield gains have been achieved by breeding triticale. They are seen when comparing the yield performance of the barley and triticale tested germplasm over six seasons in the RBYT nursery in comparison with the long term barley check Beecher. Triticale was compared with improving sets of barley lines (ICARDA research highlights 1984), and therefore their improved ranking over time indicates important advances in selection of triticale primarily for low yield environments (Fig. 3). There was a surge of new barley lines outyielding the long term check as early as 1979/80 season. By comparing the 79/80 with the 82/83 list of entries, the long term check Beecher and the high yielding improved check Faiz (Formerly ER/Apm) were the only common genotypes to both. Further improvement in the quality of the germplasm after 1979/80 is clearly demonstrated in Table 5. With the introduction into the RBYT of genotypes specifically selected for the dry areas, the ranking of the improved check fell from first to second and 5th place in 81/82 and 82/83, respectively. These improving barley yield levels make it difficult to assess the progress made in triticale improvement as we are comparing with increasing values. Therefore, improved ranking of triticale in comparison with the long term check and with better barley genotypes is an assurance that progress made in triticale breeding is even greater than what it appears from ranking alone. In fact, there is a marked improvement in yield levels of triticale. Initial improvement in triticale performance started in 1979/80 when the triticale line Beagle was introduced. The triticale line Drira/M2A (X15893), was similar to Beagle in yield potential. These two triticales were taller than all the barley genotypes tested and also later maturing. As under Mediterranean conditions water stress often occurs during the grain filling period, it is therefore expected that greater progress in yield improvement and adaptation to dry areas will be achieved by selecting earlier maturing triticale genotypes.

Zillinsky also believes that 10 -15 % yield increase could be achieved if triticale could produce grain with equal density to wheat (1974). A primary objective of selection in triticale is therefore the improvement of grain filling and seed density. They should remain important criteria to consider while selecting earlier, shorter, and higher tillering triticale; otherwise, genotypes such as M2A, having similar maturity and plant height as Beecher, but much lower yield, will continue to be produced.

Although grain yields of triticale improved over time, they remained lower than those of the barley; and indications are that this inferiority is partly inherent to the kind of germplasm used in breeding programs working for the dry Mediterranean environments. The use of germplasm which is not adapted to the WANA region is partly responsible for the inferiority of triticale in comparison with barleys. This observation is supported by the following findings: firstly, yields of triticale were found to be higher outside the WANA over the six seasons. Grain yield of Beecher was also higher outside WANA for four out of the six seasons studies, but for Beecher this difference is small. This indicates that not only the growing conditions in the ICARDA region are harsher than elsewhere, but also that the germplasm tested was not as well adapted as Beecher. Secondly, in CIMMYT's International Triticale Yield Trials, triticale was found to show yield advantages over wheat in the Himalayas, East-Africa, South America, and parts of Europe but not in West Asia or the Mediterranean countries (CIMMYT Report 1983). Thirdly, it was found in India that triticale lines selected from CIMMYT germplasm, have a comparative advantage when grown under irrigation or higher fertility conditions, as well as in area with acidic soil under high elevation, but not under rainfed areas with prolonged moisture stress and high temperatures (Srivastava 1974). Since germplasm developed outside WANA region performed poorly under prevailing local stresses, attempts for improving triticale yield through breeding of genotypes using adapted local ryes and wheats were made. Preliminary results of this latter strategy had shown that it is possible to improve triticale adaptation to WANA (triticale program results; in 1982 and 1983 ICARDA Annual Report). Fourthly, results of this study (Table 3) have shown that triticale is not responsive to improved conditions in areas traditionally under barley. Barley in spite of increased diseases pressures, takes better advantage of occasional high moisture availability, with the sole exception of 1979/80 season when very high fertility conditions, lodging and diseases impaired Beecher barley performance. Fifthly, triticale lacked consistency of performance and usually appeared either among the top five lines or the bottom five lines, and therefore showed lack of adaptability leading to wide fluctuations among sites. This was supported by the results of 1982/83 season, when yield was expressed as percent of site mean yield (Table 2). At sites where diseases were a major factor, the yield and ranking of triticale were relatively high. However, at sites where barley diseases were not significant, the yield and consequently ranking of triticale were comparatively poorer.

Results of this study raise the question: for which environments should triticale be developed. Evidence is that elite triticale lines can produce more grain yield than either bread or durum wheat, both within (ICARDA 1984, International

Nursery Report, Cereal Nurseries 1982-83; and Hadjichristodolou 1984) and outside WANA (CIMMYT 1983; Bishonoi and Hughes 1979; Morey 1979; Bernard *et al.* 1979; Skovmand *et al.* 1984). However, triticale developed so far, lacked the adaptability, yield performance and stability that barley shows under stress, and therefore are inferior to barley in grain production, at least within the region covered by this study. Following these results, it appears profitable that the initial efforts should aim at developing triticale for areas where a comparative advantage over wheat is likely. This can be a better strategy particularly if the superior nutritional quality is maintained (Bernard and Laroche 1985) and if these agroecological niches where wheats are at a disadvantage are identified. Ferrière (1984) found that triticale in comparison with wheat is more vigourous at the end of cold winters and superior in poorly drained soils and in the presence of diseases. Touraine and Ammar (1984) found that the level of tolerance showed by a triticale variety to different NaCl concentrations should encourage its cultivation in semi-arid areas of Tunisia where increased NaCl concentrations in irrigation water were accompanied by decreases in the dry matter produced by barley, whereas no similar decreases were observed in triticale dry matter production.

Stability analyses in this study (Table 3), have shown that triticale lacked consistency of performance over years and locations. Moreover, it was generally less responsive to good conditions than Beecher barley in spite of its resistance to most barley diseases, but performed similarly, or slightly better than Beecher at low yielding sites. In Cyprus, however, Hadjichristodoulou (1984) showed that one promising triticale line outyielded the widely grown barley cultivar Athenais, when tested over 13 environments but was surpassed by the newly released barley cultivar Kanthara. However, in the study of Hadjichristodoulou (1984), it was found that the triticale line had higher regression coefficients than Athenais barley. One apparent reason for the discrepancy between the two studies is inherent to the barley cultivars used as checks. Athenais is, contrary to Beecher, very early, has poor tillering capacity, and is probably less responsive to environment changes. Nevertheless, the other major reason for opposite results of the two studies could be due to differences in seed rate. In the RBYT, triticale is traditionally sown at equal seed rate as barley, and since it has a much lower tillering capacity, the resulting triticale tiller density would be much lower. This would have reduced the triticale ability to respond to improved conditions as barley did, but whenever water availability was less, the lower population density of triticale, provided weeds were controlled, would be more desirable. In the experiment by Hadjichristodoulou, triticale was sown at a rate 50 % higher than that of barley. The increased rate has probably enhanced the yielding potential of triticale under favorable environments, but under stress conditions, seed yield was reduced.

The seemingly opposite results of the two studies highlight the difficulties and potential dangers in comparing the performance of the two crops. Ideally, the optimal seeding rate for each crop should be used. However, the optimal seed rate is site specific and seldom clearly determined for different environments, even for barley. In Syria, Anderson (1984) demonstrated that the optimum density for triticale was higher under higher yielding environments. His findings support the results obtained in this study where Triticale performance was poor in the more favorable environments. In areas of Manitoba, Canada (Larter *et al.* 1971), and in Alabama, USA (Bishonoi 1980), optimum seed rates for triticale were necessarily higher than seed rates for wheat because of shrivelled seed. These results indicated that triticale should be planted at seed rates that assure equal plant population per unit areas as obtained by other competing cereals.

Finally, the authors wish to emphasize that this study constitutes only a preliminary attempt to investigate the potential of triticale to replace barley in some environments of the semi-arid areas of West-Asia and North-Africa, where with sheep raising, it is economically the only profitable crop available to farmers. Continued search for higher biomass producing and better quality feed should encourage identifying well defined areas where triticale could replace barley and contribute more to the welfare of farmers. This study did identify a number of sites where triticale outyielded the locally predominant barley for two or more seasons.

The authors do realize that there might be a bias against triticale in this study since only one or two triticale lines are included in the RBYT, whereas barley is represented by a wider spectrum of genotypes. However, this bias was reduced by comparing the same long term barley check and the higher yielding triticale line whenever the two are included. It is hoped that additional research comparing promising barley and triticale populations under appropriate agronomic practices be carried out in the dry areas, and similar studies looking into the profitability of triticale in comparison with wheat be undertaken. It is also hoped that selection efforts will improve rapidly seed density and harvest index, reduce plant height and increase tillering capacity of triticale. Zillinsky (1974) believes that further increments in grain yield of triticale are excepted from higher tillering capacity. Tillering in particular, is an important adjusting mechanism under erratic conditions; it is with earliness and seed filling a major difference between barley and triticale in dry areas.

References

Anderson W.K. (1984). Plant populations for triticale in a Mediterranean environment. *Field Crops Res.* **8**: 281-285.

Bernard M. et Laroche G. (1985). Le bel avenir du triticale. *Bull. Tech. Inf. Serv. Agric.* Vol. **397-398** : 108-112.

Bernard M., Branlard M.J., Farouk El Tallaoui M., Laroche G., Bourdet A., et Feillet P. (1979). Caractéristiques qualitatives et quantitatives des protéines de triticales : étude des lignées sélectionnées en France. Int. Symp. Seed. Protein. Imp. in Cereals and Grain Legumes, 1978, Neuherberg Aut, Vienna, I.A.E.A., 2,237-259.

Bishonoi V.R. (1980). Effect of seeding rate and row spacing on forage production of triticale, wheat, and rye. *Crop. Sci.* **20** : 107-108.

Bishonoi V.R. and Hugues J.L. (1979). Agronomic performance and protein content of fall planted triticale, wheat, and rye. *Agron. J.* **71** : 358-360.

CIMMYT. (1983). p. 40-83, in CIMMYT review for 1982, Mexico.

Ferriere J. (1984). Le triticale tient ses promesses. *Cultivar* **Vol. 175** : 51-52.

Finlay K.W. and Wilkinson G.N. (1963). The analysis of adaptation in a plant breeding programme. *Aust. J. Agric. Res.* **14** : 742-754.

Hadjichristodoulou A. (1984). Performance of triticale in comparison with barley and wheat in semi-arid Mediterranean region. *Expl. Agric.* **20** : 41-51.

Harlan J.R. (1976). Barley. *In* « Evolution of crop plants ». p. 93-98. Simmonds N.W., ed. Longman.

ICARDA. (1982). Ann. Report, Syria. p. 96-97.

ICARDA. (1984). Ann. Report for 1983, Syria.

Larter E.N., Kaltsikes P.J., and McGinnis R.C. (1971). Effect of date and rate of seeding on the performance of triticale in comparison to wheat. *Crop. Sc.* **11** : 593-595.

Morey D.D. (1979). Performance of triticale in comparison with wheat, oat, barley and rye. *Agron. J.* **71** : 98-100.

Skovmand B., Fox P.N., Villareal, R.L. (1984). Triticale in commercial agriculture : progress and promise. *Adv. Agron.* **37** : 1-45.

Srivastava J.P. (1974). Prospects of triticale as a commercial crop in India. p. 87-92. in Triticale - R. McIntyre and M. Cambell , Eds. Ottawa, Canada, IDRC.

Srivastava J.P. (1981). Barley - its status and potential in North Africa and the Middle East.p. 6-18. In proceedings. Barley Diseases and Associated Breeding Methodology Workshop, Rabat, Maroc, 1981.

Touraine B., Ammar M. (1985). Etude comparée de la sensibilité au sel d'un triticale et d'une orge. *Agronomie* **5 (5)** : 391-395.

Zillinsky F.J. (1974). The development of triticale. *Adv. Agron.* **26** : 315-346.