Competition Effects of Major Weed Species at Various Densities on Yield and Yield Components of Barley (*Hordeum vulgare* L.)

Takele Negewo[1], Matias Mekuria[2] and Temam Hussien[3]
[1]*Ambo Plant Protection Research Center, P.O. Box 37, Ambo, Ethiopia*
[2]*Awassa Agricultural Research Center, P.O. Box 6, Awassa, Ethiopia*
[3]*Alemaya University, P.O. Box 138, Dire Dawa, Ethiopia*

Abstract

A study on the competitive interactions of food barley, cultivar HB-42, with four dominant weed species [*Avena fatua* L., *Erucastrum arabicum* Fisch. & May., *Guizotia scabra* (Vis.) Chiov. and *Snowdenia polystachya* (Fresen.) Pilg.] at different plant density levels (0, 10, 20, 40, 80, 160 and 320 plants/m^2) was made at Ambo Plant Protection Research Center, Ambo, during 2000, 2002 and 2003. The competition effect of the major weed species at various densities on yield and yield components of barley and the relative competitiveness of the weed species were determined. Both weed species and weed densities showed significant differences against most parameters considered. However, weed species by density interaction was not significantly different for all parameters. Weed density significantly decreased barley grain yield mainly through reducing number of tillers, number of productive spikes and biomass yield of barley. Barley grain yield decreased linearly with the increasing weed density (r^2 = -0.59). The lowest yield was obtained at the maximum density (320 weed plants/m^2). Grain yield reduction due to weed competition ranged 22–50%. *S. polystachya* was the most competitive causing 50.3% reduction, while *E. arabicum* was the least (22.4%). Averaged over the species, the number of weeds that caused a significant yield loss in barley was more than 10 weed plants/m^2.

Key words: barley, competition, weed density, weed species

Introduction

Barley is one of the major cereal crops grown in the highlands of Ethiopia, and it covers about 11% of the total grain cropped area (CACC, 2003). The average national yield of the crop is only 1173 kg/ha (CSA, 2004). Weed, both grass and broad-leaf, is one of the major constraints of barley production on peasant farms. More than 80 weed species were found associated with barley production in Ethiopia, among which 21 were regarded as major weed species (Hailu and Leur 1996, Rezene 1986, SPL 1988). An informal survey made in West Shewa Zone on farmers' barley fields over two years revealed that weed densities were as high as 380 plants/m^2 for broadleaf and 230 for grass weeds (Personal Observation). Besides, the dominant species were *Avena fatua, Erucastrum arabicum, Guizotia scabra* and *Snowdenia polystachya.*

Weeds in crops compete for nutrients, moisture, light and space. The competition of weeds affects the growth and thus lowers the yields of crops. Weeds account for 25% of the crop yield losses annually in the agriculture of least developed tropical countries (Akobundu 1987). In Ethiopia, weed problems are also worsening in the rain-fed barley-growing highlands for many reasons. The peasant sector is almost entirely dependent on cultural practices for weed control. In addition, there are limited options for crop rotation and it is impossible for peasant farmers to completely remove grass weeds in cereal crops. Later emerging weeds, unclean farmers' seed reserves and farmlands contaminated with much weed seeds contribute to the weed problem in the subsequent cropping seasons. Moreover, wet condition of the main rainy season favors rapid and abundant growth of weeds and consecutively results in heavy weed infestation in the crop field.

In many barley producing areas, barley fields are left un-weeded or hand-weeded late in the season after the weeds might have already affected the yield potential of the crop. Under such ineffective weed management, it is common to observe barley fields infested with weeds and poor crop stands resulting in low grain yield far below the world average (2348 kg/ha) (Onwueme and Sinha 1991). This is partially attributed to the poor weed management leading to high barley yield loss (19.2%) due to weed competition (SPL 1981).

The crop yield loss due to weed competition varies according to weed density and weed species present in the field (Radosevich 1984). Hence, to timely decide on weed control, knowledge of the damage level due to a particular weed species and its density is important. The information can also be used to make appropriate cultivar selection and rotation in weed management. However, in Ethiopia, such information was not available for the major weeds of barley. Therefore, the current study was made to determine the competition effects of the major weed species at various densities on yield and yield components of barley.

Materials and Methods

The experiment was conducted at the Plant Protection Research Center (PPRC), Ambo, during the main cropping seasons of 2000, 2002 and 2003. The experimental site is located about 100 km west of Addis Ababa at an altitude of 2180 m, latitude of $8^{0}58'$N and longitude of $37^{0}52'$E. The annual mean minimum temperature is about 11 ^{0}C and the mean maximum 26 ^{0}C. The nine years (1995–2003) average total annual rainfall and evaporation were about 1100 mm and 60 mm, respectively. The soil type is Vertisol, consisting of 67% clay, 18% silt, 15% sand and 1.5% organic matter with a pH of 7.7.

Seed samples of the four weed species from weed-infested barley fields were collected at the end of 1999 crop season. Germination tests were conducted to determine the amount of seeds and the preconditioning date required. The seed amount was important to be able to obtain the specified weed plant densities and the preconditioning date to synchronize the date of crop and weed seedling emergence on the experimental field (Table 1).

Accordingly, to minimize the risk of poor weed emergence under field condition, including the 50% allowance in number, an average of 3.6 seeds of *Avena fatua,* 2.9 seeds of *Snowdenia polystachya* and 2.4 seeds of each *Erucastrum arabicum* and *Guizotia scabra* were needed to obtain 1 seedling of the respective weed species in the

Table 1. Mean 50% germination date and germination percentage of barley and weed seeds in the green and wire-house at Ambo, 2000

	50% germination date (no. of days after sowing)			% germination		
Plant species	Green-house	Wire-house	Mean	Green-House	Wire-house	Mean
H. vulgare	3	4	3.5(1)*	87	92	89.5(1.2) *
A. fatua	5	7	6.0(4)	44	41	42.5(3.6)
E. arabicum	3	4	3.5(1)	77	55	66.0(2.4)
G. scabra	4	5	4.5(2)	65	61	63.0(2.4)
S. polystachya	3	7	5.0(3)	65	41	53.0(2.9)

*Numbers in parentheses indicate the required adjustment for sowing date and seed rate of the plant species, correspondingly mechanically infested experimental field. Moreover, to synchronize the seedling emergence date of barley and the weeds, *A. fatua, S. polystachya* and *G. scabra* were sown four, three and two days, respectively, before the sowing date of barley. Whereas, *E. arabicum* was sown on the sowing date of barley. Thus, the subplots were hand-sown using the pre-determined amount of weed and barley seeds sequentially in the first week of July of each season.

The experiment was laid out in split-plot arrangement with three replications. The main plots consisted of four weed species: *A. fatua* and *S. polystachya, E. arabicum* and *G. scabra*. The subplots consisted of seven weed densities: 0, 10, 20, 40, 80, 160 and 320 plants/m^2 . The subplots comprised 1.6 m long 7 rows of barley each 20 cm apart. Rows were marked by using string and weed seeds were sown in rows equidistant between the barley rows to ease separation of grass weeds from barley, maintain weed density levels and data collection.

The food barley cultivar HB-42 was used as the test crop. Barley seed sowing was made at the recommended seed rate, 85 kg/ha. Urea (46% N) and DAP (18/46% N/P_2O_5) fertilizers were also drilled following barley rows at 60 and 26.4 kg/ha rates, respectively, on the same day before seed covering. Half of the Urea was applied at planting time and the remaining half at tillering stage of the crop.

The non-target weed species and surplus seedlings of the target weed species in the experimental plots were continuously hand-removed before reaching two pair leaves stage. Plots with less than the desired weed densities were replanted by transplanting seedlings sown on the same date with the test weed seeds outside of the experimental plots.

A net plot size of 1 m^2 with the central 5 rows was marked in each sub-plot for ease of data collection, i.e., to better estimate competition effects of the major weeds on barley productivity. An average population of 268 barley plants/m^2 was established in every plot during the experiment.

Data were collected on number of tillers, number of productive tillers, above ground biomass and grain yield per plot. Test weight and 1000 seed weight of the crop were also determined. The data for all parameters were analyzed using SAS program for ANOVA and t Test (LSD) for mean separation at the $p = 0.05$ level, respectively (SAS Software Release 8.2).

Results

The main treatments showed significant differences against most of the parameters considered. Whereas, weed species by density interaction effects did not differ for all parameters. The four weed species and also the weed density levels showed highly significant difference ($p = 0.01$) in their effects on number of tillers, productive tillers, biomass yield and grain yield, and significant difference ($p = 0.05$) on thousand-grain weight.

The four weed species showed highly significant difference in their effects on the number of tillers and productive tillers. At the maximum density (320 plants/m^2), *A. fatua, S. polystachya, E. arabicum* and *G. scabra* reduced number of barley tillers by 21.0, 25.9, 11.2 and 2.5%, respectively (Table 2). These weeds similarly reduced productive tillers by 31.4, 29.6, 17.8 and 16.5%, respectively (Table 3). Number of tillers and productive tillers in barley decreased as weed population increased and vice versa. Both parameters were significantly affected with higher weed densities of over 40 weed plants/m^2 (tables 2 and 3).

Table 2. Mean effects of weed species and density on tillers/m^2 of barley at Ambo in 2000, 2002 and 2003

Weed species	Weed density (plants/m^2)							Mean
	0	10	20	40	80	160	320	
A. fatua	515	561	504	515	457	402	407	480B*
E. arabicum	608	498	542	553	518	535	540	542A
G. scabra	555	589	588	571	566	516	541	561A
S. polystachya	539	589	507	521	492	445	399	499B
Density mean	554AB*	559A	535AB	540AB	508BC	475C	472C	

*Means followed by the same letter(s) within a column or a row are not significantly different at 0.05 probability level, according to t Test (LSD) of SAS – GLM Procedure.

Table 3. Mean effects of weed species and density on heading ability (number of productive tillers/m^2) of barley at Ambo in 2000, 2002 and 2003

Weed species	Weed density (plants/m^2)							Mean
	0	10	20	40	80	160	320	
A. fatua	337	315	293	287	265	247	231	282B
E. arabicum	370	344	315	318	327	306	304	326A
G. scabra	332	340	322	341	318	320	278	322A
S. polystachya	304	339	278	272	283	284	214	282B
Density mean	336A*	334AB	302BC	305ABC	298C	289CD	257D	

*Means followed by the same letter(s) within a column or a row are not significantly different at 0.05 probability level, according to t Test (LSD) of SAS – GLM Procedure.

Table 4. Mean effects of weed species and density on biomass yield (kg/ha) of barley at Ambo in 2000, 2002 and 2003

Species	Weed density (plants/ m^2)							Mean
	0	10	20	40	80	160	320	
A. fatua	10269	9909	9277	9707	8154	6954	6722	8713AB
E. arabicum	11101	9892	8916	9555	8604	9264	7442	9253A
G. scabra	10422	9776	8967	10038	8803	8405	7749	9166AB
S. polystachya	9326	9740	9008	8439	8744	7931	5085	8325B
Mean	10280A*	9829 AB	9042BCD	9435 ABC	8576CD	8139D	6749E	

* Means followed by the same letter(s) within a column are not significantly different at 0.05 probability level, according to t Test (LSD) of SAS – GLM Procedure

Table 5. Mean effects of weed species and density on thousand grain weight (g) of barley at Ambo in 2000, 2002 and 2003

Species	Weed density (plants/m^2)							Mean
	0	10	20	40	80	160	320	
A. fatua	43.0	42.1	43.5	42.0	41.2	42.7	44.6	42.7A
E. arabicum	42.2	41.3	40.9	40.7	40.3	41.6	42.5	41.3B
G. scabra	41.2	40.7	43.0	42.5	41.0	42.3	41.1	41.7B
S. polystachya	41.8	42.3	41.5	40.8	41.1	41.4	40.4	41.3B
Mean	42.1AB	41.6AB	42.2A	41.6AB	40.9B	42.0AB	42.1AB	

* Means followed by the same letter(s) within a column are not significantly different at 0.05 probability level, according to t Test (LSD) of SAS – GLM Procedure

Similar to the number of tillers, and productive tillers; biomass yield of barley was significantly affected by weed density and weed species (Table 4). Barley biomass yield was reduced from 10280 kg/ha in weed-free check to 6749 kg/ha (34.3% reduction) at the highest weed density. Generally, weed densities over 10 weed plants/m^2

significantly reduced barley biomass weight. The increasingly higher weed densities were negatively correlated with the number of barley tillers ($r^2 = -0.43$), productive tillers ($r^2 = -0.37$) and biomass yield ($r^2 = -0.61$) ($p < 0.01$).

Thousand-grain weight (TGW) showed significant difference due to weed density and weed species (Table 5). The lowest TGW (41.3 g) was obtained due to the competition effect of *E. arabicum* and *S. polystachya* while the highest (42.9 g) was due to *A. fatua* competition. Test weight (TW) was significantly affected due to weed species only. The TGW and TW values showed low response trend to the increasing weed population.

There was significant variation among weed species in their competition effects on barley grain yield (GY) (Table 6). The lowest average GY (2479 kg/ha) was obtained from competition due to *S. polystachya*, while the highest (2973 kg/ha) was obtained under the competition of *E. arabicum*. The trend of GY

Table 6. Mean effects of weed species and density on grain yield (kg/ha) of barley at Ambo in 2000, 2002 and 2003

Weed species	Weed density (plants m^{-2})							Mean
	0	10	20	40	80	160	320	
A. fatua	3285	3102	2906	2836	2626	2059	1952	2681BC
E. arabicum	3619	3142	2808	2976	2458	2997	2810	2973A
G. scabra	3377	3154	2784	2992	3010	2489	2129	2848AB
S. polystachya	2867	3020	2835	2337	2556	2316	1424	2479C
Mean	3287A*	3104AB	2833BC	2785BCD	2663CD	2465D	2079E	

*Means followed by the same letter(s) within a column or a row are not significantly different at 0.05 probability level, according to t Test (LSD) of SAS – GLM Procedure.

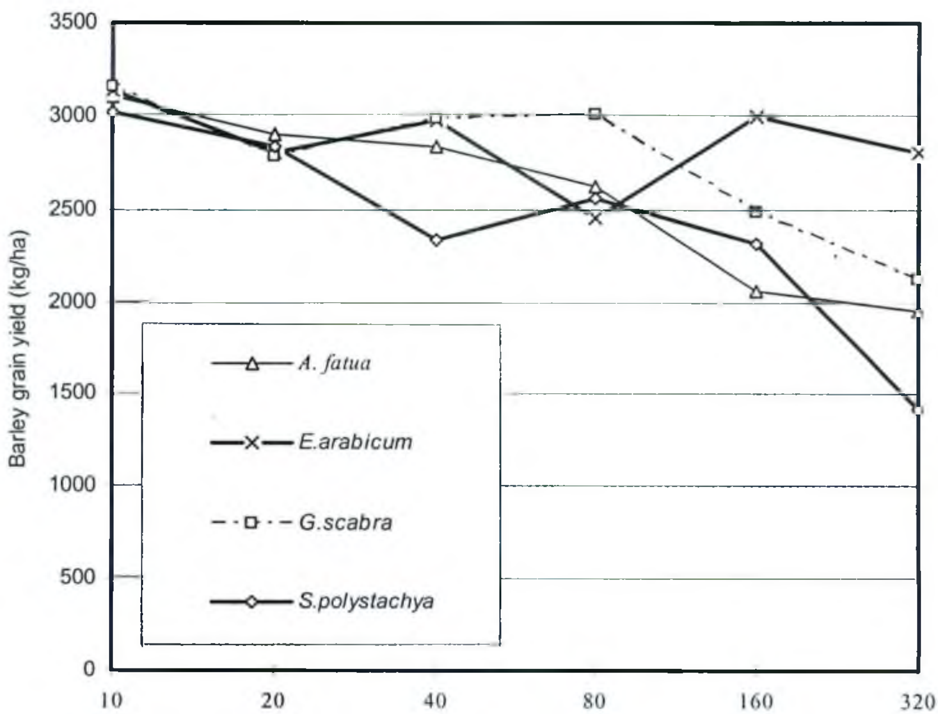

Figure 1. Relatioship betw een w eed density and mean grain yield of barley at Ambo in 2000, 2002, 2003.

in response to the types of weed species is similar to the results of productive tillers and biomass yield, indicating the more competitiveness of *S. polystachya* followed by *A. fatua* than the broad-leaf weeds. Decline in barley grain yield was linearly proportional to the increasing weed densities but yield reductions at the maximum density of 320 weed plants/m^2 ranged from 22.4 to 50.3% across the weed species. The grass weed *S. polystachya* was the most competitive (50.3% yield reduction), while the broad-leaf weed *E. arabicum* was the least competitive (22.4% yield reduction).

GY showed highly significant variation with the increasing weed densities (Table 6). It decreased significantly as weed densities increased beyond 10 weed plants/m^2. It was decreased from 3287 kg/ha at weed-free check to 2833 (13.8%), 2785 (15.3%), 2663 (19%), 2465 (25%) and 2079 kg/ha (36.8% reduction) at 20, 40, 80, 160 and 320 weed plants/m^2, respectively. The increased weed densities were negatively and highly significantly correlated with the GY of barley (r^2 = -0.59). In general, GY and yield components decreased as the weed density levels increased and increased as the weed density levels decreased (Figure 1).

Discussion

The results of the study showed that weed competition reduced barley yield and yield components by competing with the crop for essential growth requirements as the total plant population increased per unit area. The grass weeds had more effect on barley parameters than the broad-leaf weed species. The higher reduction effects of the grass weeds could be attributed to a similar nature as that of barley crop competing for the same growth factors.

In the present study, number of tillers, grain yield, productive tillers and biomass yield of barley were proportionally more affected by the weed competition than thousand grain weight and test weight. The effects of weed species and their densities on barley parameters, especially on number of tillers, productive tillers and biomass yield, were similar to the overall effects on grain yield. TW and TGW results fully disagree with the results recorded on the effects of weed species on tillering and heading ability of the crop. The result suggested that barley grain yield loss is primarily attributed to a reduction in number of tillers, fertile tillers and biomass yield. Wilson and Peters (1982) reported that barley grain yield was reduced by wild oats through a reduction of the number of fertile tillers. In their study of *A. fatua* competition with spring barley, the authors found that 60% of the barley yield loss was attributed to the reduction of the number of fertile barley tillers. Similarly, Blandrige et al. (1996) reported that yield loss in barley from weed competition is caused by reduction in number of barley tillers, although in few cases competition could lead to smaller and fewer seeds per spike. Godel (1935) reported that weed competition in cereals has a slight effect on kernel weight, supporting the TGW result obtained from the current experiment. However, unlike the low effect of weed competition on TW in the current study, on the study of competition between *A. fatua* and spring barley in UK, Wilson and Peters (1982) indicated that a smaller grain size was responsible for the crop yield reduction.

Barley grain yield decreased with increasing weed density and on the contrary, decreasing weed population resulted in increased grain yield particularly with the grass weed species. The four weed species were more or less equally competitive at the lower weed density levels; but the grass weeds were relatively more competitive than broad-leaf weeds at higher densities. Weed densities significantly affected most of the parameters in barley during each of the three years of the trial. Averaged over the weed species, the number of weeds required to cause a significant yield loss in barley was beyond 10 weed plants m^{-2}. The influential effects of weed density on crop were confirmed by several studies (Carlson and Hill 1985, Cousens et al. 1987, Taye and Tanner 1999).

The insignificant effect of weed species by density interaction on yield and yield components of the crop indicated the insignificant difference in the competitive ability among the biologically different weed species at the same density level.

Acknowledgement

We would like to express our thanks and appreciations to Ato Tariku Hunduma who contributed a lot in analyzing the collected data. We thank Dr. Taye Tessema for his critical review and comments on the paper. Our thanks is also extended to those who contributed in one way or another in the production of the paper.

References

Akobundu IO. 1987. Weed science in the tropics. *Principles and Practices*. John Wiley and Sons, Ltd. New York. pp. 21–28.

Blandrige DE., Brann DE., Fergusson AH., Henry JL., Thmpson RK. 1996. *Weeds and Weed control.*

Carlson HL., Hill JC. 1985. Wild oat (*Avena fatua*) competition with spring wheat: Plant density effects. *Weed Science* **33**:176–181.

Central Agricultural Census Commission (CACC). 2003. Ethiopian Agricultural Sample Enumeration, 2001/02. Statistical report on socio-economic characteristics of the population in agricultural households, land use, and area and production of crops. Part I. Addis Ababa, Ethiopia.

Central Statistical Authority (CSA). 2004. Agricultural Sample Survey of the Federal Democratic Republic of Ethiopia 2003/04. Report on land utilization of private peasant holdings, 'meher' season). *Statistical Bulletin* 302. Addis Ababa, Ethiopia.

Cousens R., Brain P., O'Donovan JT., O'Sullivan PA. 1987. The use of biologically realistic equations to describe the effects of weed density and relative time of emergence on crop yield. *Weed Science* **35**:720–725.

Godel GL.1935. Relation between rate of sowing and yield of cereal crops in competition with weeds. *Science of Agriculture* **16**:165–168.

Hailu Gebre, Joop van Leur (eds). 1996. *Barley Research in Ethiopia: Past Work and Future Prospects. Proceedings of the First Barley Research Review Workshop*, 16–19 October 1993, Addis Ababa: IAR/ICARDA. Addis Ababa, Ethiopia.

Onwueme IC., Sinha TD. 1991. Field crop production in tropical Africa. *Principles and Practices*. Ed. CTA, the Netherlands. pp. 225–231.

Radosevich SR. 1984. *Weed ecology: Implication for vegetation management*. John Wiley and Sons, New York. pp. 194–200.

Rezene Fessehaie. 1986. A review of weed science research activities on wheat and barley in Ethiopia. In: *A Review of Crop Protection Research in Ethiopia*. Tsedeke Abate (ed.) Proceeding *of the First Ethiopian Crop Protection Symposium,* 4–7 Feb., 1985. Institute of Agricultural Research, Addis Ababa, Ethiopia. pp. 121–148.

Scientific Phytopathological Laboratory (SPL). 1981. Progress report for the period 1980. Ambo, Ethiopia.

Scientific Phytopathological Laboratory (SPL). 1988. Progress report for 1987/88. Ambo, Ethiopia.

Taye Tessema, Tanner DG. 1999. Determination of economic threshold densities for the major weed species competing with bread wheat in Ethiopia. pp. 249-272. In: *The tenth Regional Wheat Workshop for Eastern, Central and Southern Africa, CIMMYT*. Addis Abeba, Ethiopia.

Wilson BJ., Peters NCB. 1982. Studies of competition between *Avena fatua* and spring barley. I. Influence of *Avena fatua* on yield of barley. *Weed Research* **22**: 143–148.