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COMPETITIVE ABILITY OF ETHIOPIAN SPRING BREAD WHEAT CULTIVARS WITH *AVENA FATUA* L.

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ABSTRACT

Competitive interactions of four spring bread wheat cultivars (*Triticum aestivum* L.) with four wild oat (*Avena fatua* L.) seedling densities were assessed in field studies in southeastern Ethiopia during three cropping seasons (1991-93). Grain yield of wheat was linearly proportional to the seedling density of wild oats, but yield reductions at the maximum density of 90 weed seedlings m^{-2} ranged from 26 to 63% across the wheat cultivars. The semidwarf cultivar Dashen was the most sensitive to wild oat competition, while the intermediate height cultivar Enkoy was the least affected. Wheat cultivars varied markedly in their ability to suppress *A. fatua* tillering and seed production, differentially affecting wild oat seed and straw yield, panicle production, seed number $panicle^{-1}$, and thousand kernel weight. Given the limited access of Ethiopian peasant farmers to grass herbicides, wheat breeders should be encouraged to exploit such variability, and develop germplasm with a greater inherent ability to compete with wild oats.

Key Words: Competition, *Triticum aestivum*, weeds, wild oats

RÉSUMÉ

Les interactions compétitives de quatre cultivars de blé à pain du printemps (*Triticum aestivum* L.) et de quatre densités de graines d'avoine sauvage (*Avena fatua* L.) ont été évaluées dans des études en champs dans le sud-est de l'Éthiopie durant trois saisons de cultures (1991-93). Le rendement en graines du blé était proportionellement linéaire à la densité des graines d'avoine sauvage, mais les reductions en rendement à la densité maximale de 90 graines par metre carré s'étendait de 26 a 63% à travers les cultivars de blé. Le cultivar semi-nain Dashen était le plus sensible à la compétition avec l'avoine sauvage,tandis que le cultivar Enkoy à hauteur intermédiaire était le moins affecté. Les cultivars de blé variaient de façon dans leur capacité de reduire le tallage et la production de graines du *A.fatua*, affectant ainsi différentiellement le rendement de graines et de pailles de l'avoine sauvage, la production de panicule, le nombre de graines par panicule et le poids de milles grains. Vu l'accès limité des paysans Éthiopiens aux herbicides, les producteurs de blé devraient être encouragés à exploiter une telle variabilité, et développér des germoplasmes avec une plus grande capacité inherente pour rivaliser avec l'avoine sauvage.

Mots Clés: Concurrence, *Triticum aestivum*, mauvaises herbes, avoine sauvage

INTRODUCTION

The highlands of Ethiopia contain most of the 280,000 ha of spring bread wheat cultivated annually in the country (Tanner and Mwangi, 1992). In specific, highly suitable zones (i.e., >2000 m a.s.l), bread wheat occupies up to 45% of the total cropped area, and the majority of the wheat crop is cultivated by small-holders using the traditional ox traction system (Chilot *et al.*, 1992). Since the early 1970s, agricultural research in Ethiopia has focused on the intensification of small-holder bread wheat production, particularly through the introduction of semidwarf, input-responsive cultivars (Tanner *et al.*, 1993). The proportion of the national bread wheat area sown to high yielding varieties, which in most cases carry one of the dwarfing genes *Rht1* or *Rht2*, has been estimated to be as high as 75% (Tanner and Mwangi, 1992).

Farming system surveys have revealed that grass weeds, in general, and wild oat (*Avena fatua* L.), in particular, represent a major constraint to bread wheat production on peasant farms in the Ethiopian highlands (Chilot *et al.*, 1992). Counts taken in farmers' fields in Arsi Region of southeastern Ethiopia revealed early weed densities as high as 265 broadleaf and 362 grass weeds m^{-2} (Tanner *et al.*, 1993). The density of *A. fatua* panicles at maturity in on-farm trials in Arsi Region ranged up to 184 panicles m^{-2} for the worst infested site, while the mean density across 7 farmers' fields was 49 panicles m^{-2} (Amanuel *et al.*, 1992).

The wild oat problem appears to be worsening in the Ethiopian highlands for several reasons. More than 70% (and often up to 90%) of cropped area is sown to cereals by peasant farmers, limiting their options for crop rotation, and weed seed contamination in farmers' seed reserves is quite high (Chilot *et al.*, 1992). Furthermore, the peasant sector is almost entirely dependent on cultural practices for weed control, i.e., frequent tillage with the ox-plow prior to sowing, and hand weeding of the emerged crop (Tanner and Giref, 1991). While mechanized state farms utilize relatively expensive, high efficacy broadleaf and grass herbicides, peasant farmers have only limited access to the low-cost broadleaf herbicide 2,4-D. Understandably, it is virtually impossible for peasant farmers to distinguish and manually remove wild oat seedlings from a broadcast wheat crop sufficiently early to reduce yield losses. The magnitude of this yield loss was estimated by superimposing the grass herbicide diclofop-methyl on peasants' wheat fields in southeastern Ethiopia: the farmers' practice of selective and partial hand weeding of broadleaf weeds registered a 44% yield loss relative to the grass herbicide treatment (Tanner *et al.*, 1993).

Recent changes in agronomic practices in the wheat growing zones could be expected to further increase the severity of wild oat infestations. Increased adoption of shorter, high yielding bread wheat cultivars may exacerbate wild oat competition with the crop (Balyan *et al.*, 1991). Increased usage of fertilizer, particularly nitrogen, is recommended in most wheat production zones in Ethiopia; however, nitrogen fertilizer has been observed to increase the incidence of *Avena fatua* in wheat in Ethiopia (Tanner *et al.*, 1993) and elsewhere (Carlson and Hill, 1985b).

Since peasant farmers have extremely limited access to grass herbicides, an alternative approach to minimize wild oat competition in bread wheat would be to utilize cultivars capable of competing more effectively with the weed. Variation in the competitive ability of wheat cultivars has been reported (Balyan *et al.*, 1991), and may be related to crop morphology, particularly plant height. Other morphological features such as large, lax leaves and a spreading canopy capable of maximizing light interception may contribute to superior competitive ability in wheat (Sayre *et al.*, 1991). It is also known that competitive interactions between the wheat crop and wild oats are dependent upon the densities of both species (Carlson and Hill, 1985a; Cudney *et al.*, 1989).

The results reported herein originate from a study of the ability of four popular Ethiopian bread wheat cultivars to compete with wild oats over a range of weed seedling densities.

MATERIALS AND METHODS

Field experiments were conducted in Arsi Region at the Kulumsa Research Centre (KRC) of the Institute of Agricultural Research of Ethiopia (altitude 2200 m a.s.l., latitude 8°10' N, longitude 39°10"E), during the three cropping seasons of

1991-1993. The KRC soil is a clay loam (an intergrade between luvic Phaeozem and eutric Nitosol) with 3.3% organic matter, 0.157% total nitrogen, 22 ppm P (Mehlich), and a pH of 5.7 (in water).

The experimental design was a split-plot with three replications. Main plots consisted of 4 bread wheats (Israel, Enkoy, ET13 and Dashen), all being commonly grown by peasant farmers in Ethiopia (Chilot *et al.*, 1992). This selection of cultivars represents a range of releases over time, extending from an ancient, unimproved, tall line to a modern, CIMMYT-derived semidwarf (Table 1). Wild oat seedling densities, consisting of an additive series of 0, 30, 60 and 90 seedlings m^{-2}, were established as subplots within the varietal main plots.

A weed-free seedbed was prepared by discing and harrowing immediately prior to sowing wheat. Subplots consisted of 10 rows of wheat spaced at 20 cm and extending 5 m in length. Rows were marked by hand, and fertilizer (39 kg N and 20 kg P ha^{-1}) was placed in the rows and partially mixed with the soil using sticks. Wheat was then sown in the rows at the commercially recommended seed rate of 150 kg ha^{-1} during June of each year. This seed rate is commonly used by peasant farmers in Arsi Region when sowing newly purchased seed of improved wheat varieties (Chilot *et al.*, 1992). By incorporating an additive series of wild oat densities within the wheat seed rate practiced by farmers, this trial simulated farmers' field conditions in measuring the effects of inter-species competition.

Subsequent to covering the wheat seed, but on the same day, rows for wild oat were marked equidistant between the wheat rows, and seed of *Avena fatua*, harvested from peasant farmers' fields at the end of the previous season, was sown at 90, 180 and 270 seeds m^{-2}. At the 2-3 leaf stage, wild oat seedlings were manually thinned to give the desired seedling densities of 30, 60 and 90 seedlings m^{-2}, respectively. Two subsequent thinnings were carried out at successive two week intervals to maintain the desired seedling densities by removing late germinating wild oat seedlings. At each time of thinning wild oats, all broadleaf weed seedlings were removed manually to avoid interference with the wheat and wild oat interaction.

Cropping season rainfall was 457, 537, and 494 mm in 1991-1993, respectively, and temperatures and other environmental conditions were within the normal range each year (Table 2).

At maturity, wheat plant height was measured from the soil surface to the tip of three randomly selected main culms. Wheat spike and wild oat panicle densities were counted in a total area of 1.0 m^2 in each subplot. Wild oat seeds were harvested periodically (before shattering) from the net harvest area (3.0 m^2) of each subplot. At maturity, wheat and wild oat biomass was harvested at ground level, and separated into grain and straw of wheat and wild oat; for each subplot, the weight of the chaff remaining after grain threshing was added to the straw weight. Grain and straw yields for each species were expressed in kg ha^{-1} (at field moisture content), and harvest indices were calculated for wheat. Thousand kernel weights were determined for

TABLE 1. Description of the four spring bread wheat cultivars included in the competition study

Cultivar	Origin	Year of release	Height[a] (cm)
Israel	N/A[b]	N/A[b]	120
Enkoy	Kenya	1974	104
ET13	Ethiopia	1981	117
Dashen	CIMMYT	1984	94

[a]: In the current study.
[b]: Origin unclear, but grown in Ethiopia from the turn of the century.

TABLE 2. Climatic data for the Kulumsa Research Centre for 1991-93

	1991	1992	1993
Rainfall (mm)			
Annual	811	809	930
Cropping season[a]	457	537	494
Mean Maximum Temp. (°C)			
Annual	20.1	22.4	22.1
Cropping season[a]	18.7	21.3	21.2
Mean Minimum Temp. (°C)			
Annual	9.1	11.4	11.0
Cropping season[a]	8.9	11.7	11.4

[a]: June to October, inclusive.

both species, and were used to derive grains spike^{-1} and grains m^{-2}.

Analysis of variance was conducted for each measured parameter in each season, and analyses combined across seasons were subsequently carried out (since responses were similar in each season). Orthogonal contrasts were used to determine the curvilinear response of each parameter to wild oat seedling density. Varietal means were compared by the LSD test at the P=0.05 level.

RESULTS AND DISCUSSION

Effects of wheat cultivars and wild oat seedling density on wheat crop parameters and yield components. Of the nine wheat crop parameters measured in this study (Tables 3 and 4), six differed significantly among the four cultivars included. Of these, only three, namely height, Harvest Index (HI), and thousand kernel weight (TKW) exhibited non-significance for the interaction of cultivars x *A. fatua* density. All of the wheat parameters, except straw yield, varied significantly across seasons.

The semid-warf cultivar Dashen, at 94 cm height (Table 3), was significantly shorter than Enkoy (104 cm) which was in turn shorter than ET13 and Israel (117 and 120 cm, respectively).

ET13 appeared to be poorly adapted to the Kulumsa environment, yielding lower than the old line Israel (Table 3). In fact, ET13 is considered to be specifically well adapted to areas with Vertisolic soils unlike the clay loam of the study area. By contrast, the semidwarf Dashen performed relatively well having a high TKW (Table 4), and a high HI (Table 3).

Total biomass at maturity (wheat + *A. fatua*) did not vary among the four cultivars (Table 3), nor was there a significant interaction of cultivars with *A. fatua* density. However, in contrast to the report of Cudney *et al.* (1989), total biomass production increased linearly with the addition of wild oats to the canopy: total biomass increased by 7.2% with the introduction of 90 *A. fatua* seedlings m^{-2}.

TABLE 3. Effects of wheat cultivars and wild oat seedling density on wheat crop parameters

Treatments	Grain Height (cm)	Straw yield (kg ha^{-1})	Harvest yield (kg ha^{-1})	Total index (%)	Biomass[a] (t ha^{-1})
Wheat cultivar:	***[b]	*[b]	***[c]	*[b]	NS[b]
Dashen	94	3002	5501	34.6	13.2
Enkoy	104	3515	7650	31.5	13.0
ET13	117	2477	8236	23.1	12.9
Israel	120	3232	8116	28.6	13.0
LSD(P = 0.05)	4	637	678	6.7	NS
A. fatua m^{-2}:	NS[c]	***[c]	***[c]	***[c]	*[c]
0	109	3966	8495	32.4	12.5
30	109	3169	7413	30.3	13.0
60	109	2775	7019	28.7	13.3
90	108	2317	6577	26.5	13.4
Linear[d]	NS	***	***	***	**
Quadratic	NS	*	NS	NS	NS
Cultivar x *A. fatua* density interaction:	NS[c]	***[c]	**[c]	NS[c]	NS[c]
Mean	109	3057	7376	29.5	13.0

*, **, ***: Significant F-tests at the 5%, 1%, and 0.1% levels, respectively.

[a]: Sum of wheat and *A. fatua* above-ground biomass.

[b]: Significance level relative to the corresponding mean square for interaction with seasons.

[c]: Interaction with seasons not significant.

[d]: Linear and quadratic components of the density main effect.

Of the nine wheat crop parameters, all except height and TKW differed significantly in response to *A. fatua* seedling density (Tables 3 and 4). Except for spikes m^{-2}, none of these responses varied significantly across seasons. Thus, the effects of *A. fatua* competition appeared to be more consistent across seasons than the inherent differences among the wheat cultivars.

TABLE 4. Effects of wheat cultivars and wild oat seedling density on wheat grain yield components

Treatments	Spikes m^{-2}	Grains $spike^{-1}$	Thousand grains m^{-2}	TKW (g)
Wheat cultivar:	NS[a]	NS[a]	**[a]	**[a]
Dashen	415	21.9	9.2	33.1
Enkoy	625	23.1	14.1	24.9
ET13	506	22.1	10.9	23.4
Israel	482	19.6	9.5	34.3
LSD(P = 0.05)	NS	NS	2.2	5.2
A. fatua m^{-2}:	*[a]	***[b]	***[b]	NS[b]
0	562	25.6	14.1	28.7
30	492	23.4	11.2	29.1
60	501	19.7	9.9	29.3
90	474	18.1	8.4	28.6
Linear[c]	*	***	***	NS
Quadratic	NS	NS	**	NS
Cultivar x *A. fatua* density interaction:	***[b]	*[b]	***[b]	NS[b]
Mean	507	21.7	10.9	28.9

*, **, ***: Significant F-tests at the 5%, 1%, and 0.1% levels, respectively.
[a]: Significance level relative to the corresponding mean square for interaction with seasons.
[b]: Interaction with seasons not significant.
[c]: Linear and quadratic components of the density main effect.

Competition from wild oats at a density of 90 seedlings m^{-2} significantly reduced mean wheat grain yield by 42%, straw yield by 23%, HI by 18%, spikes m^{-2} by 16%, grains $spike^{-1}$ by 29%, and grains m^{-2} by 40%, relative to the control values. These results differ from the report of Rooney (1991) in which wild oats at a density of 25 plants m^{-2} significantly decreased wheat TKW, but not spike density (spikes m^{-2}).

Five of the wheat parameters exhibited a significant interaction between wheat cultivars and *A. fatua* density (Tables 3 and 4), and none of the interactions varied across seasons. The interaction effects were similar for grain and straw yield, spikes m^{-2}, grains $spike^{-1}$, and grains m^{-2}. For each trait, Dashen exhibited the most pronounced deleterious effect from wild oat competition, while Israel and Enkoy generally showed the least impact.

The grain yield of each cultivar was linearly related to wild oat density (Figure 1) in agreement with the results of Cudney *et al.* (1989). The slopes of the individual regression lines ranged from -11.0 to -31.8 kg ha^{-1}/(wild oat seedling m^{-2}).

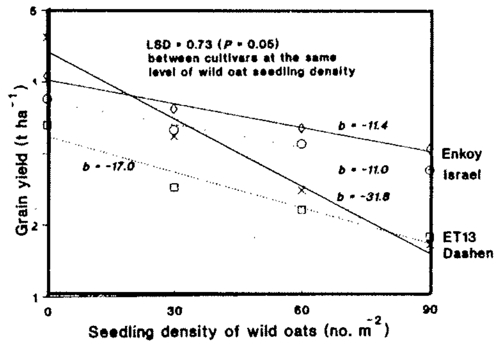

Figure 1. Effect of different densities of wild oat competition on the grain yield of four Ehiopian spring bread wheat cultivars.

Comparing these slopes, Dashen significantly differed from ET13 ($P<0.05$) and from Enkoy and Israel ($P<0.01$), while these three cultivars did not differ from each other. The R^2 values for the four regression lines ranged from 0.91 to 0.98 ($P<0.05$).

There was a marked varietal crossover in response to increasing wild oat competition. In the absence of wild oats, the highest-yielding cultivar, Dashen (4621 kg ha^{-1}), significantly outyielded Israel and ET13. However, under competition from 90 *A. fatua* seedlings m^{-2}, Dashen (1695 kg ha^{-1}) was significantly lower yielding than both Israel and Enkoy. Expressed as a percentage of their yields in the absence of wild oat competition, Dashen, ET13, Israel, and Enkoy lost 63, 47, 27, and 26%, respectively. The magnitude of these losses is similar to the range of 27 to 60% reported for five winter wheat cultivars under competition from 146 and 162 wild oat (*Avena ludoviciana*) plants m^{-2} in two seasons in India (Balyan *et al.*, 1991). Results of this study also concurs with their finding that the greatest yield loss was experienced by the wheat cultivar having the highest yield under weed-free conditions.

In contrast, however, the tallest cultivars in the current study were not the ones least affected by wild oat competition as in Balyan *et al.* (1991). While Enkoy was intermediate in plant height (Table 1), it was clearly less sensitive to competition from wild oats than the taller ET13. The yield loss reported for Enkoy in this study compares well with the 17% yield loss previously reported for Enkoy under competition from a lower density of *A. fatua* (eg. 84 panicles m^{-2}) (Amanuel *et al.*, 1992).

Straw yields declined less dramatically than grain yields, but followed the same ranking order. Dashen, ET13, Israel and Enkoy exhibited losses of 49, 18, 15 and 11%, respectively.

As the TKW of wheat was neither affected by wild oat seedling density nor its interaction with cultivar, the deleterious effect of wild oat competition in the current study was wholly due to a reduction in the number of wheat grains m^{-2}. In fact, the percentage reductions in grains m^{-2} at the highest level of wild oat competition paralleled the grain yield losses. In the same ranking order, reductions in grains m^{-2}, relative to the control, were 63, 45, 26 and 25%, respectively. Reductions in grains $spike^{-1}$, ranging from 18 to 42% across the four cultivars, exceeded the associated reductions in spikes m^{-2}, which ranged from 2 to 35%. For each parameter, Dashen consistently showed the greatest decline, ET13 was intermediate, and Enkoy and Israel were the least affected by increasing wild oat density.

Effects of wheat cultivars and wild oat seedling density on *Avena fatua* parameters. All the wild oat parameters measured were differentially affected by wheat cultivars, and the only effect to differ across seasons was wild oat TKW. All the parameters, excluding TKW, were significantly affected by wild oat seedling density, and only the effect on panicle density varied across seasons. Four of the wild oat parameters, specifically panicle density, seeds m^{-2} and $panicle^{-1}$, and seed yield, exhibited a significant interaction between wheat cultivars and wild oat density. None of the interactions varied across seasons.

TABLE 5. Effects of wheat cultivars and wild oat seedling density on *Avena fatua* parameters

Treatments	Panicles m^{-2}	Seeds $panicle^{-1}$	Straw yield (kg ha^{-1})	Yield (kg ha^{-1})	TKW (g)
Wheat cultivar:	***b	***b	***b	***b	*a
Dashen	206	96	2386	3866	14.0
Enkoy	231	30	759	1685	12.7
ET13	116	86	1086	1782	11.7
Israel	217	25	731	1530	13.5
LSD(P = 0.05)	33	19	184	683	1.3
A. fatua m^{-2}:	*a	P<0.10b	***b	***b	NSb
30	135	62	909	1470	13.1
60	191	60	1266	2230	13.1
90	251	55	1546	2947	12.7
Linear[c]	**	*	***	***	NS
Quadratic	NS	NS	NS	NS	NS
Cultivar x *A. fatua* density interaction:	***b	P<0.10b	***b	NSb	NSb
Mean	193	59	1240	2216	13.0

*, **, ***: Significant F-tests at the 5%, 1%, and 0.1% levels, respectively.
a: Significance level relative to the corresponding mean square for interaction with seasons.
b: Interaction with seasons not significant.
c: Linear and quadratic components of the density main effect.

Wild oat seed yield varied in response to wheat cultivars, *A. fatua* seedling density, and the interaction between these two factors (Table 5). Wild oat seed yield increased significantly within each wheat cultivar in response to increased wild oat density. The significant interaction originated in the differential response of wild oat seed yield to *A. fatua* density within bread wheat cultivars (Table 6). Israel showed the greatest percentage increase in wild oat seed yield, and Dashen exhibited the lowest, contrasting the effects of 30 and 90 seedlings m^{-2}. However, at both *A. fatua* densities, Dashen allowed the highest level of wild oat seed production, Israel and Enkoy the lowest, and ET13 occupied an intermediate position. Thus, it is clear that cultivars differ in their ability to suppress wild oat seed production, and this ability is relatively consistent across a range of wild oat densities.

TABLE 6. Effects of wild oat seedling density and wheat cultivar on wild oat seed yield (kg ha^{-1})

Cultivar	*A. fatua* sowing density (seedlings m^{-2})		Relative increase (%)
	30	90	
Dashen	1852	2989	61
Enkoy	522	930	78
ET13	791	1328	68
Israel	473	936	98
LSD(P = 0.05)*	238		

*: The LSD(P = 0.05) for differences between seedling densities within the same cultivar is 186 kg ha^{-1}.

The number of wild oat seeds m^{-2} varied in response to both main factors and their interaction (data not shown). Seed number increased significantly within each cultivar in response to higher wild oat density. Unlike the situation for *A. fatua* seed yield, however, the number of wild oat seeds produced in Dashen plots was significantly higher than the number produced in the other three cultivars, which did not differ from each other at the 90 weed seedlings m^{-2} density (data not shown). This discrepancy between ET13 occupying an intermediate position for wild oat seed yield, but not for seed number (at the 90 m^{-2} density) is apparently due to differential effects on the TKW of *A. fatua*.

The TKW for *A. fatua* varied only in response to differential effects of the bread wheat cultivars used in this study (Table 5). ET13 significantly reduced wild oat TKW relative to Israel and Dashen, while Enkoy significantly lowered TKW relative to Dashen. Thus, wild oat TKW appeared to be more sensitive to competition from bread wheat than the converse (Table 4). Rooney (1991) similarly concluded that wild oat was more affected by competition than was wheat.

The differential effect of wheat cultivars on wild oat TKW has an important implication. Peters (1985) concluded that wild oat populations arising from heavy seed consist of plants capable of producing more panicles, seed and dry matter per plant, and of reducing the dry weight of barley (*Hordeum vulgare* L.) more than populations of similar density originating from light seed. Thus, the semi-dwarf wheat cultivar Dashen allowed the production of a greater amount of and heavier wild oat seed, contributing to a serious build-up of wild oat in the soil seedbank.

Wild oat straw yield varied in response to wheat cultivars and wild oat sowing density (Table 5), but was not affected by the interaction between these two factors. The wild oat straw yield produced within Dashen was significantly greater than that produced within plots of the other three cultivars, which did not differ from each other.

The mean wild oat panicle density in this study was 193 panicles m^{-2} (Table 5), comparable to the highest site mean (184 m^{-2}) reported by Amanuel *et al.* (1992) in Arsi Region. Panicle density varied in response to wheat cultivars, to wild oat seedling density, and to the interaction between

TABLE 7. Effects of wild oat seedling density and wheat cultivar on wild oat panicle density (no. m^{-2})

Cultivar	*A. fatua* sowing (seedlings m^{-2})		Relative density increase (%)
	30	90	
Dashen	141	294	109
Enkoy	135	311	130
ET13	80	151	89
Israel	186	248	33
LSD(P = 0.05)*	42		

*: The LSD(P = 0.05) for differences between seedling densities within the same cultivar is 32 m^{-2}.

these two factors. The interaction means (Table 7) revealed that at the low wild oat density, panicle density followed the order ET13 < Enkoy and Dashen < Israel. At the high seedling density, wild oat panicle density followed the order ET13 < Israel < Dashen and Enkoy. Apart from the shift in rank and order, it is interesting to note that the cultivars Enkoy and Israel, which resulted in the lowest wild oat seed and straw yields and seed numbers m^{-2} and $panicle^{-1}$, did not apparently have a similar effect in suppressing wild oat panicle density. Such a discrepancy between wild oat seed yield and inflorescence number has been reported by Cudney *et al.* (1989) who attributed it to a survival strategy of the weed.

Peters (1985) noted a higher number of empty florets in panicles of *A. fatua* grown under competitive pressure from barley compared to wild oats grown in monoculture. In the current study, the number of wild oat seeds $panicle^{-1}$ was significantly lower as a result of the competitive effects of Israel and Enkoy relative to ET13 and Dashen (Table 5). Across wild oat seedling densities, the wheat cultivars retained a consistent significance in ranking for wild oat seeds $panicle^{-1}$: Israel and Enkoy < ET13 and Dashen (data not shown).

Thus, the competitive effects exerted by the wheat cultivars included in this study apparently operated in a complex fashion, differentially affecting the developmental stages of the wild oat plant. Wheat cultivars differed in their ability to reduce wild oat panicle production, seed number $panicle^{-1}$ and m^{-2}, wild oat TKW, and, thereby, wild oat seed yield.

Through the intensification of crop production practices, Ethiopia has the potential to increase the national level of self-sufficiency for wheat grain above its current 55% (Tanner and Mwangi, 1992). Changes in agronomic practices, such as increased adoption of high yielding, semidwarf wheat cultivars and the application of higher levels of nitrogen fertilizer could, however, be expected to exacerbate the current problem of wild oats in wheat (Tanner *et al.*, 1993). Globally, the serious yield reductions that occur as a result of competition from wild oats necessitate the use of herbicides to control this weedy grass. Although experience in Ethiopia has shown that high efficacy chemicals such as fenoxaprop-P-ethyl can reduce the panicle density of *A. fatua* in wheat by 94% (Amanuel *et al.*, 1992), farmers are constrained by their limited access to such herbicides.

In the absence of a comprehensive crop production package, it will be necessary to fully exploit the variation existing within bread wheat germplasm for the ability to compete effectively with *Avena fatua*. This variation is not necessarily correlated with crop stature. Apparently, multiple modes of competition exist, operating at different stages during the development of the weed. Cultivars with low competitive ability will facilitate the deposition in the soil seedbank of more and larger seeds of *A. fatua*, raising a fundamental question of the sustainability of the cropping system. To optimize food grain production, Ethiopian wheat breeders should utilize competitive ability with weeds as a selection criterion in the national wheat breeding programme. In addition, national policy makers may need to adopt a more positive stance towards the utilization of crop inputs.

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