Review

Breeding Malting Barley under Stress Conditions in South America

Silvia E. GERMÁN

Instituto Nacional de Investigación Agropecuaria La Estanzuela, Colonia, Uruguay, South America

Abstract: The annual average area sown with barley (*Hordeum vulgare*) in South America during 1999–2003 was 795 000 ha. In Argentina, Brazil, Chile and Uruguay, two-rowed spring cultivars are used mostly for malt production. Research has been developed in private malting companies and official institutions supported by the industry. In Argentina, tolerance to drought and heat stress during grain filling are important in drier areas. Yield and malt extract had been improved in cultivars released from 1940 to 1998. In Brazil, progress in grain yield, grain size, malting quality, early maturity, and resistance to net blotch, powdery mildew, and leaf rust has been achieved by EMBRAPA and malting companies. Higher tolerance to soil acidity and resistance to spot blotch are required. Since 1976, malting barley breeding in INIA-Chile has improved grain yield, grain size, beer production efficiency, and resistance to scald, net blotch, stripe rust, and leaf rust. Uruguay produces high quality malt exported mainly to Brazil. Malting companies have released locally bred and introduced cultivars since the early 1970's. Initiated in 1988, INIA-Uruguay breeding program has improved yield, malting quality, and lodging and disease resistance. Fusarium head blight is a new challenge for research in Brazil and Uruguay. Information regarding malting barley production, the most important stresses in different areas of production, and breeding progress under South American conditions is provided.

Keywords: *Hordeum vulgare* L.; plant breeding; stress conditions; Argentina; Brazil; Chile; Uruguay

The average annual area sown with barley in South America during the last five years (1999–2003) was 795 000 ha (FAOSTAT 2004). In Argentina, Brazil, Chile, and Uruguay (Southern Cone of South America), barley is used mostly for malt production. In Bolivia, Colombia, Ecuador and Peru, most barley is used for food and feed. Other countries in South America do not have adequate conditions to develop the barley crop at a commercial level (Arias 1995). Therefore, the information provided will be focused on malting barley breeding in the Southern Cone countries. In this region, an average of 505 000 ha per year were sown with barley in the period 1999–2003, with an average yield of 2.2 t/ha and a total production of 1 100 000 mt per year (Table 1). In the period 1998–2002, Argentina exported barley and malt, Chile and Uruguay imported barley and exported malt, and Brazil imported barley and malt.

Two-rowed spring cultivars with malting quality sown during the fall or winter are almost exclusively used in the Southern cone. Most of the crop area is sown under contract with the industry.

Barley research in the region began in the 1910's in the public sector, and then in private malting companies and official institutions supported by the industry (Arias 1995). Traditional breeding methods have been used in most programs. Anther

Table 1. Average barley area, grain yield, total grain and malt production (1999–2003) and commerce (1998–2002) in the countries of the Southern Cone of South America

Country	Barley					Malt	
	harvested area (ha)	grain yield (kg/ha)	total production (mt)	imports (mt)	exports (mt)	imports (mt)	exports (mt)
Argentina	248 687	2305	571 009	6134	123 045	16 268	230 109
Brazil	137 727	2030	275 355	125 409	16 832	647 041	774
Chile	18 812	3843	70 745	47 279	298	16 873	53 795
Uruguay	99 220	1936	185 592	58 548	7768	5	169 496
Southern cone*	504 446	2186	1 102 701	237 370	147 943	680 187	454 175

Source: FAOSTAT (2004)

*Argentina, Brazil, Chile and Uruguay: total area harvested, production, imports and exports; average grain yield

culture for the production of double haploids was introduced in EMBRAPA (Brazil) breeding program recently. Marker assisted selection is not being used as a routine tool in the regional programs.

Important progress has been made in the adoption of technology at the commercial crop level. An average grain yield increase rate of 27.1 kg/ha per year during the last 20 years can be explained by the improvement of the crop management practices and the adoption of new more productive cultivars. However, the average regional yield of about 2.2 t/ha is considerably lower than the potential yield of the crop under adequate growing conditions, indicating that large areas of production in the Southern Cone occur under stress conditions. Therefore, breeding for stress tolerance is one of the most relevant objectives for malting barley breeding in the region.

Argentina

Approximately 250 000 ha per year were sown with barley in Argentina in the last five years (Table 1). The average yield of the crop was 2.3 t per ha, resulting in an annual total production of 571 000 tons during 1999–2003. The malting capacity of the Argentinean industry is 385 000 tons of barley per year.

Most barley is sown in Buenos Aires Province (latitude 34° to 39° South), where rainfall varies from 300 to 500 mm during the growing period. The Southeast, West, Southwest, and North Centre areas of production account for about 50, 5, 20 and 25% of the total production, respectively (Cattaneo 2001).

Four programs are currently breeding malting barley in Argentina: INTA (National Institution for Agricultural Technology) at Bordenave, Maltería Quilmes at Tres Arroyos, Maltería Pampa at Coronel Suarez, and more recently, Anheuser Bush at Balcarce (Cattaneo 2004 – pers. commun.). Emphasis has been laid on the selection of high yielding, high quality cultivars that can compete with wheat in the most productive areas. Selection for drought tolerance (characteristic of the South West area) and high temperatures during grain filling has been indirect, through the selection of high and stable grain yield and grain quality. The most prevalent diseases are net blotch (*Pyrenophora teres*) and scald (*Rhynchosporium secalis*) while minor diseases are leaf rust (*Puccinia hordei*), powdery mildew (*Blumeria graminis* f.sp. *hordei*), take all (*Gaeumannomyces graminis*), and Fusarium head blight (mainly incited by *Gibberella zeae*) (Carmona & Barreto 1995). Even when diseases are present, they are not an important yield limiting factor in Argentina, due to cool temperatures and low rainfall, and the selection for resistance is not a relevant objective for the breeding programs.

In the 1950's, European cultivars Beka and Union were used in half of the growing area. These high quality cultivars, as the European germplasm in general, were not adapted to Argentinean conditions (Savio 2003 – pers. commun.). Other cultivars used were locally bred, had good adaptatation but their malting quality was lower than required. Maltería Quilmes started a barley breeding program in 1974, when the first crosses were made. The cultivars released by this program were Quilmes Pampa (1983), Q. Alfa (1983), Q. 27-1 (1983), Q. Centauro (1985), Q. Sur (1987), Q. Palomar (1994), Q. Painé (1997), and Q. Ayelén (1998) (Aguinaga – pers. commun.).

Cultivars bred by Maltería Quilmes have been predominant since Q. Pampa was widely adopted. The cultivars sown in 2000 were Q. Alfa (44% of the growing area), Q. Palomar (25%), B1215 developed by Anheuser Bush (16%), Scarlett developed by Breun (10%) and others (5%) (Cattaneo 2001). This varietal composition was altered in that 33% of the area was sown with Scarlett, 20% with Q. Ayelén, 16% with Q. Alfa, 12% with Q. Palomar, 10% with B1215, 5% with Q. Paynee and 4% with others (Cattaneo – pers. commun.) in 2003.

Grain yield and malting quality have been improved. Comparing nine cultivars released since 1940, Abeledo *et al*. (2003) found that yield had increased in those released since 1980, and Passaella *et al*. (2003) demonstrated that malt extract had increased in the new cultivars compared to the old ones.

Higher yielding cultivars account for part of the average yield increase of 19.8 kg/ha per year obtained at the commercial level since 1984. Plumpness (measured as percentage of grains bigger than 2.5 mm) increased from 70% in 1973–1977 to 92% in 1990–1994 (Tomaso 1995). The biggest challenge that needs to be addressed is the unstable protein content of the harvested grain. Grain protein may vary from 7% in the highly productive areas under no water stress to 16% where yield is limited, usually due to drought.

Brazil

The average barley area harvested in Brazil in the last five years was 137 700 ha (Table 1). The average yield was 2.0 t/ha, resulting in a total production of 275 355 mt. The barley production provides 30 to 60% of the raw material required by the industry, which has a malting capacity of 420 000 ton per year (Minella 200?). Malt production represents one third of the brewing industry requirement.

The most important barley production area is in the Southern states of Río Grande do Sul (70%), Santa Catarina (4%), and Paraná (26%), between latitudes 24° and 31° South, in altitudes from 500 to 1100 mosl (Minella 2000). Average rainfall during the growing season is 700 mm. A small area is being developed in central Brazil (latitude 15° South) under irrigation, in altitude higher than 800 mosl. Sowing dates vary from May to mid June, according to the location. Highly variable rainfall and temperature are the major crop limiting factors (Minella 2000). Soil acidity associated to a high Al content as well as diseases can drastically decrease grain yield and quality.

Malting barley breeding started in 1920 (Arias 1995) based on the selection of introduced barley cultivars best adapted to Brazilian conditions. Crossing began in the 1950's. Brahma and Antartica brewing industries began to work in barley breeding in the 1940's and 1950's, respectively (Minella 200?). In 1976, EMBRAPA (National Agricultural Research Institution) initiated a barley breeding program in Passo Fundo, RS. An agreement with the private sector (Antartica, Brahma and Cooperativa Agraria Entre Rios Ltda.) began to operate in 1994, coordinating private and official research efforts and increasing breeding. AmBev, a new company resulting from the fusion of Antartica and Brahma in 2000, is now the biggest malting company in South America with malting plants also in Uruguay, Argentina, and Venezuela (Zschoerper & Sperotto 2001).

Breeding objectives of Brazilian programs involve high and stable grain yield and malting quality, early maturity, tolerance to soil acidity (Al), decreased grain sterility, tolerance to sprouting and high temperatures during grain filling, and resistance to lodging and to prevalent diseases: net blotch, powdery mildew, leaf rust, spot blotch (*Cochliobolus sativus*), Fusarium head blight and *Pyricularia grisea* (Minella 200?). Germplasm used involves locally developed cultivars and lines as sources of adaptation and other characteristics, and two row malting materials introduced mainly from Europe, Canada, USA, and Australia.

Different crossing and selection schemes are used according to the objectives of the crosses. Modified bulk or genealogy methods or SSD (up to four generations per year) are used for specific crosses (Minella 200?). Double haploids obtained from anther culture have been used in the program since 1998 (Brammer 2003). The industry performs quality testing.

All cultivars recently grown have been developed in Brazil. BR2 (released by EMBRAPA in 1989) was the most widely grown cultivar from 1994 (Minella 2000) to 2002. MN 698 (released by Brahma in 1997) increased its relative area up to 40% in 2002, and together with BRS 195 (released by EMBRAPA in 2000) were the most widely used cultivar in 2003

(30% of the growing area each), followed by cvs. EMBRAPA 127 and EMBRAPA 128 (released in 1997) with 15% of the growing area each (Minella – pers. commun.). Other cultivars released in the last decade were not so widely grown.

Genetic progress was assessed by testing eighteen cultivars released from 1969 to 1996 during two years (Só E Silva 1999). The three parameters studied were improved: grain yield increased by 31.7 kg per year, protein content decreased by 0.057% and malt extract increased by 0.065% per year. Results from another experiment comparing cultivars used by Brahma since the 1960's indicate that yield and malt extract increased, and β-glucans and protein content decreased in newer cultivars (Sperotto 2000). The introduction of soil acidity tolerance in cultivars FM 404 and Antarctica 01 allowed the expansion of the crop, and early maturity was essential for double cropping. Higher yielding cultivars are responsible for part of the commercial yield increase of 35.5 kg/ha per year in the last 20 years. Quality parameters have improved significantly since the release of cultivars MN 599, MN 656, EMBRAPA 127 and MN 698. Plumpness increased from 65 to 95%, and malt extract from 79 to 82% in new cultivars (Minella 2001). The first net blotch resistant cultivar, BR 2, was released in 1989 and derives its resistance from Norbert (Minella 200?). Newer cultivars BRS 195 and BRS 224 (released in 2000 and 2002, respectively), combine resistance to net blotch, powdery mildew, and leaf rust, the most prevalent leaf diseases (Minella 200?). The challenge for the future involves improving spot blotch, Fusarium head blight and lodging resistance. The level of tolerance to abiotic stresses (deficit/excess rainfall and Al) should also be improved. Possible sources of higher levels of tolerance to Al are the barley cultivar Dayton and some native *Hordeum stenostachys* lines (Minella & Silva 1996; Sawasato *et al*. 2003).

Chile

The barley crop occupied an average area of 18 800 ha per year in the last five years (Table 1). Average grain yield in the same period was 3.8 t/ha. Barley produced in 1999–2003 was 70 745 mt, 80% of which was used for malting and sown under contract with local industries. Higher yield than that in the rest of the region is explained by favourable weather conditions in a higher latitude environments in the Southern areas where most of the production takes place. Sowing times are July to September, from the Northern to the Southern barley areas (Beratto *et al*. 1998) (approximate latitude 34° to 42° South).

Most prevalent diseases limiting yield and quality are scald, net blotch, leaf rust, yellow rust (*Puccinia striiformis*), take all, and BYDV (Gilchrist 1989). Parts of the barley growing area have acid soils with toxic levels of Al (trumao soils).

INIA (National Agricultural Research Institute) installed a breeding program in Temuco in 1976, and signed an agreement with one of the brewing industries (Compañía Cervecerías Unidas, CCU) in 1978, which is still operative (Beratto 2001). Campex Semillas also work in barley breding. Breeding objectives are high yield and high quality winter, facultative, and spring types adapted to different production regions, and resistance to diseases (mainly scald and net blotch), lodging and shattering (Berattto 1999).

Cultivars grown before the beginning of the agreement with CCU were of European origin, well adapted to Chilean conditions (cool temperatures and long days during grain filling). Cvs. Breuns Wisa and Firlsbeck Union were used in 1978. Cv. Carina replaced cv. Breuns Wisa in 1980. In 1983, cvs. Granifen INIA-CCU (first cultivar developed by INIA) and Aramir were released. Cv. Libra INIA was released in 1989, cv. Leo INIA (a line from the ICARDA/CIMMYT program) in 1991, and cv. Acuario INIA in 1995. By 1999, 100% of the area was sown with Acuario INIA, a high yielding cultivar with high lodging resistance, moderate susceptibility to scald, resistance to stripe rust, and high quality attributes (large grain size, low grain protein content, and high extract) (Beratto *et al*. 199?).

Yield increase during the last 20 years has been the highest of the region (71.5 kg/ha per year) and reflects the genetic improvement of this trait. Progress has also been made by INIA breeding program in the quality characteristics. There has been a significant increase in grain size during 28 years of breeding. The quantity of grain required to produce 100 l of beer decreased from 18.5 kg of barley in 1984 to16 kg in 2000 (Beratto 2001). Sources of genetic resistance to relevant diseases, mainly scald, have been identified. The Campex Semillas Baer program has selected barley for tolerance to the toxic effect of low pH and high Al soil content since 1992, releasing the malting cultivar Aurora B with tolerance derived from the feed barley cv. Carmen B (von Baer & Borie 1999).

Uruguay

The average barley area harvested in the last five years was 100 000 ha (Table 1). The average yield in the same period (1.9 t/ha) was negatively influenced by the extremely bad 2001 harvest when the yield was 0.9 t/ha, due to problems associated with excess rainfall. Most barley produced in the country (average of 185 500 mt in 1999–2003) is exported as malt mainly to Brazil. The industry has a malting capacity of about 250 000 tons.

Barley is planted in the South West region of Uruguay between latitudes 32° and 35° South. Average annual rainfall is 1000 mm and during the crop season 550 mm. Sowing time is June and July, but later sowing dates are frequent due to excess rainfall.

Most important factors limiting crop production are diseases, favoured by high moisture during spring time, and abiotic stresses such as excess rainfall, high temperatures during grain filling, and drought during part of the growing cycle mostly in late sown crops.

Cultivars selected from heterogeneous landraces were the result of early barley breeding that began in 1914. Breeding was discontinued until 1968, when the private company FNC (now MOSA) established a breeding program, making the first crosses in the country. In the 1980's, malting industries OMUSA and CYMPAY started their breeding programs which have now fused (MUSA). INIA (National Agricultural Research Institute) and the Faculty of Agronomy began to work significantly in breeding in 1988 and 1991, respectively. The National Barley Board was created in 1991 as an agreement between the official programs (INIA, Faculty of Agronomy and LATU, the Technological Laboratory of Uruguay), and the malting industries. Through this agreement, the private sector supports public institutions which results in increased research and coordination. INIA and the private programs develop commercial cultivars and the Faculty of Agronomy and INIA work in germplasm development. Micromalting, malting and brewing tests are performed by LATU and the industry.

The breeding objectives are high and stable yield and malting quality, and resistance to the most prevalent diseases (net blotch, spot blotch, leaf rust, scald, Fusarium head blight), lodging, and straw breakage. A new potential problem is the spot form of net blotch (*Dreschlera teres* f.sp. *maculata*), identified for the first time in 2003 (Pereyra & Germán 2004). Photoperiod response is an important adaptation attribute, conferring flexibility in planting dates (important due to high rainfall during sowing time) and concentrating anthesis at the end of September to mid October, the best period for grain filling initiation (Germán *et al*. 2000). High harvest index, slow early development and tiller synchrony is required to improve yield potential (Castro & Kemanian 1999).

Germplasm used in the programs comprise locally developed materials, cultivars and lines from the region and Australia, which is adapted to Uruguayan conditions in terms of maturity and photoperiod response. Germplasm from Europe provides excellent malting quality, and resistance to lodging, leaf rust, powdery mildew and scald. Dwarf European cultivars are of late maturity and have small grain size which decreases markedly in late sowing dates. Germplasm from North Dakota adapts particularly well to the Northern growing area where spot blotch and high temperatures during grain filling are more common.

Traditional breeding methodologies are used, advancing generations in an irrigated summer nursery or in the greenhouse. Selection for some traits is done under specific conditions. Sources of resistance to diseases, advanced lines and commercial cultivars are field tested in separate nurseries under conditions favourable for each disease, including adequate planting dates, artificial inoculation, and spreader rows (Pereyra 1996). Spot blotch is also assessed in the Northern region, where it is more frequent and severe. Fusarium head blight tests are performed in the greenhouse to assess type I and type II resistance (Pereyra & Stewart 2001). Seedling resistance to net blotch, spot blotch and leaf rust is also assessed. Control of diseases using genetic resistance may have a short duration due to the appearance of new virulent pathotypes of the pathogens. The presence of different pathotypes of *Pyrenophora teres* (Gamba & Tekauz 2002), *Cochliobolus sativus* (Gamba & Estramil 2002) and *Puccinia hordei* in Uruguay has been demonstrated. Some lines with adult plant resistance to leaf rust have been identified and are being used as sources of potentially longer lasting resistance to the disease.

The Faculty of Agronomy provides support to breeding programs developing germplasm with specific characteristics and is beginning to work in *Qtl* analysis. Emphasis in research is given to spot blotch resistance and genetics, characterisation of vegetative and reproductive phases, and seed dormancy and water sensitivity.

During the last 10 years, 25 cultivars locally developed or introduced from Argentina, Brazil, Australia, Europe and North Dakota have been used by the industries. The main reason for the renewal of cultivars has been susceptibility to diseases, and the increase of quality requirements by the Brazilian industry. Cv. Clipper was grown in 20 to 40% of the growing area for a long period until 1999. In 2003, cvs. Norteña Daymán and N. Carumbé, both from North Dakota, were grown in 36% of the area. Cv. Perún from the Czech Republic, Q. Ayelén from Argentina, MUSA 936 developed in Brazil, and CLE 202 developed by INIA-Urguay, had 10 to 15% of the growing area each.

INIA breeding program has improved different traits in three steps since 1988. In the first step, cv. Estanzuela Quebracho (selection from Western Australia) was released. This cultivar with improved yield and straw strength allowed to use highly productive soils and better crop management practices. The second step was to increase the level of resistance to diseases, developing lines resistant to leaf rust and net blotch, and some lines resistant to scald and spot blotch. The third step was to improve malting quality. Cv. CLE 202 (Defra × FNCI 22), resistant to net blotch, scald and leaf rust, was released recently. It is a dwarf type (as cv. Defra), but the late maturity associated with this characteristic is balanced with photoperiod response, which determines a relatively short maturity and better performance than the European germplasm in late sowing dates. Four new lines are under multiplication by the industry, which has been very successful releasing high-yield and high quality cultivars.

The challenge for the future is to obtain earlier maturity lines adapted to the Northern growing area, and to increase the level of resistance to spot blotch and Fusarium head blight as well as tolerance to abiotic stresses.

Acknowledgements: To Euclydes Minella, Dr. Gerardo Arias (EMBRAPA, Brasil), Ing. Edmudo Beratto (INIA Chile), Ing. Mario Cattaneo (Maltería Pampa, Argentina), Ings. Silvia Pereyra, Marina Castro, Juan Díaz (INIA, Uruguay), Dr. Ariel Castro, Ing. Fernanda Gamba (Facultad de Agronomía, Uruguay), Ing. Sergio Pieroni (MUSA), and others that provided information or contributed in other ways to this review.

References

Abeledo G., Calderini D., Slaffer G. (2003): Genetic imporovement of barley yield potential and its physiological determinants in Argentina (1944–1998). Euphytica, **130**: 325–334.

Arias G. (1995): Mejoramiento genético y producción de cebada cervecera en América del Sur. FAO, Santiago, Chile.

Baer E. von, Borie G. (1999): Obtención de cebadas tolerantes a aluminio y acidez. In: Congr. Latinoamericano de Cebada. Resúmenes (3). Mesa Nacional de Entidades de Cebada Cervecera, FAO, Colonia, Uruguay: 12.

Beratto E. (1999): Investigación en Mejoramiento Genético de Cebada en Chile. In: Beratto E. (ed.): Congreso de Cebada Maltera (2). Paginas, Temuco, Chile: 63–72.

Beratto E. (2001): Contributions of breeding and crop management to increasing barley yield and grain quality in Chile. In: Vivar H.E., McNab A. (eds): Breeding Barley in the New Millenium. Proc. Int. Symp. CIMMT, Mexico, D.F.: 10–17.

Beratto M.E., Andrade V.O., Peyrelongue C.A., Espinoza N.N. (199?): Qué variedades sembrar? In: Beratto M.E. (ed.): Normas técnicas de producción de cebadas con calidad maltera. INIA Carillanca, Temuco, Chile, 3–4.

Brammer S.P. (2003): Resultados da cultira de anteras de cevada, durante o período de 1998 a 2002, como apoio ao programa de melhoramento gnético de cevada na EMBRAPA Trigo. In: De Marchi F.M. (ed.): Reunião Anual de Pesquisa de Cevada (23). EMBRAPA Trigo, Passo Fundo, Brasil, 61–67.

Carmona M., Barreto D. (1995): Enfermedades fúngicas de la cebada cervecera en la provincia de Buenos Aires (Argentina) in 1991. Fitopatol. Bras., **20**: 509—510.

Castro A., Kemanian A. (1999): Aproximación a un modelo de crecimiento del cultivo de cebada optimizado para el ambiente de producción del Uruguay. In: Congr. Latinoamericano de Cebada. Resúmenes (3). Mesa Nacional de Entidades de Cebada Cervecera. Colonia, Uruguay: 57.

Cattaneo M. (2001): Información cosecha 2000/2001 – Argentina. In: Minella E. (ed.): Reunião Anual de Pesquisa de Cevada (21). EMBRAPA Trigo, Passo Fundo, Brasil: 113–119.

FAOSTAT (2004): Faostat agriculture data (online). Rome, FAO. Available at: http://apps.fao.org/page/collections?subset=agriculture. Verified: April 13 2004.

Gamba F., Estramil E. (2002): Variation in virulence within an Uruguayan population of *Cochliobolus sati-*

vus. In: Int. Workshop Barley Leaf Blights. ICARDA, Aleppo, Syria: 20–21.

Gamba F., Tekauz A. (2002): Physiologic specialization in Uruguayan isolates of *Pyrenophora teres*. In: Int. Workshop on Barley Leaf Blights. ICARDA, Aleppo, Syria: 15–16.

Germán S., Arbelbide M., Abadie T., Romero R., Peculio A. (2000): Characterization of photoperiod response of barley genotypes from diverse origin. In: Logue S. (ed.): Int. Barley Genet. Symp. 8. Waite Campus, Adelaide University, Adelaide, Australia: 267–268.

Gilchrist L. (1989): Enfermedades de la cebada en Chile. In: Beratto E. (ed.): Mejoramiento y producción de cebada en Chile. INIA Serie Carillanca, Temuco, Chile, **12**: 85–90.

Minella E. (2000): Adapting barley to unfavourable environments: results from Brazil. In: Logue S. (ed.): Int. Barley Genet. Symp. 8. Waite Campus, Adelaide University, Adelaide, Australia, 267–268.

Minella E. (2001): Desafios e potencialidades do melhoramento genético de cevada no Brasil. In: Minella E. (ed.): Reunião Anual de Pesquisa de Cevada (21). EMBRAPA Trigo, Passo Fundo, Brasil, 31–40.

Minella E. (200?): Melhoramento de cevada. In: Borem A. (ed.): Melhoramento de plantas cultivadas. Viçosa, MG, UFV, 2nd ed. (in press).

Minella E., Silva M.S. (1996): Breeding for aluminum tolerance in Brazil. In: Slinkard A., Scoles G., Rossnagel B. (eds): Int. Barley Genet. Symp. 7. Mister Print Productions Ltd., Saskatoon, Canada: 528–529.

Passaella V.S., Savin R., Abeledo L.G., Slafer G.A. (2003): Malting quality as affected by barley breeding (1944–1998) in Argentina. Euphytica, **134**: 161–167.

Pereyra S. (1996): Identificación de fuentes de resistencia a enfermedades de cebada en Uruguay. In. Beratto E. (ed.): Congreso de Cebada Maltera (2). Páginas, Temuco, Chile: 173–174.

Pereyra S., Germán S. (2004): First report of spot-type of barley net blotch caused by *Pyrenophora teres* f.sp. *maculata* in Uruguay. Plant Disease, **88**: 1162.

Pereyra S., Stewart S. (2001): Investigación en Fusariosis de la espiga de cebada en Uruguay. In: De Marchi F.M. (ed.): Reunião Anual de Pesquisa de Cevada (21). EMBRAPA Trigo, Passo Fundo, Brasil: 41–68.

Sawasato J.T., Fae G.S., Furtado A.F., Federizzi L.C., Winge H. (2003): Detecção e análise da tolerancia ao alumínio em novas amostras populacionais de *Hordeum stenostachys* do Rio Grande do Sul. In: De Marchi F.M. (ed.): Reunião Anual de Pesquisa de Cevada (23). EMBRAPA Trigo, Passo Fundo, Brasil, 93–100.

Só e Silva M. (1999): Contribuição do melhoramento genético no rendimento de grãos e na qualidade industrial de cevada cervejeira no Brasil. In: De Marchi F.M. (ed.): Reunião Anual de Pesquisa de Cevada (19). EMBRAPA Trigo, Passo Fundo, Brasil: 293–298.

Sperotto J.T. (2000): Evolução do programa de melhoramento genético de cevada cervejeira na Companhia Cervejaria Brahma – Filial Maltaria Navegantes. In: De Marchi F.M. (ed.): Reunião Anual de Pesquisa de Cevada (20). EMBRAPA Trigo, Passo Fundo, Brasil: 113–119.

Tomaso J.C. (1995): Cultivo de cebada cervecera en Argentina, producción e investigación genética. In: Reunión Latinoamericana de Cebada Cervecera (1). FAO SNAG, Cochabamba, Bolivia: 69–74.

Zschoerper O.P., Sperotto A.L. (2001): A nova empresa AMBEV e sua política de fomento à produção e pesquisa de cevada. In: De Marchi F.M. (ed.): Reunião Anual de Pesquisa de Cevada (21). EMBRAPA Trigo, Passo Fundo, Brasil: 19–22.

Received for publication August 2, 2004
Accepted September 24, 2004

Abstrakt

Germán S. E. (2004): **Šlechtění sladovnického ječmene v podmínkách stresu v Jižní Americe – review.** Czech J. Genet. Plant Breed., **40**: 140–147.

Průměrná roční plocha osévaná ječmenem (*Hordeum vulgare*) byla v Jižní Americe v letech 1999–2003 795 000 ha. V Argentině, Brazílii, Chile a Uruguayi se pro výrobu sladu používají hlavně dvouřadé jarní odrůdy. Výzkumné práce probíhají v soukromých sladovnách a ve veřejných institucích podporovaných průmyslem. V sušších oblastech Argentiny je důležitý znakem tolerance k suchu a k tepelnému stresu během nalévání zrna. V letech 1940–1998 bylo u povolených odrůd zjištěno zvýšení výnosu jak zrna, tak i sladového extraktu. V Brazílii bylo zaznamenáno zvýšení výnosu a velikosti zrna, zlepšení sladařské kvality a dosažení ranosti a rezistence k závažným chorobám. Požadována je tolerance k půdní kyselosti a rezistence k houbě *Cochliobolus sativus*. Šlechtěním sladovnického ječmene v INIA-Chile se od roku 1976 podařilo zlepšit výnos a velikost zrna, zvýšit efektivnost výroby piva a odolnost k chorobám. Uruguay produkuje vysoce kvalitní slad, který se vyváží hlavně do Brazílie. Šlechtitelský program INIA (Uruguay) započatý v roce 1988 vedl ke zvýšení výnosu, sladovnické kvality a odolnosti k poléhání a chorobám. V Uruguayi a Brazílii je novým požadavkem rezistence k fusariose klasu. Jsou uvedeny informace o výrobě sladového ječmene, o nejvýznamnějších stresových činitelích v různých produkčních oblastech a o šlechtitelském pokroku v jihoamerických podmínkách.

Klíčová slova: *Hordeum vulgare* L.; šlechtění; stresové podmínky; Argentina; Brazílie; Chile; Uruguay

Corresponding author:

Dr. Silvia E. Germán, Instituto Nacional de Investigación Agropecuaria (INIA) La Estanzuela, C.C. 39173, Ruta 50, km 12, Colonia, C.P. 70000, Uruguay, South America
tel.: + 598 574 80 00, fax: + 597 574 80 12, e-mail: sgerman@inia.org.uy