THIRD SOUTH AMERICAN OATS CONGRESS

INIA La Estanzuela
Colonia · Uruguay
11th - 12th November, 1997

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OATS CONGRESS

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November 11-12, 1997

Mónica Rebuffo
Tabaré Abadie
Editors

The Quaker
Oats Company

Instituto Nacional de
Investigación Agropecuaria
(INIA)

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Acknowledgments

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We would also like to thank the participants, some of whom traveled long distances to attend the Congress, and whose contributions are essential for the success of this event.

Lastly, we would like to thank very specially to Ms. Karina Cabrera, from INIA La Estanzuela, for her participation in the organization of this Congress, and for her assistance in the editing of these Proceedings.

Mónica Rebuffo
Tabaré Abadie

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WORKSHOP

"OATS IN SOUTH AMERICA IN 2020"

POSTERS

A LOOK BACK AT 20 YEARS OF OAT RESEARCH CONDUCTED IN THE QUAKER OATS' INTERNATIONAL OAT IMPROVEMENT PROGRAM -- A NORTH AMERICAN VIEWPOINT

M.E. McDaniel

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A brief history of the oat project entitled "Breeding Oat Cultivars Suitable for Production in Developing Countries" is given in each of the yearly Quaker Oat reports bearing that title. As most of you are aware, the project was formally established in 1974 by Dr. H.L. Shands, Emeritus Professor of Agronomy at the University of Wisconsin at Madison, with funding provided by the United States Agency for International Development. The USAID grant provided funds through 1976, and the Quaker Oats Company assumed financial support of the project after the USAID grant expired; therefore, Quaker is completing its 21st year of sponsoring this project this year. The Quaker Oats Company primarily was interested in developing adapted milling oat varieties suitable for production in each of the Central and South American countries in which they had commercial cereal processing plants. The major thrust in oat improvement in the project has been in Brazil, Argentina, and Chile.

However, it should be pointed out that the Quaker Experimental Nursery has been sent to as many as 30 locations in North and South America, Africa, the Mid-East, Europe, and Australia in some years. The nursery basically has been sent to anyone requesting it, since I have been distributing the seed.

I will always be grateful to Dr. Shands for getting me involved in Quaker's International Oat Improvement effort. He recognized that I had some rust-resistant material, and that the "winter" oats such as those grown in the Southern U.S.A. were relatively well adapted in certain areas of South America, as evidenced by the success of 'Suregrain' in Argentina. Becoming a part of the Quaker program allowed me to visit Brazil, Argentina, Uruguay, Chile, Peru, Colombia, Ecuador, and Paraguay, and to broaden my knowledge of South America and its people. Don Schrinckel and Sam Weaver were very helpful in getting me oriented on my initial trips to South America and in translating my Texas English. I will never forget Elmar Floss pleading "Help me, Mr. Schrinkel!" when he could not understand a word I said.

I have enjoyed working with all the U.S.A. cooperators in this effort -- with Dr. Shands, Dr. Brinkman, Dr. Forsberg, and Ron Duerst of the University of Wisconsin (all of whom provided pure-line and segregating entries for the Quaker experimental oat nurseries), and more recently, with Dr. Stuthman of the University of Minnesota. I am particularly indebted to Dr. Brinkman for writing the Quaker Nursery reports during the 1980's and to Dr. Forsberg for writing these reports for the 1990's. I believe that including a broad spectrum of oat germplasm in the program and in making "wide" (spring x winter) crosses generated very diverse material from which suitable lines could be selected for diverse environments. Dr. Shands used that approach at the inception of the USAID project, and I believe that the method has served us all well.

To my knowledge, at least 50 varieties have been released from the Quaker effort. The largest number has been in Brazil, home of some of the world's most virulent races of crown rust. Improved varieties also have been released (or are in the process of release) in Argentina, Chile, and Uruguay. At least one new variety (a naked oat line selected at Castelar, Argentina) was released in Colombia. About 10 new varieties from the Quaker material have been released (or are currently in the release process) in Australia. I think we all can be proud of this variety-development accomplishment.

I also treasure the friendships I have developed with South American oat research personnel. It has been a thrill for me to see many of you develop and amplify your skills since I made my first trip to South America in 1979. Many of you have received advanced degrees either in your own countries, or in the United States. A good number of you have made trips to the U.S.A. to observe oat breeding programs. Several of you visited me in Texas, and I enjoyed all those visits; Carolyn and I were happy to be able to return some of the hospitality that you always extended to us when we were in each of your countries.

I know that I speak for each of the North American members of the Quaker International Oat Improvement team (both past and present) when I say that we treasure your friendship, as well as the professional relationships developed as a result of the long-term cooperative research effort. In some cases, we have watched your children grow up (in one-year increments, from one year's trip to the next), and really feel like part of your families.

In closing, I would like to point out that involvement in the Quaker International Oat Improvement Project has been very beneficial to the U.S.A. cooperators. Having our advanced oat pure-lines and segregating material subjected to very virulent crown rust races allows selection of the best level of resistance to more virulent rust races than we currently have. As a result, a large part of my early-generation and advanced breeding lines have at least one South American pure-line or early-generation selection as one of the parents. Since the Quaker International Oat Improvement effort has proved to be a "winning" situation for both North and South American cooperators (as well as for Australian oat workers), I hope that it will serve as a model to encourage greater cooperation among the world's oat workers. Such cooperation (whether within-country, within-continent, between-continent, or even "global") would be very beneficial to the world's oat research effort. It goes without saying that I hope that the Quaker International effort continues to have great success, and to show the great value of cooperative oat research efforts.

BREEDING OAT CULTIVARS SUITABLE FOR PRODUCTION IN DEVELOPING COUNTRIES - PROGRESS AND IMPORTANCE FOR SOUTH AMERICA

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Since 1974, there are a intensive cooperation between the University of Wisconsin, Texas A & M University and University of Minnesota and oat research programs of Argentina, Brazil Chile and Uruguay, through the project " Breeding oat cultivars suitable for productions in developing countries". The main objectives of the project is the development of new cultivars with higher yield potential, better adaptability to different countries, better grain quality and resistance to the most important diseases, such as crown rust (*Puccinia coronata* Cda.), stem rust (*Pucccinia graminis* f. sp. *Avenae)* and barley yellow dwarf virus (BYDV).

The project was formally established in 1974 by Dr. Hazel Lee Shands, Emeritus Professor of Agronomy at the University of Wisconsin with funding provided for two years (1974/1976) by a grant from the United States Agency for International Development -USAID (Brinkman and Shands, 1985). After 1976 since that time the Quaker Oats Company assumed funding responsibilities for the project and the most of the oat improvement work has been centered in South America, especially in Argentina, Brazil, Chile and Uruguay, because Quaker Oats has milling operations in these countries (Forsberg *et al.*, 1997).

In the mid - 1970s Dr. Milton E. McDaniel, Texas A & M University was actively involved in the project. From the late 1970s and early 1980s to 1990, Dr. Marshall Brinkman of the University of Wisconsin assumed major responsibility for direction and coordination of the program. Dr. Robert A. Forsberg, Emeritus Professor of Agronomy, University of Wisconsin and Ronald D. Duerst became the Wisconsin cooperators in 1990. Also are involved in the project Donald Schrickel and Samvel E. Weaver, grain improvement of Quaker Oats Company (Chicago). Since 1990, Romulo Trombetta, Quaker Agronomist of South America became activities at the project.

The principal activities of the project is the developing and distributing, each year, to different locations at Argentina, Brazil and Chile a series of pure lines and a series of F_2 or F_3 segregating populations (Quaker Nursery). The Quaker Team has made a annual trip to South America each November to visit the testing locations. These visits of Shands, McDaniel, Brinkman, Forsberg, Weaver, Schrickel, Charlie Brown (University of Illinois), Deon Stuthman (University of Minnesota) are very important for the South America oat breeders like consultants.

A majority of the most recent cultivars in Argentina, Brazil and Chile have been developed from the pure lines and segregating populations in the Quaker Nursery (Forsberg *et al.*, 1997).

The release of new cultivars has contributed significantly to the improved oat production and milling situation in Argentina, Brazil and Chile (Forsberg *et al.*, 1997).

Doctor Shands made the first trip in South America in mid-1960s. In Brazil Shands collaborated with the Agricultural Experimental Station - IPEAS (Agricultural Minister- Pelotas and Sertão, near Passo Fundo, CNPT/EMBRAPA since 1974), University of Rio Grande do Sul, University of Pelotas, University of Santa Maria and Quaker Oats Company (Porto Alegre). From the introduction of genetic materials was released by the IPEAS the cultivars IAS 2, IAS 3, IAS 4 and IAS 5. The University of Rio Grande do Sul introduced from USA the cultivars Coronado and Suregrain, those were the most important oat cultivars during about 20 years in the State of Rio Grande do Sul.

Also in the mid 1960s was recommended the cultivars Entre Rios, Agraria, Socorro and Vitoria at the Cooperativa Agraria Mista Entre Rios (Guarapuava-PR), selected from lines introduced from USA. These cultivars were cultivated in this region until mid - 1980s.

At the University of Rio Grande do Sul (Guaiba, now Eldorado do Sul) the oat breeding was initiated in 1974 with the Dr. Fernando I. F. de Carvalho. This program involved now the oat breeders and professors Luiz Carlos Federizzi, Sandra Milach and Marcelo Pacheco and selected 16 cultivars at this time: UFRGS1, UFRGS 2, UFRGS 4, UFRGS 5, UFRGS 6, UFRGS 7, UFRGS 8, UFRGS 9, UFRGS 10, UFRGS 11, UFRGS 12, UFRGS 14, UFRGS 15, UFRGS 16, UFRGS 17 and UFRGS 18.

In 1977 the oat germplasm was transferred from the CNPT/EMBRAPA to the University of Passo Fundo and since that time carrying out the Oat Research Program. During 1977 to 1997 decisive the cooperation University of Passo Fundo and the Quaker project (Floss *et al.*, 1996). As a result from twenty years of these activities, conducted myself and Lizete Augustin, seventeen new oat cultivars were released with a significant improvement at the oat crop in Brazil: UPF 1, UPF 2, UPF 3, UPF 4, UPF 5, UPF 6, UPF 7, UPF 8, UPF 9, UPF 10, UPF 11, UPF 12, UPF 13, UPF 14, UPF 15, UPF 16 and UPF 17. The UPF cultivars represented, in the last year, 85% of the total certificate seeds in the State of Rio Grande do Sul.

The Cooperative of Entre Rios carrying out a oat breeding program and some lines are actually in evaluation. The Agronomist, Juliano Almeida is the breeder and made is Master Course at the Texas A & M University by the adviser of Dr. Milton McDaniel.

From 1978 to 1994 de Cooperative of Ijui (COTRIJUI) conducted a oat breeding program by Renato Borges de Medeiros and Volnei Viau. As a result was released four new cultivars: CTC 1, CTC 2, CTC 3 and CTC 5.

In cooperation with the University of Passo Fundo and University of Rio Grande do Sul the CPPSE/EMBRAPA of São Carlos (São Paulo) and Agronomic Institute of Paraná (IAPAR) are involved in oat research program.

The oat programs in Argentina released many cultivars during the last years as Suregrain (1969), Moregrain (1978), Millauquén INTA (1987) and Cristal INTA (1990) from the Bordenave Station and Bonarienses Payé (1991) from the Barrow Station (Tomaso, 1994). These cultivars are significantly better than older cultivars in one or more traits (Forsberg *et al.*, 1997). The oat breeding program in Argentina involved Héctor Carbajo, Juan C. Tomaso and Liliana Wehrhane.

The Carrilanca Station, INIA, Chile, initiated a oat breeding program in 1964 and in 1975 was included at the Quaker Program. As result was released the cultivars Yecufén (1981), Nehuén (1974), América (1985) and Urano (1992). As product of crosses made in Chile was released the cultivars Ancafén (1978) and Llaofén (1982) (Beratto, 1994). The leader of the breeding program is Edmundo Beratto.

During various years was also evaluated the Quaker Nursery at La Estanzuela Station (Uruguay), involved Monica Rebuffo. The cultivars released in Uruguay in the last years are for fodder purpose and not for grain.

In conclusion, it is very grateful for me the involvement in the Quaker project during 20 years. I saw the improvement of oat crop in Brazil, visited the Wisconsin and Texas A&M University (1982), Temuco (1987), Aberystwith (1985), Barrow and Bordenave (1991), La Estanzuela (1995) and Saskatoon (1996) and knew many oat researchers in many locations. The project Breeding Oat Cultivars Suitable for Production in Developing Countries is the best example of success cooperative program. Thanks for all, specially, thank you Dr. Shands, Dr. McDaniel, Dr. Brinkman, Dr. Forsberg, Dr. Stuthman, Dr. Weaver and Donald Schrickel.

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INTERNATIONAL TRADE OF OATS

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World oat production declined by 24% during the past ten years (Table 1). The decline was caused by lack of demand, low net returns per hectare and government programs. Relative to other feed grains, oats are expensive and do not have the same feeding value. The demand for oats as food increased slightly for the same period. The increase in food demand does not replace the decrease in feed demand. The North American Free Trade Agreement (NAFTA), General Agreement on Trade and Tariffs (GATT), the European Economic Community and the Mercosur have affected world oat production and trade. Government subsidies for raw commodities and transportation will decrease over the next several years and that will be beneficial to oats in the short term. However, the rapid decline in oat production will continue into the future until an economic equilibrium is met.

Table 1. World Production of Oats

October / September Crop Year
(1,000 Metric Tons)

				USDA SEPTEMBER
Country	1987	1992	1996	1997
U.S.	5.424	4.271	2.253	2.720
Canada	2.957	2.829	4.381	3.500
Sweden	1.440	807	1.200	1.200
Finland	813	1.058	1.260	1.800
France	1.045	700	620	550
Germany	3.043	1.314	1.610	1.500
Poland	2.428	1.229	1.580	1.600
FSU	15.876	14.130	10.000	10.530
Argentina	650	450	320	300
Australia	1.738	1.966	1.670	1.800
Others	5.227	4.993	5.626	5.490
TOTAL	40.641	33.747	30.520	30.990

The Former Soviet Union (FSU) is the world's largest producer of oats (Table 1). However, there are no exports from the FSU (Table 2) because of internal requirements and lack of infrastructure. The U.S.A., Canada, Sweden and Finland account for approximately 30% of the world oat production and 90% of the exports. Less than 3% of the world oats are produced in the Southern Hemisphere. However, oats are important in Argentina, Brazil, Chile, Uruguay, New Zealand and Australia. Oats are used as a winter cover crop, winter pasture, summer forage and as a cash grain crop in these countries. The only significant exports come from Australia. Fifty-two percent of the Australian oats go to Japan, 44% to Chile, Peru and Ecuador and about 4% are exported to Asia (Table 2).

Table 2. 1997/98 World Oat Trade Matrix* (000) T

Oct/Sep Year	Canada	Sweden	Finland	Australia	Others	World
United States	1.350	350	100			1.800
EU					25	25
Japan	25			65		90
Latin America	25			55		80
O W Europe					50	50
E Europe						0
FSU						0
Others			50	5		55
World 1997/98	1.400	350	150	125	75	2.100
World 1996/97	1.600	350	100	250	75	2.375

*AgResource Company

Oat production in Australia remained essentially flat for the past ten years while that in Brazil, Chile and Uruguay increased slightly. Argentine oat production declined about 50%. The average oat yields in Chile increased to over 3 T/HA and those in Brazil and Uruguay remained unchanged (Table 3). The yields in Argentina actually declined during the same time period. Chile has an excellent environment to grow oats and the yields there reflect the genetics of the new varieties. Brazil, Uruguay and Northern Argentina are subjected to tremendous rust pressure. Consequently, new varieties must be released very often to stay ahead of the rust. The challenge is to find more durable rust resistance in order to give the newer varieties a chance to express their true yield potential in rust environments. The area planted to oats in the major oat growing area of Argentina was reduced by competition from barley, sunflowers and wheat. High world prices and demand for the other grains have pushed the oats onto less favorable land in Argentina.

Table 3. South American Oat Production, Yields and Area

ARGENTINA*

Year	Planted Area (000) HA	Harvested Area (000) HA	Yield T/HA	Production (000) T
1987	1.530	495	1.33	658
1988	1.960	355	1.29	458
1989	1.830	420	1.42	596
1990	2.100	325	1.41	458
1991	1.815	370	1.24	459
1992	2.180	370	1.08	400
1993	2.006	360	1.16	418
1994	1.971	303	1.22	370
1995	1.980	240	1.00	240
1996	2.000	280	1.30	364
1997	1.900	300	1.08	324

BRAZIL*

Year	Harvested Area (000) HA	Yield T/HA	Production (000) T
1987	175	1.2	210
1988	139	1.1	153
1989	235	1.1	259
1990	174	1.0	174
1991	228	0.8	182
1992	295	1.0	295
1993	292	1.1	321
1994	309	1.1	340
1995	180	0.9	162
1996	300	1.0	300
1997	320	1.0	320

CHILE*

Year	Harvested Area (000) HA	Yield T/HA	Production (000) T
1987	55	2.6	143
1988	60	2.4	146
1989	68	2.6	179
1990	78	2.7	211
1991	70	3.2	225
1992	68	3.0	202
1993	57	3.1	176
1994	58	3.2	185
1995	55	2.2	120
1996	85	3.8	320
1997	60	3.3	200

URUGUAY**

Year	Harvested Area (000) HA	Yield T/HA	Production (000) T
1984	49	1.0	49
1985	33	0.6	20
1986	42	0.7	29
1987	58	1.0	58
1988	52	1.2	62
1989	65	1.1	72
1990	51	1.0	51
1991	35	0.8	28
1992	37	1.1	41
1993	45	0.9	41
1994	31	1.1	34
1995	32	1.1	35

*Personal Communication from R. V. Trombetta

**Direccion de Censos Y Encuestas, Serie Informativa, Boletin Nro. 179. Septiembre, 1995

From 1987 to 1997, the area planted to oats in the U.S.A. has declined by 70%. Government programs unfavorable to oats, competition from other crops, Canadian rail subsidies, declining feed demand, and diseases, especially crown rust, have contributed to the sharp reduction in area planted to oats. Table 4 shows this decline in planted area. The major oat producing states of Iowa, Minnesota, North Dakota, South Dakota and Wisconsin have suffered an almost 75% decline in area planted to oats. Some of the same forces that have caused sharp declines in the U.S.A. are at work in Argentina. During the same period, oat production in the U.S.A. has declined by almost 50% (Table 5). The continual release of new, high yielding varieties buffered the production decline in the U.S.A.

Table 4. U.S.A. Annual Oats Planted Area. (000 Hectares)

State	1987	1992	1997
Alabama	18	20	18
Arkansas	9	10	8
California	154	154	142
Colorado	40	32	26
Georgia	22	32	28
Idaho	26	24	32
Illinois	850	162	38
Indiana	243	40	24
Iowa	1700	344	133
Kansas	97	81	50
Kentucky	11	0	0
Maine	17	11	11
Maryland	7	5	4
Michigan	142	56	40
Minnesota	850	283	166
Missouri	61	36	18
Montana	95	67	56
Nebraska	328	133	73
New Jersey	2	0	0
New York	93	56	48
North Carolina	42	36	22
North Dakota	425	316	283
Ohio	142	89	52
Oklahoma	65	44	36
Oregon	36	26	34
Pennsylvania	117	89	77
South Carolina	24	23	20
South Dakota	567	364	174
Tennessee	0	0	0
Texas	445	283	235
Utah	11	18	20
Virginia	14	0	0
Washington	30	26	14
West Virginia	5	4	2
Wisconsin	526	322	214
Wyoming	30	22	24
TOTAL	7.244	3.208	2.122

Table 5. U.S.A. Annual Oats Production by State (000 TON)

State	1987	1992	USDA Aug. 1997
Alabama	18	21	13
Arkansas	18	23	15
California	41	40	34
Colorado	39	22	24
Georgia	24	53	36
Idaho	39	21	20
Illinois	190	115	78
Indiana	92	40	34
Iowa	537	364	279
Kansas	94	113	74
Kentucky	5	0	0
Maine	41	31	23
Maryland	13	8	8
Michigan	248	113	75
Minnesota	661	507	276
Missouri	46	35	23
Montana	88	73	56
Nebraska	255	223	103
New Jersey	3	0	0
New York	156	111	95
North Carolina	51	43	24
North Dakota	527	542	275
Ohio	253	175	118
Oklahoma	33	29	30
Oregon	75	61	53
Pennsylvania	215	189	127
South Carolina	26	32	26
South Dakota	766	621	287
Tennessee	0	0	0
Texas	143	83	113
Utah	14	15	9
Virginia	7	0	0
Washington	28	26	19
West Virginia	5	5	2
Wisconsin	626	498	327
Wyoming	32	24	26
TOTAL	5409	4256	2702

Canadian oat production has increased slightly to feed the demand and loss of production of oats in the U.S.A. and South America. Transportation subsidies and government controlled wheat prices have given Canadian producers the incentive required to grow more oats. Table 6 shows the combined supply and disappearance in the U.S.A. and Canada. The 1997 North American oat production is estimated to be about 6.2 million metric tons. Projections for 1998

American oat production is estimated to be about 6.2 million metric tons. Projections for 1998 indicate a continued decline in North American oat production with the U.S.A. declining more rapidly than Canada. Also note that the ending stocks are getting critically low. Interestingly, the Minneapolis Grain Exchange price is remaining relatively constant at about $140 per ton. The price stability may indicate that the supply is remaining much higher than the demand. When the supply and demand come closer together, more price volatility might be expected.

Table 6. U.S.A. Canada combined Oats. Supply/Disappearance (Million Hectares and Million Metric Tons)

SUPPLY	1994	1995	1996*	1997*
Area Harvested	3.11	2.40	2.77	2.78
Average Yield	2.24	2.17	2.39	2.23
Production	6.96	5.21	6.61	6.19
Beginning Stocks	2.44	2.20	1.38	1.57
Net Imports	0.34	0.00	0.09	0.09
Total Supply	9.74	7.41	8.08	7.86
DISAPPEARANCE				
Net Exports	0.00	0.13	0.00	0.00
Domestic Use	7.55	5.90	6.52	6.76
Total Disappearance	7.55	6.03	6.52	6.76
Ending Stocks	2.20	1.38	1.57	1.09
Minneapolis ($/Ton)	102.00	157.00	140.00	138.00

* AgResource Company

The oat production in China has received little attention because these oats are not involved in world trade. The U.S.A. Department of Agriculture - Foreign Agriculture Service estimates that the oat production in China is 500.000 metric tons. However, Sparks Companies, Inc. estimates that production is about 3 million metric tons of which 600.000 T are available for internal commercial trade. From personal observation, the Sparks estimate seems very reasonable. At least 95% of the oats in China are naked oats (*Avena nuda*). The majority are consumed as food on or near the farm where they are produced. There are oat processing facilities for the manufacture of consumer products. A small percentage of the oats is used as animal feed.

OATS SITUATION IN ARGENTINA

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SUMMARY

Oats production in Argentina has been decreasing since 1987 being 1989 the last year in which a 600.000 tons production was achieved. In 1995 production was the lowest in history due to the drought.

This years´s production will be similar to that of previous years always following a decreasing trend.

A nivel nacional la producción de avena ha disminuido sensiblemente desde 1987 1988 último año en que se logró una producción de 600.000 toneladas.

Tabla 1. Argentina Oats Production

Año	000has area	000has harvested	000 mtonnes	yields-tons
1987	1.530	495	660	1.33
1988	1.960	355	460	1.29
1989	1.830	420	600	1.42
1990	2.100	325	460	1.41
1991	1.815	370	460	1.24
1992	2.180	370	400	1.08
1993	2.006	360	420	1.16
1994	1.971	303	370	1.20
1995	1.980	240	240	1.00
1996	2.000	280	360	1.30
1997	1.900	300	325	1.083

La superficie sembrada con avena es más o menos constante, lo que ha disminuido considerablemente es la superficie cosechada.

Las perspectivas de la avena para la nueva campaña son semejantes a las del ciclo anterior en cuanto a superficie y volumen, se estima una producción total de 325.000 toneladas.

Por tener rendimientos menores que el trigo y la cebada y la necesidad de utilizar fungicidas para el control de royas, los costos de producción de avena son superiores a los de los cultivos alternativos. Muchos productores tradicionales de avena se han inclinado hacia el trigo candeal (*Triticum durum*) y cebada forrajera.

La industria ha ofrecido para esta campaña contratos de producción tomando el precio del trigo como referencia. Con un stock inicial de 5000-6000 toneladas, necesidad de avena semilla similar a la de años anteriores, demanda de avena como forraje semejante y muy bajo volumen de exportación, se puede estimar que el precio para el grano de avena durante 1998 será similar al del trigo.

Se prevé que en las próximas campañas el cultivo de avena siga la tendencia mundial de disminución en la superficie sembrada. El volumen de la producción futura dependerá en gran medida de la posibilidad de lograr nuevas variedades resistentes-tolerantes a los ataques de roya y de encontrar nuevas alternativas de manejo para el cultivo.

RECENT BRAZILIAN OAT PRODUCTION

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BRAZIL

Oat planted hectarage, harvested grain hectarage, production and yield of Brazil from 1990 through 1997 are given in Table 1. An important point to be made is that the Brazilian Statistics Service consider two species, white oat (*Avena sativa*) and black oat (*Avena strigosa*), in the harvested grain hectarage. Considering that black oat has lower yield potential than white oat, this may explain the low yields that were achieved along the years. While oat is grown in São Paulo and Mato Grosso do Sul States and then towards the South, they are presently concentrated in the Southern States: Paraná, Santa Catarina and Rio Grande do Sul. Harvested grain hectarage, production and yield of the three Southern States are presented in Table 2.

Table 1. Oat planted hectarage, harvested grain hectarage, production and yield of Brazil, 1990 through 1997.

Year	Planted (ha)	Harvested grain (ha)	Production (t)	Yield (kg/ha)
1990	202 311	193 200	177 760	920
1991	274 166	265 081	230 423	869
1992	284 375	284 025	297 361	1047
1993	270 286	268 018	262 816	980
1994	310 180	281 545	260 995	927
1995	172 565	165 179	180 880	1095
1996 ‡	-	147 110	196 279	1334
1997 ‡	-	189 390	283 223	1495

† Source: IBGE - Brazilian Statistics Service. ‡ Projected.

THE STATE OF PARANÁ SITUATION

The agricultural statistical agencies from the different Southern States have a different approach in collecting data about oat production (Table 2). The Paraná Department of Agriculture considers harvested grain hectarage both species of oats (white and black oats). For instance, there is a projection that about 56000ha of white oat will be harvested by the end of the 1997 season (Groxko, 1997, personal communication). The remaining area of about 75300 ha of black oat will be harvested for seed increase purpose. Nevertheless, large areas in the State of Paraná are switching from black to white oats. This fact is happening mainly in the North part of the State, due to the implementation of a new oat mill facility, located in Mauá da Serra, which was inaugurated on March 1997. Another traditional oat growing region in this state is located in Guarapuava, where the Cooperativa Agrária Mista Entre Rios is located. During the 1997 season, 8 158 ha of white oat were grown for grain purposes in this location. The Cooperativa Agrária is still the major supplier for Quaker Oats Company mill facility, located in Porto Alegre. Oat cultivar seed amount that was produced in 1996 and commercialized prior the 1997 growing season in the State of Paraná is listed in Table 3.

Table 2. Oat harvested grain hectarage, production and yield of Paraná, Santa Catarina and Rio Grande do Sul, 1990 through 1997.

	Paraná †			Santa Catarina ‡			Rio Grande do Sul §		
Year	Harvested grain (ha)	Production (t)	Yield (kg/ha)	Harvested grain (ha)	Production (t)	Yield (kg/ha)	Harvested grain (ha)	Production (t)	Yield (kg/ha)
1990	31 537	34 317	1 088	9 850	12 287	1 247	147 788	127 622	864
1991	70 473	74 096	1 051	14 395	18 161	1 262	178 617	136 075	762
1992	66 672	67 184	1 008	9 840	10 939	1 112	201 653	217 160	1 077
1993	55 148	52 171	946	8 440	8 165	967	213 380	200 641	940
1994	55 252	67 522	1 222	12 440	13 801	1 109	208 232	175 956	845
1995	100 000	111 000	1 110	12 755	11 368	891	57 746	47 378	820
1996	84 175	113 000	1 342	14 255	12 302	863	45 454	69 148	1 521
1997 ¶	131 470	172 500	1 312	15 595	18 430	1 182	45 455	70 354	1 548

† Source: SEAB/DERAL - Paraná Department of Agriculture - 1997 (white and black oat for grain production).
‡ Source: IBGE - County Agricultural Production Institute - 1997 (white and black oat for grain production).
§ IBGE, 1990-1997 (white oat for grain production).
¶ Projected.

Table 3. Oat cultivar seed amount produced in 1996 and commercialized prior the 1997 growing season in the State of Paraná, Brazil †.

Cultivar	Amount	Sub-total	Cultivar	Amount	Total amount
White oat	(kg)	(%)	Black oat	(kg)	(kg)
IAC - 7	1 767 920	61.37	Comum black	5 691 425	
UPF - 7	2 160	0.07			
UPF - 15	229 440	7.96			
UPF - 16	205 400	7.13			
UFRGS - 14	215 640	7.48			
UFRGS - 15	332 280	11.53			
UFRGS - 16	18 000	0.62			
UFRGS - 18	109 960	3.82			
Sub-total	2 880 800	100.00		5 691 425	
% of the total	33.6			66.4	8 572 225

† Source: SEAB/DEFIS - Paraná Department of Agriculture - Seed Division - 1997

THE STATE OF SANTA CATARINA SITUATION

Oat harvested grain hectarage, production and yield of Santa Catarina from 1990 through 1993 are given in Table 2. The Santa Catarina agricultural statistical service also considers harvested grain hectarage both species of oats (white and black oats). However, it is known that most of the oat grown in this area is black oats (Ramos, 1997; Lino, 1997, personal communications). Oat is mainly grown in the Midwest (Campos Novos) and in the West part of Santa Catarina (Xanxerê and Abelardo Luz), for forage and cover crop purposes.

THE STATE OF RIO GRANDE DO SUL SITUATION

The State of Rio Grande do Sul used to rank first in total white oat harvested grain hectarage until 1996. Nevertheless, it may change this year. While Rio Grande do Sul has a projected grain hectarage of 45455 ha of white oats, the Paraná State has a projection of 56000 ha for 1997. That means that if projections are confirmed, this year Paraná will be the top white oat grain producer. The Department of Agriculture Statistics of Rio Grande do Sul considers harvested grain hectarage only white oats. Most of all white oats cultivated in Passo Fundo, Lagoa Vermelha and Vacaria is harvested for grain. The oat cultivar seed amount that was produced in 1996 in the State of Rio Grande do Sul is listed in Table 4.

Table 4. Oat cultivar seed amount produced in 1996 in the State of Rio Grande do Sul, Brazil †.

Cultivar White oat	Total Amount (kg)	Sub-total (%)
CTC - 1	28 260	0.24
CTC 185-B17	17 980	0.15
CTC - 3	115 060	0.98
CTC - 5	6 950	0.06
IAC - 7	40 000	0.34
UFRGS - 7	329 280	2.79
UFRGS - 10	83 000	0.70
UFRGS - 14	378 430	3.21
UFRGS - 15	158 400	1.34
UFRGS - 16	456 340	3.87
UFRGS - 17	113 750	0.96
UFRGS - 18	32 570	0.28
UPF - 7	1 461 050	12.39
UPF - 14	462 690	3.92
UPF - 15	860 480	7.30
UPF - 16	6 712 830	56.91
UPF - 17	537 480	4.56
Total	11 794 550	100.00

† Source: MAA-DFA/RS-SPV. Brazilian Department of Agriculture - State of Rio Grande Sub-division. Elaborated by R.C. Rosinha. 1997. EMBRAPA/Sementes Básicas. Passo Fundo. RS.

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AREA, PRODUCTION AND YIELD OAT TREND IN CHILE

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SUMMARY

The area, production and yield oat trend in Chile, in the last 60 years, has diminished in area seeded in 40.3 %, while the production and yield have increased in 76.1 % and 122 %, respectively.

The gains in production are consequence, in 54.7 %, of the advances in the oat breeding in grain yield and agronomic type, reached during the last 30 years, with the new oat varieties released through: a) introduction and selection of foreign materials; b) bulk and pure line selection of Chilean germplasm; c) hybridization and selection of segregation material. The agronomic management have contributed in this increased production in 45.3 %, specially: fertilization and weeds control.

At present, the area seeded is 66.264 has, the total production 1.940 ton, and national average oat grain yield 2.93 ton/ha.

INTRODUCCIÓN

La Dirección de Estadísticas y Censos, y en la actualidad el Instituto Nacional de Estadísticas de Chile (INE) han sido, desde 1935, los organismos oficiales del gobierno encargados de recolectar, procesar e informar anualmente de la superficie, producción y rendimiento, de diferentes cultivos, entre éstos los cereales. La metodología empleada, avala la base técnica y respaldo de la información entregada.

Esta es la razón, porque el análisis de la evolución de los parámetros antes mencionados abarca un período que se extiende desde 1935 a 1995.

EVOLUCIÓN DE LA SUPERFICIE, PRODUCCIÓN Y RENDIMIENTO

La evolución de la superficie, producción y rendimiento de avena en Chile, en los últimos 60 años, se ha caracterizado por una disminución de la superficie sembrada con este cereal de 40.3 %, un aumento de la producción de grano de 76.1 % y un incremento de los rendimientos nacionales promedios de 122 %.

Chile, actualmente, produce más avena con una menor superficie, debido a un sustancial incremento de los rendimientos. La mayor producción obtenida, se explica en un 54.7 %, por los avances logrados a través del fitomejoramiento genético de este cereal, vía la incorporación al cultivo comercial de nuevas variedades de avena, ya sea introducidas, seleccionadas y creadas, y el 45.3 % restante, se puede explicar por la incorporación y mejoramiento de técnicas agronómicas en el manejo del cultivo, tales como fertilización y control de malezas (Hernández, 1994).

La evolución de la superficie y producción de avena, expuesta anteriormente, se representa con la tendencia que han tenido estos parámetros en los 12 últimos quinquenios (Figura 1) analizados. Se optó por estudiar las tendencias en base a quinquenios, ya que estos permiten entregar una información más real, de la evolución de la superficie y producción, que los antecedentes anuales; ya que, neutralizan efectos de sequía, enfermedades, precios, accidentes climáticos, etc., que se producen anualmente.

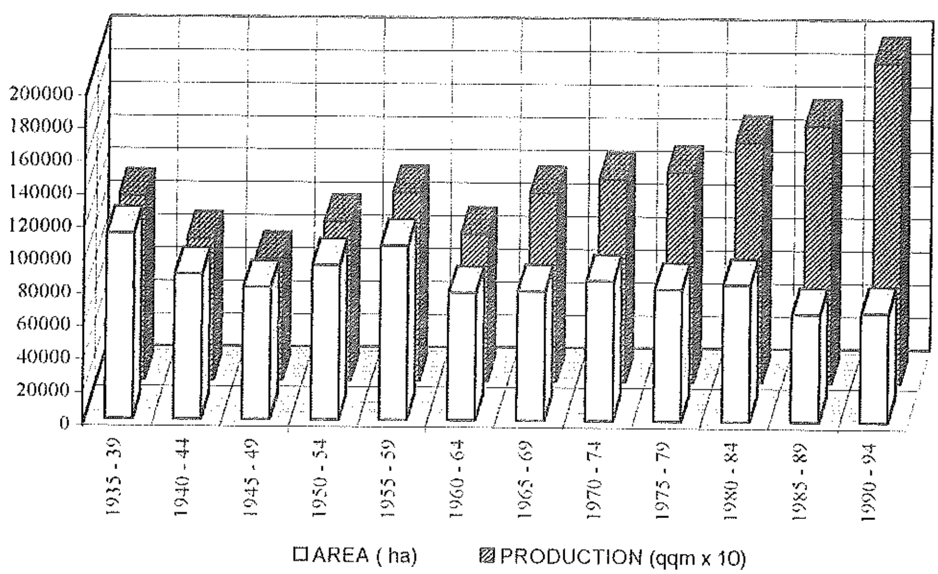

Figure 1. Area And Production Oat Trend in Chile, in Five Year Periods (1935-1994).

La evolución de los rendimientos nacionales promedio se representan anualmente en la Figura 2, con el propósito de estudiar las tendencias de éstos, desde 1935 a 1995, y determinar, en lo posible, el o los factores causales que han influido en el aumento de los rendimiento en un periodo de 60 años.

COMENTARIOS

Las perspectivas futuras de aumento de rendimiento siguen siendo altamente positivas, puesto que aún subsiste una gran brecha entre los rendimientos nacionales promedios con los rendimientos promedios de los agricultores innovadores y, entre los rendimientos promedios obtenidos en el Centro Regional de Investigación Carillanca, con la mejor variedad comercial y el rendimiento máximo obtenido, a nivel de investigación, con la mejor línea avanzada.

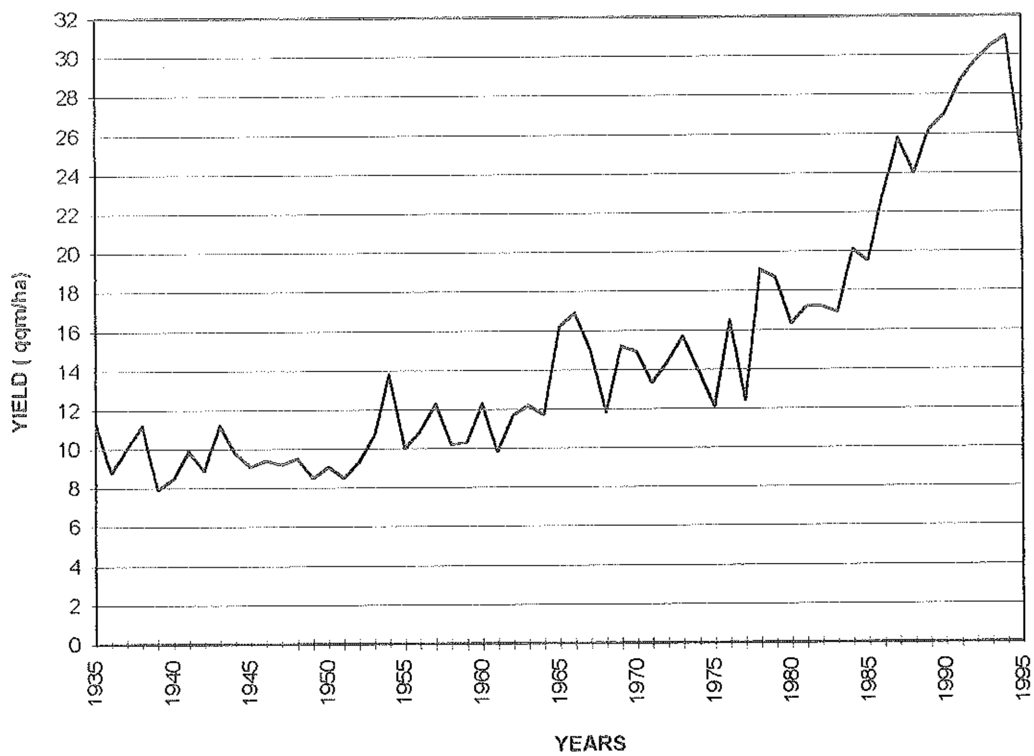

Figure 2. Annual Trend of Oat Yield in Chile (1935 - 1995).

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OAT USE AND PRODUCTION IN URUGUAY

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Historically, oat has been a multipurpose crop planted for numerous reasons other than a cash grain crop. The role of oat in the livestock-grain production system is to add flexibility to the time of planting, the availability of fall and winter forage, the high accumulation of spring forage and the establishment of undersown legumes.

Oat ranks first in winter forage species, preceding annual ryegrass (Table 1). The utilization of oat for forage and grain is a common production practice. Oat harvested as grain accounts for only about 24% of total crop area.

Table 1. Sown area (ha) of winter annual forage species for period 1951 through 1990.

	1951	1966	1970	1980	1990
Total Oat	356.053	355.258	250.566	296.453	263.810
Double-purpose oat	80.713	102.263	66.596	65.018	52.037
Grazing oat	275.340	252.995	183.970	149.842	211.773
Annual Raygrass	7.208	82.416	75.294	39.265	53.335
Others	38.501	46.523	18.218	4.658	9.946
Total	401.762	484.197	344.078	340.376	330.421

Source: Dirección de Agronomía, 1952; Dirección de Economía Agraria, 1968, 1973; Dirección de Investigaciones Económicas Agropecuarias, 1983; Dirección de Censos y Encuestas, 1994.

The agricultural significance of oat in Uruguay has fallen since the mid-1950s, when it ranked first in hectares planted among the principal forage crops. The proportion of oat hectarage sown for forage and double purpose dropped slightly from 89% in 1951 to 80% in 1990 (Table 1). Government support in the 1960s determined a sharp increase in the area planted to perennial pastures (Table 2). Although oat area planted for forage or double purposes has been relatively stable between 1951 and 1990, its relative share has fallen sharply. In 1951, oat hectarage represented 75% of all forage crops, whereas in 1990 it dropped to 25%.

Table 2. Area (ha) of annual and perennial forage crops for period 1950 through 1990.

	1951	1966	1970	1980	1990
Annuals	459.415	567.674	419.305	378.046	406.455
Winter	401.762	484.197	328.161	340.376	330.421
Summer	57.653	83.477	91.144	37.670	76.034
Perennial	17.078	278.512	507.119	493.973	659.652
Total	476.493	846.186	926.424	872.019	1.066.107

Source: Dirección de Agronomía, 1952; Dirección de Economía Agraria, 1968, 1973; Dirección de Investigaciones Económicas Agropecuarias, 1983; Dirección de Censos y Encuestas, 1994.

Oat area harvested for grain rose to almost 65.000 ha in 1989 but since then it has declined to an average of 36.000 ha for the period 1991 through 1995 (Figure 1). Low grain yields and small variations between years determined a similar trend for grain production. Average yield for the period 1984 through 1995 was 989 kg/ha. The lowest average yield was 613 kg/ha in 1985, and the highest 1.231 kg/ha in 1988.

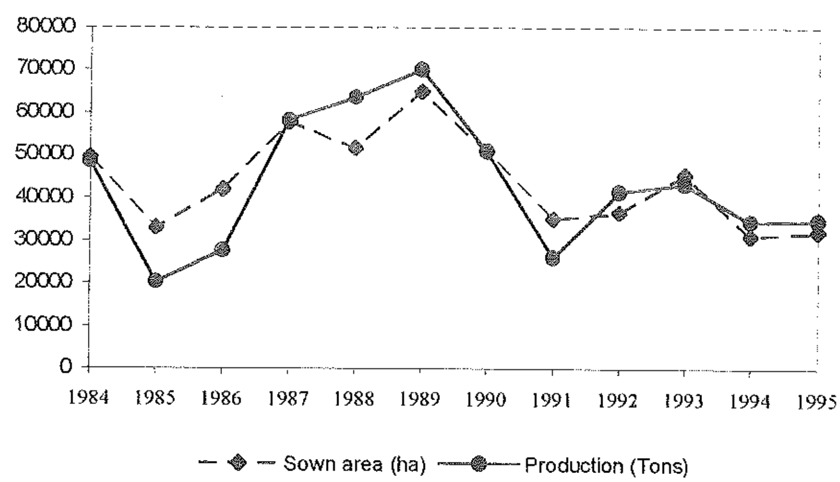

Figure 1. Sown area (ha) and grain production (ton) for double purpose oats in Uruguay. Period 1986-1995. Source: Dirección de Censos y Encuestas, 1995, 1997.

Oat for grazing is grown through out the country. However, the regional distribution of oat for grain follows a similar pattern to that of wheat and barley, competing for available land resources. The highest proportion of oat, for either double purpose or grain harvesting, is sown in the area most suitable for agriculture (Table 3). The agricultural zone (Soriano, Rio Negro, Paysandú and Colonia) accounted for an average 64% of all the oat grown in Uruguay for grain during 1991, whereas the dairy area (San José, Canelones, Montevideo, Florida) accounted for only 3%. Traditionally, the oat grain was consumed, either as cattle feed or seed for next crops, on the farm where the grain was produced. However, this pattern has changed with the increase of intensive dairy farming, where the oat seed is bought on the market, and the oat crop is used primarily as forage.

Table 3. Regional distribution of double purpose oat (ha) and grain production (ton) for 1991.

Region	Sown area (ha)	%	Harvested area (ha)	%	Grain production (ton)	%
Agriculture	37885	75%	13674	78%	10993	75%
Extensive Beef Cattle	11386	22%	4075	23%	3197	21%
Dairy Cattle	1425	3%	639	4%	558	4%
TOTAL	50696	100%	17633	100%	14748	100%

Source: DICOSE, 1992.

Even though official records are not available, the contribution of oats to the total area of winter annual forages has probably declined in the 1990s. Successful wheat cultivars for double purpose (grain and forage) have been adopted by the dairy farm as an additional source of winter forage.

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GENOTYPE X ENVIRONMENT INTERACTION IN OATS: THE CASE OF BRAZIL REGIONAL TRAILS

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INTRODUCTION

Genotype by environment interactions can be a problem in most breeding programs, specially because genotypes are selected in one environment and they are used in distinct agronomic systems, but it represents an opportunity to effectively maximize grain yield in different environmental and agricultural conditions. Analysis of regional trials performed over years and locations can proportionate relevant information regarding: 1) differences in target environments; 2) allocation of resources as replications, locations and number of years of test; 3) identification of best selection sites; 4) identification of varieties with better performance across environments (adaptability and stability); 5) recommend varieties for each specific environment.

Oat (*Avena sativa* L.) is grown in Brazil in the southern states of Rio Grande do Sul (RS), Santa Catarina (SC) , Parana (Pr) and São Paulo (SP). New lines are tested in several locations in each state before recommendations are made. Previous studies with oats in Brazil indicated that genotype by years interaction is more relevant than genotype by locations (Carvalho *et al.*, 1982; Federizzi *et al.*, 1993; and Augustin *et al.*, 1997). A new set of high yielding oat varieties have been released in recent years and they were tested over several environments with and without application of fungicide to control crown rust (*Puccinia coronata avenae*). The objective of the present study was to do a post-factor analysis of genotype by environment interaction with regards to performance of the varieties and the number of sites for selecting and testing oat genotypes in Brazil.

MATERIALS AND METHODS

Genotypes utilized were all recommended varieties in Brazil: CTC 1, CTC 2, CTC 3, CTC 5, UFRGS 7, UFRGS 10, UFRGS 14, UFRGS 15, UFRGS 16, UFRGS 17, UFRGS 18, UPF 7, UPF 13, UPF 14, UPF 15, UPF 16 and UPF 17. Locations and years (x) where the experiments were realized are:

Location / Year	State	1993		1994		1995		1996	
		W/F	F	W/F	F	W/F	F	W/F	F
Eldorado do Sul (ELD)	RS	x	x	x	x	x	x	x	x
Passo Fundo (PF)	RS	x	x	x	x	x	x	x	x
Vacaria (VC)	RS	x	-	x	-	x	-	x	-
Lages (LA)	SC	-	-	-	-	x	-	x	x
Campos Novos (CN)	SC	x	x	x	x	x	x	x	x
Ponta Grossa (PG)	Pr	x	x	x	x	x	x	x	x
Entre Rios (ER)	Pr	x	x	x	x	x	x	x	x
Maua da Serra (MA)	Pr	-	-	x	-	x	x	x	x
Londrina (LD)	Pr	-	-	x	x	x	x	-	-
S. Miguel (SM)	Pr	-	-	-	-	-	-	x	x
Irati (IR)	Pr	-	-	-	-	x	x	x	x
S. Carlos (SC)	SP	-	-	x	-	x	-	x	x
Parapanema (PA)	SP	-	-	x	-	-	-	x	x
Piracicaba (PI)	SP	-	-	-	-	-	-	x	-

All experiments consisted of three replications where tebuconazole 0,75 l/ha (F) was applied and three replications without application of the fungicide (W/F). Plots were composed of 5 rows spaced 0,20m and 5m long. Only the three central rows were harvest for yield. Analysis of variance was performed with the mean grain yield using the procedure GLM of SAS. Varieties, years and locations were considered random and fungicide fixed. Three different analysis were performed with locations being grouped in different ways: 1) each location as an environment (MS all); 2) considering the state as an environment (MS state); 3) allocating the locations in two macro environment, the traditional (ELD, PF, VC, CN, PG, ER) and the others as one environment (MS two). Mean Square and variance components were estimated for each analysis. Varieties performance was tested using Eberhard and Russel (1966) model for each level of fungicide. A standardized score was obtained for each variety/location/years and a frequency distribution of scores was obtained for each variety. A correlation between the grain yield obtained for each variety in the selection sites (ELD, PF and ER) with the grain yield of the same varieties in the test sites was performed using all data for each location.

RESULTS AND DISCUSSION

Main anova results are in Table 1. When each location was considered as an environment (MS all) main effects and interactions were significant. When more the one location was joined as

Table 1. Mean square oat grain yield in three different arrangement of locations in South Brazil.

Source	Df	MS all	Df	MS state	Df	MS two
Year(Y)	3	67 112 205**	3	68 434 836**	3	68 434 836**
Location(L)	13	19 922 445**	3	33 232 659**	1	12 838 086**
Genotype(G)	16	4 558 361**	16	3 789 125**	16	3 789 125**
Fungicide(F)	1	31 448 381**	1	1 928 573**	1	1 928 573**
L x Y	21	8 307 305**	8	6 231 640**	2	8 085 767**
G x Y	47	558 799*	47	383 365	47	385 032
G x L	208	411 336*	48	557 727	16	714 143
G x F	16	478 268*	16	530 271	16	521 671
G x Y x L	323	268 572*	125	260 792	31	321 679
G x Y x F	37	135 078	37	130 060	37	117 131
G x L x F	190	159 540	51	329 728	17	212 005
Error	429	208 610	498	691 745	666	764 821

** Significant 0.01

single environment all interactions were non significant. There was a considerable increase in the MS of interaction genotype x location and also a three fold increase in the error term, which had a big impact in the variance components. When comparing with previous studies (Carvalho *et al.*, 1982; Federizzi *et al.*, 1993) the MS values for main effects and interactions were inferior in the present study (mean grain yield was higher). These results suggest that present varieties are more homogeneous in performance or that more locations included in this study are close to the average. Decreasing the number of environment of test may lead to non significant genotype by locations and genotype by year interaction by increasing the error term what may lead to more difficulties in discriminating varieties due to experiment imprecision. With this set of new genotypes the genotype by year interaction was lower, which implies that the number of years of testing may be fewer than four. In contrast with the anova results, correlation between the selection sites (ELD, PF and ER) with testing sites (Table 2) was poor for several different locations. Correlation shows that Eldorado do Sul (ELD) and Passo Fundo (PF) are very similar and have a good agreement with most traditional testing sites (VC, CN, LA, PG) but not with Entre Rios and the other more northern locations. Entre Rios shows good correlation with other two locations in Pr and one location in SP. When the correlation was performed in the experiments with application of fungicide only ELD showed good correlation with four different testing sites. This data suggest that ELD and PF are good predictors for most of the locations from the southern state of Brazil , but are very poor predictors for ER and for SP state. Entre Rios represents a unique environment, as locations in S.Paulo state and they should have a testing and a selecting sites in those particular environments.

Variety performance in terms of mean grain yield with and without fungicide, as a regression coefficient (b) and deviation (Sd) are in table 3. The best varieties were UFRGS 17 and UPF 16, and CTC 2, UFRGS 14, UFRGS 17, UFRGS 18 and UPF 16 with more than 3000 kg/ha in the experiment without and with fungicide respectively. The oldest varieties UFRGS 7 and UPF 7 showed the lowest mean grain yield. CTC 5, UFRGS 14, and UFRGS 17 showed $b<1$

Table 2. Correlation of oat grain yield between selecting and testing sites with (F) and without (W/F) application of fungicide in Brazil.

Location	ELD	ELD	PF	PF	ER	ER
	W/F	F	W/F	F	W/F	F
Eldorado do Sul(ELD)	-	-	0.80**	0.41**	-0.23	0.12
Passo Fundo (PF)	0.80**	0.41**	-	-	-0.23	0.02
Entre Rios (ER)	-0.23	0.12	-0.12	0.02	-	-
Vacaria (VC)	0.65**	-	0.64**	-	-0.10	-
Campos Novos (CN)	0.59**	0.32	0.47**	-0.03	-0.14	0.34
Lages (LA)	0.89**	0.30	0.79**	-0.02	0.06	0.19
Ponta Grossa (PG)	0.67**	0.69**	0.67**	0.10	0.05	0.04
Londrina (LD)	0.24	0.16	0.31	0.45**	0.07	0.27
Maua da Serra (MS)	0.70**	0.59**	0.70**	0.24	0.12	-0.01
Irati (IR)	0.25	0.67**	0.18	0.24	0.44**	0.44**
S. Miguel (SM)	0.24	0.17	0.08	0.11	0.89**	0.46**
São Carlos (SC)	-0.18	0.15	-0.02	0.37	0.18	0.30
Parapanema (PA)	0.05	0.34	0.03	0.16	0.66**	0.15
Piracicaba (PI)	0.03	-	0.00	-	0.26	-

** Significant 0.01

and UFRGS 15, UPF 7, UPF 13, and UPF 16 have b> 1 when fungicide was not used. In the experiments with fungicide CTC 5, UFRGS 7, UFRGS 10, UFRGS 14 and UPF 14 showed b<1 and CTC 3, UFRGS 15, UPF 13, UPF 15 and UPF 16, had b>1 the other varieties have b=1. In low yield environments UFRGS 14 and UFRGS 17 should be recommended, and UPF 15, UPF 16 and UFRGS 15 are recommended for higher yielding environment. Deviations from the regression line were significant for most varieties in the middle and low yield levels, among the high yielding genotypes only UFRGS 17 had significant deviations. These results showed that there are varieties with high mean grain yield, good adaptation and stability for high and low environments. Also, that fungicide did not increase the stability of varieties, the b value is almost the same, and it has effect only in the mean (grain yield). The standardized scores in Table 4, gives the probability of each variety to produce above the mean grain yield in this sample of environments. Only UPF 16 has the probability over 80% and CTC 2, CTC 5,UFRGS 14, UFRGS 15, UFRGS 17 and UFRGS 18 have probability over 65 % in the experiment without fungicide. In the experiment with application of fungicide to control crown rust CTC 2, CTC 5, UFRGS 14, UFRGS 15 and UPF 16 have more than 70% of probability to produce above the mean grain yield. Old varieties as CTC 1, UPF 7 and UPF 14 have the probability less than 20% of producing better than the average. These results suggest that a number of varieties are most likely to perform well in this set of environments.

Table 3. Mean grain yield, regression coefficient (b) and deviation from the regression (Sd) for oat varieties with (F) and without fungicide (W/F) in Brazil .

Genotype	Mean W/F	Mean F	b W/F	b F	Sd W/F	Sd F
CTC 1	2234	2773	0.98	0.92	180219	58253
CTC 2	2896	3091	1.03	0.94	240223	131037
CTC 3	2838	2918	0.94	1.17*	165140	123645
CTC 5	2754	2995	0.83*	0.81*	179408	214940
UFRGS 7	2167	2728	1.11	0.81*	369201	368256
UFRGS 10	2484	2734	1.10	0.87*	273529	250540
UFRGS 14	2817	3123	0.80*	0.84*	189995	130034
UFRGS 15	2825	2898	1.14*	1.21*	162565	181238
UFRGS 16	2691	2744	0.91	0.95	197121	94901
UFRGS 17	3162	3568	0.55*	0.90	358337	445597
UFRGS 18	2830	3195	0.92	1.01	171019	157638
UPF 7	2076	2377	1.15*	1.11*	235346	138651
UPF 13	2315	2841	1.25*	1.20*	343159	114768
UPF 14	2379	2521	0.99	0.80*	166520	84637
UPF 15	2774	2928	1.08	1.20*	192779	128976
UPF 16	3126	3208	1.12*	1.15*	216287	206578
UPF 17	2752	2682	1.05	0.98	623983	563826

* b significantly higher or lower than 1.
** significant 0.01

Table 4. Probability of oat varieties to yield more than average in Brazil.

Variety	Without fungicide %	With fungicide %
CTC 1	13.2	40.0
CTC 2	71.1	80.0
CTC 3	65.8	53.3
CTC 5	71.1	72.0
UFRGS 7	23.7	40.0
UFRGS 10	33.3	37.5
UFRGS 14	68.4	76.7
UFRGS 15	65.8	72.0
UFRGS 16	50.0	48.0
UFRGS 17	65.7	63.6
UFRGS 18	65.7	54.5
UPF 7	13.2	10.0
UPF 13	28.9	56.7
UPF 14	15.8	16.7
UPF 15	63.2	60.0
UPF 16	86.8	76.7

CONCLUSION

Data indicate that joining different locations in few environments will increase the error, decreasing the power to discriminate genotypes. The decrease in values for the genotype by year interaction may indicate that fewer than four years can be used for testing or that this current set of genotypes are more homogeneous in response. Besides the current testing sites, a selecting site at S. Carlos or another place in SP state, should be added. Genotypes with high grain yield that will perform well in low and high yielding environments can be selected from the current varieties in use.

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EXPLORING CROP ADAPTATION THROUGH THE STUDY OF MULTI ENVIRONMENT TRIALS (METS)

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ABSTRACT

Adapted cultivars are those that perform better than other cultivars over a series of environmental conditions. Broad adaptation describes the response of a cultivar with superior performance across most of the environments, and specific adaptation describes the response of a cultivar with higher level of performance in specific environments. Multi Environment Trials (METs), routinely conducted by breeding programs and national evaluation systems, are a privileged source of information for the study of crop adaptation, because they evaluate the two basic ingredients of the production system: the genotypes and the environments. Two kinds of models, with advantages and limitations, are used to model adaptation: a) statistical models for GxE interaction, and b) crop growth models for the prediction of potential yield. The integration of these two kinds of models is a major goal of research in crop adaptation. This could lead to a new generation of models of adaptation with predictive capability for a larger number of genotypes on a range of environmental conditions. This paper argues in favor of Factorial Regression as a candidate methodology for the development of this new kind of models. In addition we recommend that a retrospective analysis of the Oat nursery should be used for further studies in oat adaptation.

INTRODUCTION

In an agricultural production system it is of primary interest to obtain a good quantity, quality and reliability of the harvestable product. The choice of the cultivar is central for the production system, and so is its adaptation. Generally, the term adaptation is related to the performance of a trait such as yield, and in this case an adapted cultivar is that one that can attain higher yield, or greater stability, than other cultivars across environments. In a more general sense, adapted cultivars are those that perform better (quantitatively or qualitatively) than other cultivars over a series of environmental conditions. In addition, adapted cultivars are required to produce the desired quantities of high quality food while being in harmony with their environment.

Crop adaptation to varying environments is a central topic of scientific research for disciplines as diverse as Plant Breeding, Agronomy, and Evolutionary Biology. From a biological point of view, the study of adaptation tries to understand the phenomena by which a superior phenotypic expression results from the continuous interaction of genotypes and environments over time (van Euwijk, 1996). From an economical point of view, it is very important to have some level of predictability of the performance of existing and newly developed cultivars, in relation to critical environmental factors. These factors can be biotic (pests, diseases, weeds), or abiotic (radiation, temperature, water, nutrients). Some of these factors determine the potential growth of the crop (radiation, temperature), others act as stresses reducing the possibilities of the crop to attain its potential growth (drought, diseases).

GENERAL VS. SPECIFIC ADAPTATION

The concepts of broad and specific adaptation are often used to describe the relative performance of genotypes when adaptation is evaluated in more than one environment. Broad adaptation describes the response of a cultivar with superior performance across most of the environments, and specific adaptation describes the response of a cultivar with higher level of performance in specific environments. In general, these concepts are only defined in a statistical way, because the physiological basis of the distinction between the two is poorly understood (Cooper and Byth, 1996). Specific adaptation is often associated with the occurrence of positive GxE interactions (Comstock and Moll, 1964). The incidence of these specific interactions is of particular concern to plant breeders because they complicate the breeding strategy of selection for superior broad adaptation, and brings into question the overall effectiveness of such strategy.

The general aim of breeding programs is to improve the level of both broad and specific adaptation in breeding populations, and to produce better adapted cultivars by implementing specific selection strategies. Breeding programs have to provide some form of selection criteria to both assist the process of increasing adaptation within a population, and providing a basis for selection of new cultivars with superior adaptation. Cooper and Byth (1996) argued that an adequate understanding of plant adaptation in the target population of environments, should enable the selection for broad adaptation to be complemented by selection for specific adaptation. If the breeding objectives are expanded to incorporate elements of selection for specific adaptation, strategies for characterizing and accommodating GxE interactions are required. Indeed, according with Cooper and Byth (1996), two main strategies have been used : a) to avoid GxE interactions, and b) to exploit GxE interactions. The first approach avoids the effects of GxE interactions by subdividing or stratifying the sampling of the germplasm pool, and or the deployment of genotypes in the target population of environments. The second approach exploits the positive interactions by understanding the basis of plant adaptation, and breeding to identify recombinant individuals with desirable combination of attributes which confer positive specific adaptation to the target environmental challenges.

A large body of research has concentrated on understanding the physiological genetic basis of traits and their contribution to performance at the crop level. This has occurred almost independently of any statistical research. More specifically, the development of breeding programs to improve resistance or tolerance to biotic or abiotic stresses has followed: a) a clear definition of the target environment, that challenges or affects the adaptation of the plant, b) identification of the sources of genetic resistance or tolerance to the biotic or abiotic challenge, and c) a clear demonstration that genetic improvement on the desired trait (ex. yield) can be more rapidly achieved by indirect selection for tolerance or resistance to the stress, than through direct selection for the desired trait per se. This has been the case in selection for Al tolerance, in which an understanding of plant adaptation to a specific component of the target population of environments, has contributed to a more effective crop improvement.

Multi Environment Trials (METs), routinely conducted by breeding programs and national evaluation systems, are a privileged source of information for the study of crop adaptation, because they evaluate the two basic ingredients of the production system: the genotypes and the environments. They have been traditionally used for identifying varieties with superior performance across environments, and for recommendation of varieties for each specific environment (Crossa, 1990). They have also been used for optimizing the allocation of resources as replications, locations, and number of years (Talbot, 1984, Ceretta, 1995). In addition, they are helpful for the characterization of the target population of environments (Cooper *et al.*, 1993; Abdalla *et al.*, 1996), and for the identification of best selection sites (Cooper and Hammer, 1996).

It has been argued in favor of a greater effort in collecting information from these METs by: a) more efficient design and comprehensive statistical analysis of the trials, b) collecting more data to enable explanation of performance patterns, c) the use of crop models or genotype bioassay strategies to characterize the relevance of individual trial sites (Cooper and Hammer, 1996). In this way, the central role of METs is reinforced, but the need for more efficient coordination between agronomic and plant breeding experiments is emphasized. This is important because if statistically planned experiments can incorporate information on genetics, environment, and management, it should be possible to use the available statistical and crop growth modeling methodologies to evaluate the potential for crop improvement. Eventually, this could help to design strategies to manipulate plant genetics and crop management simultaneously to best adapt the crop, either broadly or specifically, to the environmental challenges it experiences.

MODELING ADAPTATION

While an integrated general understanding of adaptation of agricultural species in populations of environments is still not available, examples of multidisciplinary research directed to enhancing crop improvement strategies are being developed. These approaches are postulating the need to combine the basically statistical methodology used by plant breeders with the crop physiological methodologies developed by other disciplines.

Two kinds of models are used to modeling adaptation: a) statistical models for GxE interaction, and b) crop growth models for the prediction of yield potentials. Statistical models for GxE interaction were developed to analyze the observed response, for traits as yield, in METs. These models have a relatively simple structure, but their properties are well understood. They deal with many genotypes simultaneously. A limitation of these statistical models is their limited capability of prediction. Crop growth models are very elaborate, with many parameters that should predict potential yield in relation to critical environmental factors (van Euwijk, 1996). The assessment of all these parameters is time consuming and costly. Crop growth models allow limited variation of genetic parameters. The quality of their predictions is doubtful, because of insufficient knowledge about the precision of the parameters, and the lack of analytical tools to calculate the multiplication of errors (van Euwijk, 1996). The integration of these two kinds of models is a major goal for the research on crop adaptation. This could generate a new generation of models of adaptation with predictive capability for a large number of genotypes on a range of environmental conditions. Initially, a very promising area for future research could be the implementation of more refined statistical models for phenotypic expression and GxE interactions, with an increased biological content (van Euwijk, 1996).

Within the statistical models for GxE interaction, Factorial Regression is the most logical candidate for integration with crop growth models (van Euwijk and Elgersma, 1993; van Euwijk *et al.*, 1996; van Euwijk, 1996). In Factorial Regression, there is an explicit reference to the genotype and to external environmental factors. ANOVA non aditivity is modeled in terms of genotypic sensitivities and environmental potentialities (van Euwijk, 1996). The high similarity between the structure of crop growth and Factorial Regression models, should guarantee good global properties, i.e. accurate prediction over a wide range of environmental conditions (van Euwijk, 1996).

THE CASE OF THE SOUTHERN CONE

METs have been carried for several crops in the Southern Cone of South America for several years. The most prominent are the regional wheat experiments ERCOS (Ensayo Regional del Cono Sur) and LACOS (Líneas Avanzadas del Cono Sur), that have been carried on a regional level since the mid 70s. They were mainly designed as a channel for germplasm exchange, but have also been used for comparative studies of cultivar adaptation (Bainotti *et al.*, 1993). More recently, the information from ERCOS has been used for assisting a retrospective study of the evolution of wheat yield potentials in different countries of the region (Díaz and Abadie, 1997), and for the classification of environments (Abadie 1996, not published[1]). The potential for these kind of studies is tremendous, and is already being used as the starting point for further research on wheat adaptation. This experience generated with wheat, can also be transferred to other crops as oats. A regional oat nursery (Quaker Nursery) has also been carried by several breeding programs of the region during a series of years. In the present context of regional integration, a retrospective analysis of oat nursery should assist the planning of a more effcient and effective cooperative research. It could be used for further studies in oat adaptation, assessing the best selection sites, classifying environments, and identifying adequate breeding strategies.

CONCLUSIONS

Crop adaptation is essential for the stability of the production systems, and plant breeding programs should consider both broad and specific adaptation when selecting cultivars for a target population of environments. METs are a privileged source of information for the study of crop adaptation because, while evaluating both cultivars and environments, they can help to design strategies to manipulate plant genetics and crop management simultaneously. So far, there has been little integration between the two kinds of models developed to model crop adaptation: statistical and crop growth models. In this paper it is argued that Factorial Regression is a

[1] **Abadie, T. 1996.** Pattern Analysis of ERCOS. Preliminary Report. Four groups of locations with low cross over GxE interactions for wheat cultivars were identified from a sample of 15 locations throughout the Southern Cone of South America.

candidate methodology for the development of new integrated models with the ability of predicting the adaptation of a large number of cultivars to a range of environmental conditions. In the present context of regional integration a retrospective analysis of the Oat nursery, should be used for further studies in oat adaptation.

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OATS INITIAL GROWTH AND ITS INFLUENCE ON YIELD COMPONENTS

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ABSTRACT

Initial growth can have a decisive effect on oat's final yield performance since some of the yield components are set up during the early stages. Growth is visualized by plant vigor which is the expression of mainstem and tillers leaf growth and the associated root system. Nevertheless the apparent vigor can be misleading. Synchronism between mainstem and tillers developmental rate is fundamental for tiller survival. Apex size by the time the panicle differentiates usually depends on the plant's dry weight. Common stresses (water, soil fertility, diseases) can restrict plant mass accumulation and synchronism between organis growth thus limiting the yield potential expression.

INTRODUCTION

The big changes which transformed agriculture all over the world a few decades ago also affected the Cone Sul region. Several plant characteristics such as short stature are now common and played on important role in increasing yields. Nevertheless, the prospects to rapidly boost oats yield above the actual level are not very optimistic. Modern cultivating methods with more productive varieties are the goals facing agronomists and plant breeders in the next decades.

Despite the fact that some favorable plant characteristics were incorporated in new varieties, special attention has to be taken in order to assess how these characteristics perform during the life cycle. Growing conditions for the oat crop in South Brazil show some peculiarities mainly associated to rapid temperature changes and erratic precipitation over short periods. Under these conditions initial growth can have a decisive effect on final yield since the potentiality of some yield components is set up during the early stages.

The determination of some of the essential components is discussed for the early stages of the oat plant development.

PLANT DRY MASS

A high plant mass obtained by flowering is the primary factor to achieve high yields. Plant dry mass accumulates slowly during the early stages. Soil conditions (mainly nitrogen) determine the rate of dry matter accumulation (Riera, 1996).

PLANT DENSITY, TILLERING AND NUMBER OF PRODUCTIVE CULMS

The number of productive culms is initially determined by density. Usually more than 350 plants/m^2 are desirable under field conditions and generally the highest yields are achieved with these plants populations (Galli, 1996).

Tiller survival is one of the main constraints that limit the number of productive culms. Under stressing conditions, emission is reduced (mainly for the first tiller) and developmental rate is restricted. Thus, the tiller capacity to compete in the plant community is low and its survival is impaired. Nitrogen in the early stages is an essential element for tiller development. It can increase the survival rate and the size of tillers.

PANICLE FORMATION

Panicle differentiates very early, usually beginning by de 6th leaf stage and ending up when the basal branches are visible, by the 10th leaf stage. The differentiation period usually takes around 300 - 350° GDD (about 20 days) under normal conditions. Some preliminary studies show that the length of the period is not much affected by different environments (Laitano, 1997).

Panicle size is mainly associated with the amount of dry matter accumulated by plants. Plants that are benefited by environmental conditions may have more mass, can retard the beginning of differentiation and show a longer apex at this time. The main changes are those associated with the number of differentiated parts of the panicle (number of branches, and spikelets/branch).

INITIAL GROWTH

The expression of the initial growth is commonly observed through a visual analysis in the field. It is the resultant of dry matter accumulation and its partitioning in several plant parts as discussed above. Tillers and the differentiated panicle make important yield components.

Tillers are perceived more often through their number and not by their developmental stage. Profused tillering does not mean more panicles. Probably less tillers (first order ones) and more synchronized with mainstem are more suitable for panicle formation. By the time panicle differentiates the plant should have a vigorous growth.

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NITROGEN REQUIREMENTS AND FERTILIZATION PRACTICES FOR OATS

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ABSTRACT

Nitrogen is an essential input in crop production. Mayor factors affecting the amount of N to apply are: soil type, crop characteristics, yield goal, and climate. The objective of this presentation is to discuss criteria currently used in assessing N fertilization for wheat and barley as a guideline for future research on oats. The effect of N supply on yield components most important in building up yield potentials is mentioned. Stem elongation is recognized as a critical phase in terms of N requirements and yield expression. Splitting N application in at least two doses is expected to be a feasible practice to increase fertilizer efficiency, thereby profitability. Soil mineral N may be used as a basis for N recommendation as well as plant nutrient status. Since forecasting N fertilization requires to set a yield goal, the evaluation of oats potentials for different production systems appears to be essential for an adequate fertilization program.

INTRODUCTION

Nitrogen is commonly the most limiting nutrient for crop production. Grain yield is usually directly proportional to the amount of available N to the plant, thus N has become an essential input to improve yield of most grain crops, often resulting in large economic benefits to farmers. Nevertheless, excessive N use is undesirable from the economic and environmental viewpoint, thus an adequate fertilization program should supply the amount of N required to maintain maximum crop productivity. Mayor factors effecting the quantity of N to apply are: crop characteristics and yield potential, soil type, nature of the N source and application method, and the climate.

In order to achieve maximum N efficiency it is necessary to understand N uptake and assimilation by plants, as well as N behavior in the soil. In unreliable climates, asynchrony of available water and fertilizer-N may lead to low crop N uptake, or reduced fertilizer efficiency for crop production leading to highly variable responses ranging from profitable outputs to even negative ones.

In Uruguay, there is lack of information about methods and levels of N fertilization on grain yield of oat, therefore the objective of this presentation is to discuss some of the criteria currently used in wheat and barley for assessing N requirements and fertilization strategies that are expected to apply to oats.

CROP N UPTAKE AND REDISTRIBUTION

N uptake is governed by the demand of N created by growth, provided N supply is sufficient and the root is not impaired by environmental factors. Uptake rates and kinetics are not constant for a given genotype, they may vary depending on time of the day, plant age, nutritional status and growth rate (Engels and Marschner, 1995), and depends also on available N to the plants.

Ammonium and nitrate are the mayor N forms actively absorbed by plants, but nitrate is the dominant mineral form in most agricultural soils, thus N uptake occurs mainly as nitrate, which is transported to the roots by mass flow and diffusion. Since most of the N in the soil is under organic form (97-99 %), the availability of mineral N greatly depends on mineralization of organic compounds (Stevenson, 1986).

Although N uptake can be influenced by N availability, a typical pattern involves an initial slow uptake rate in young seedlings and tillers, starting an exponential phase at jointing, associated to the rapid dry matter accumulation. In wheat, maximum rate during the rapid phase of N absorption can exceed 4 kg N ha^{-1} day^{-1}, whereas maximum rate of soil N supply by mineralization rarely exceeds 2 kg ha^{-1} day^{-1}. Consequently, stem elongation is a critical period in terms of N availability and yield expression. N uptake usually declines or ceases after anthesis due to the beginning of root death, but it may continue until maturity under favorable growth conditions, such as water and nutrient availability.

Plants can absorb N in excess and utilize it later by redistribution within the plant, being the response of many grain crops to applied N depending on this process. In most cereal crops about 80 to 90 % of the grain proteins is already present in the plant at anthesis (Kramer, T., 1979). Although recognized as genetically controlled, remobilization of N from vegetative structures to reproductive ones (N use efficiency) is influenced by external factors.

PLANT RESPONSE TO APPLIED N

When N is the mayor growth limiting factor, dry matter accumulation increases with increasing rates of N up to a maximum. The magnitude of N response depends on the available, and potentially available N in the soil, and the actual dry matter accumulation in the plant, which determines crop N requirements (Olson and Kurtz, 1982).

Soil N supply varies widely depending on the crop history, soil type and climate, among other factors. In experiments at INIA-La Estanzuela, its contribution for wheat crops growing on the same soil type (molisols) managed under a rotation systems, was estimated for several years, ranging from 60 to 190 kg N ha^{-1} depending mainly on the crop sequence, and greatly affecting grain yield response to applied N (García Lamothe, unpublished data).

A. *Grain yield, yield components and compensation phenomena*

N application in small grain crops increases leaf area due to increased number of tillers and leaf size, and may also favor the duration of the canopy, thus the overall N effect is the improvement of the photosynthetic capacity, or source capacity of the plant (García Lamothe, 1994). The sink capacity is determined by the number and size of the grains produced.

Grain yield in oats may be expressed as the product of the following components: plants/m^2, panicles/plant, grain/panicle, and weight/grain. The first three components build up the yield potential (grains/m^2) which is further converted into actual yield during grain filling. Nitrogen shortage could lead to early restrictions in the development of the source capacity resulting in reduced assimilate supply during grain development stages.

While plants/m^2 depends mainly on sowing rate, seed quality and environmental conditions, panicles plant^{-1} is greatly influenced by tillering. In wheat and barley, tillering is almost always increased by N application at sowing, provided environmental conditions are not restrictive to plant growth, and an adequate N supply may enhance tiller survival (García Lamothe, 1994; Baethgen, *et al.* 1995).

Although an adequate N availability may be beneficial to all yield components, compensatory phenomena among them, difficult the assessment of an optimum combination, or to associate any component with final yield. Grains/m^2 exhibits usually the closest relationship to grain yield in cereals, therefore the objective of N supply should be to ensure a maximum grain number (García Lamothe, 1994; Baethgen *et al.* 1995).

B. *Effects of N timing*

N applications at sowing have great effect on tillering and ears number, helping to compensate for low stand densities. However, provided a good stand of plants has been achieved, N at sowing usually has less effect on yield and the other yield components, particularly grains per ear, than N applied at tillering (García Lamothe, 1994).

The most effective time for N application is related to the latest time compatible with the period of rapid N uptake by the plant (Dougherty *et al.*, 1979). N fertilization at the end of tillering has shown the best results in wheat and barley, when mineral N at early stages is enough to ensure adequate initial tiller development, which is a common situation in our agricultural systems (García Lamothe and Martino, 1986; García Lamothe, 1994; Baethgen *et al.*, 1995). Split N applications are particularly effective when environmental conditions favor substantial losses of N from the soil during early crop stages. Nitrogen applications at or after panicle initiation will probably result in increases in percentage grain protein and to a less extent increased grain number through improved fertility.

To achieve highest yields it seems desirable to maintain photosynthetic capacity throughout the grain-filling period, which appears to be a prerequisite for nutrient uptake to continue. It has been suggested that supplementary N would delay leaf senescence, however, since this process is also genetically controlled, late N application (foliar N) may fail to maintain photosynthetic capacity in certain genotypes.

PROBLEMS ASSOCIATED WITH EXCESSIVE N SUPPLY

N in excess may be detrimental in different ways. Besides the harmful environmental impact of N losses from fertilizers, excessive N may have detrimental effects on plant growth and yield, or negatively affect the quality of the harvestable product.

Excessive foliage growth in cereals, as a result of high N supply early in the cropping season, may increase shading and create microclimatic conditions that enhance fungal diseases, while the development of a more succulent tissue usually favors pathogen penetration. High N availability, particularly at early crop stages, tends to increase height and elongation of the basal stem internodes, increasing lodging susceptibility. Furthermore, it may promote excessive tillering, being an energy drainage to the crop.

The detrimental effect on grain quality may be due to lodging, delayed maturity, new plant growth and unevenness ripening, or even changes in amino-acids composition, that affect negatively the nutritional value for human consumption (Eppendorfer, 1975).

ASSESSING N FERTILIZATION FOR GRAIN PRODUCTION

Researchers have to provide usable fertilizer recommendations to producers, where the rate of N to apply is probably the most important decision.

A. *Soil mineral N*

In Uruguay, N fertilizer recommendations for wheat are based mainly on the results of soil nitrate-N at planting. Although the spatial variability of soil nitrate and its dependence on climate are recognized as major problems in sampling fields, a close relationship ($r=0.78$, $P<0.05$) between initial soil nitrate before panting and wheat grain yield, was found at INIA-La Estanzuela. Grain yields increased linearly, about 45 kg ha^{-1} for each ppm of initial soil nitrate-N, at the 40-cm layer. When nitrate-N levels were less than 15 ppm, wheat grain increased markedly with fertilizer N up to the maximum rate (120 kg N ha^{-1}), whereas when values were greater than 36 ppm, there was no significant response to applied N.

The relationship between nitrate levels at the end of tillering (Feekes GS 5) and N response has been less consistent, nevertheless, a critical level of 15 ppm was determined for the 20-cm soil layer, providing an additional aid to fine tune fertilizer programs in wheat (García Lamothe, 1994).

B. *Plant N status*

In addition to soil nitrate levels, plant analysis can be a valuable tool in determining the need for supplementary N. Plant analyses are based on the assumption that the amount of a given nutrient in a plant is associated to its availability in the soil.

In Uruguay, N status of the plant, determined by measuring total N in plant tissues has proved to be a reasonable reliable index for wheat, although it is difficult to convert N values below the critical value into rates of N fertilizer to be applied. The highest grain yields were achieved when N content from a 20 plants sample (aboveground portion) at Feekes SG 5 was 4.1 % or higher, while a value of 2.6 % of total N was associated to grain yield lower than 2.5 ton ha^{-1} (García Lamothe, 1994). However, the analysis is time consuming and therefore the method is seldom used by producers.

Rapid tests are essential for assisting the producers in diagnosing N needs of the crop. Nitrate concentration in the stem sap, although easier to measure than total N, has shown to be highly dependent on environmental conditions during sampling, hampering the use of this measurement as a N management tool. Currently, the chlorophyll meter appears to be a promising test, providing a simple and quick method for estimating relative amount of leaf chlorophyll (Watanabe *et al.* 1980, Peltonene *et al.* 1994) thereby plant N status.

It is important to point out that the less reliable the production system the wider the range of outcomes that may result when N fertilizers are applied. Probably, the aim of future research should be to establish possible outputs or yield goals according to different production systems and the respective critical values (soil and plant critical levels).

C. *Balance method*

Ideally, to establish an accurate amount of N fertilizer to applied, all N inputs and outputs during the cropping cycle should be considered. This is the basic principle of the balance method. N requirements of the crop, determined mainly by the quantity of N removed by harvest, are considered on one side, and the amount of available N from sources other than applied N, on the other side. Basically, the amount of N to apply is the total N demand of the crop minus the amount of available N, taking into account the effectiveness of fertilizer application in increasing N availability.

Although this approach appears to be simply, it requires some estimations difficult to assess with reasonable accuracy. First of all, year to year variations on weather conditions and its interaction with expression of yield potential complicate the prediction of N requirements of the crop. In addition, soil N supply involves mineral N initially present in the soil, and N released by mineralization along the cropping season. While the former can be easily measured after field sampling, the amount of N actually mineralized is difficult to predict. Wide variation in N fertilizer efficiency values has been other constraint to the adoption of the method. For example, apparent N recovery for an optimum N rate, varied from 22 to 49 % in wheat trials where most of the manageable factor were under control (García Lamothe, unpublished), while a wider range (13 to 73 %) was determined for a relatively low N rate (40 kg ha^{-1}) under less controlled conditions (García Lamothe, 1994).

N FERTILIZER MANAGEMENT FOR IMPROVED EFFICIENCY

Fertilizer N is used more efficiently when applied as close as possible to the time of peak N demand of the crop for at least two reasons. First of all, delayed applications, lower N losses by leaching and denitrification from the fertilizer as a result of a shorter period of exposure to water excess. Moreover, early high N availability usually promotes excessive tillering, frequently associated to low tiller survival potential, which contributes to reduced fertilizer efficiency (García and Martino, 1986).

In wheat and barley, a basic dressing of 30 kg ha^{-1} is usually recommended at sowing (García Lamothe, 1994, Baethgen *et al.*, 1995), but since initial N availability is rarely limiting early plant growth, delaying the first application to tillering would be advisable in most situations. The following N application is recommended at stem elongation, where maximum N uptake is expected.

In Uruguay, the efficiency of N applied at stem elongation compared to N applied at planting was consistently better, particularly in early sown wheat crops (García Lamothe and Martino, 1986). In wheat and barley, reduced lodging was frequently obtained by splitting N application (García Lamothe, unpublished data). An additional benefit of applying N in two or more doses is the possibility of estimating supplementary N based on soil and/or plant analyses despite their aforementioned limitations, or at least based on visual evaluation of the crop.

The use of more appropriate formulations or methods of application could lead to improvement in N recovery. For example, it is well documented the potential for volatilization losses of ammonium forming fertilizers, such as urea, when surface applied. Nevertheless, fertilizer efficiency depends not only on N availability, but also on the crop capacity to use the increased available N. To obtain full response to N, no other growth factor, or management practice should be limiting yield.

It is relevant to emphasize the importance of exploiting positive interactions in maximizing crop productivity. Improved varieties and agronomic practices will increase yields and larger quantities of N could be used more effectively.

In Uruguay, where annual precipitation appears to be adequate, water stress frequently limits crop production. Other nutrient deficiencies, pests and other factors may also reduce the plant ability for use N efficiently. Research on the effect of diseases on wheat varieties and their response to applied N has shown that the use of fungicides can improve the rate of N response up to the optimum yield, (García Lamothe, 1994). The use of plant-growth regulators is expected to have similar effect on oats varieties susceptible to lodging.

FINAL REMARKS

Because soil N supply is commonly insufficient to meet crop needs an adequate N fertilization is critical for high grain yields. From an economic an environmental viewpoint, the rate of N to apply is probably the most important fertilizer decision. Forecasting N fertilization requires to estimate crop needs by setting a reasonable yield goal, therefore evaluation of oat yield potentials, appears to be essential for an adequate fertilizer management.

Due to climate, a better synchronization of N supply and demand by splitting N application in two or more doses will usually increase fertilizer efficiency, thereby productivity and profitability. Strategic N application matching crop N requirements are expected to result in yield increases in most situations, provided other growth factors are not limiting. The reliability of grain yield response to N fertilizers will be improved by controlling the most factors known to affect plant growth.

Soil mineral N can be used as a basis for N fertilizer recommendation. Evaluation of the plant nutrient status appears to be a useful tool in determining supplemental N requirement of the crop. The development of rapid and reliable diagnostic techniques should be other aim of future research, as well as site-specific evaluations of fertilizer rate x timing x method of application under different soil management systems.

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MANAGEMENT OF FORAGE OATS IN URUGUAY

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ABSTRACT

Oats are mainly used for forage production in Uruguay. The most common cultivars used for forage has fine leaves and stems, excellent tillering capacity and early flowering. New cultivars contrast in many morphological characteristics such as heading date, growth habit, tillering capacity, leaf size, grain yield potential. Main cultural practices had been adjusted for the cultivars recently released by INIA, and data on sowing density, grazing removal, forage production, and the potential used as a double purpose crop for hay or grain are reported in this paper.

INTRODUCTION

Oats are commonly used for forage in Uruguay. A substantial portion of the crop is grazed out or otherwise grazed and afterwards harvested for hay or grain when livestock are removed (double purpose). Oats have a growing season as long as seven to ten months when sown early in the year and managed for double purpose. Depending of the year, the area of oats harvested for grain represents 10 to 25% of the total area planted.

The most widespread cultivars are 1095a, released in 1930, and RLE 115, a selection of the cultivar 1095a released in 1979 (Millot *et al*, 1980). Both cultivars have early flowering, fine leaves and stems, and produce a very high number of tillers. These characteristics determine their good performance under grazing. However, the development of cultivars with different morphological characteristics and better grain production arises great interest by farmers. Main cultural practices have to be adapted for these cultivars, and they are reviewed in this paper.

CROP ESTABLISHMENT

Oats for forage are planted as the first winter cereal of the season. Early planting increases the amount of forage that can be used before winter conditions restrict the growth rate. In Uruguay, oats for grazing can be planted 60-90 days earlier than wheat, barley or triticale, because the oat crop is more tolerant to high temperatures and water deficits at the seedling stage, conditions that are prevalent at that time of the year. Planting starts as early as mid January in the dairy farms, where the land use is very intensive, and no other species adapts to such early sowing dates. Establishment could be hazardous; aphids and BYDV may become a problem at this time of the year.

Although few data are available to support the practice, 100 to 120 kg/ha of seed is a common recommendation for establishing oat crops for forage. Traditional oats have very fine leaves and high tillering capacity. As a result of intensive grazing, most of the seed lots harvested by farmers tend to be later and more prostrate than the cultivar 1095a. Higher seeding rates for the traditional type of oats usually result in either higher yields in the first grazing or earlier grazing. This is also a common practice in other countries (Shands and Chapman, 1961); where oat crops for forage are recommended to be sown at rates 50% to 100% higher than those used when the crop is grown for grain.

INIA LE Tucana is a late cultivar, with small seed size, wide leaves, high tillering capacity and erect habit of growth. Relatively little was known about the effect of the sowing density on the forage production of this oat type. Sowing densities were tested for the new cultivars INIA LE Tucana (Table 1). The experiment was cut until the end of August and then it was left to harvest grain. Tucana's plant characteristics determined the possibility to reduce the amount of seed per hectare to about a half with almost none reduction in its forage production in autumn/winter. Despite the great difference in sowing density (40 to 100 kg/ha), grain yield was similar in all treatments. This stability in grain yield indicates the excellent recovery of the cultivar after each cut. The capacity to produce forage at a low seeding rate is one of the advantages of INIA LE Tucana.

Table 1. Effect of the sowing density (kg/ha) on the yield of forage (t DM/ha) and grain (t/ha). Sowing date: 13 April 1993. Cultivar: INIA LE Tucana

Sowing Density	Forage Yield					Grain Yield
	June 2	June 25	July 27	August 27	Total	
40	0.4b[1]	0.4	0.6	1.6a	3.0b	2.5
60	0.5ab	0.7	0.7	1.5ab	3.2ab	2.5
80	0.7a	0.6	0.6	1.4b	3.3a	2.4
100	0.7a	0.6	0.6	1.4b	3.3a	2.4

[1] values within a column not sharing a common letter differ at $P<0.05$

INIA Polaris is an early cultivar, with large seed size, semiprostrate growth habit and high tillering capacity. In a similar approach to that of INIA LE Tucana, a experiment was settle to study the effect of the sowing densities on forage production (Table 2). The reduction in sowing density greatly reduced the yield in the first cut; similar effect was observed in the spring. When the oat crop is sown to produce forage in early autumn, seeding rates should be about 100 kg/ha. Rates of seed as low as 50 kg/ha could be used to produce forage in mid-winter.

Table 2. Effect of the sowing density (kg/ha) on yields of forage (t DM/ha) and grain (t/ha). Sowing date: 8 April 1996. Cultivar: INIA Polaris

Sowing Density	Cutting Date					Total Forage
	May 28	July 1	August 12	September 4	October 4	
50	0.4b[1]	0.8	1.6	1.0	0.6b	4.4c
75	0.6b	1.0	1.5	0.9	1.0a	5.0b
100	1.0a	1.0	1.5	0.9	1.3a	5.7a

[1] values within a column not sharing a common letter differ at $P<0.05$

The seed of 1095a and RLE 115, the common cultivars used for forage production, is normally produced from crops either managed as double purpose (grazing plus grain), or planted in late winter for seed production exclusively (Millot *et al, 1980)*. With the release of INIA LE Tucana, a tall and late cultivar, relatively little was know about its grain yield when sown late in the season. 1095a and RLE 115 were compared with INIA LE Tucana for grain yield and test weight in two contrasting sowing dates (Table 3). The experiment sown in autumn was cut until august, whereas the other one sown in late winter was left uncut. INIA LE Tucana has greater grain yield and test weight than the traditional cultivars in both sowing dates. Planting during autumn resulted in great differences between late and early cultivars when sown in autumn, whereas the differences were small in late winter sowing.

Table 3. Effect of the sowing date on grain yield (t/ha), test weight (kg/hl) and heading date

Cultivars	Autumn Sowing (April 13 1993)			Winter Sowing (August 5 1993)		
	Grain Yields	Test Weight	Heading date	Grain Yields	Test Weight	Heading Date
1095a	1.3a[1]	27b	15 Oct	1.4b	25b	15 Nov
RLE 115	1.9b	30b	15 Oct	1.2b	28b	15 Nov
INIA LE Tucana	2.6a	34a	7 Nov	2.8a	32a	20 Nov

[1] values within a column not sharing a common letter differ at $P<0.05$

DEFOLIATION MANAGEMENT

Careful control of grazing is required to maximize forage yields of oats. Continuous grazing usually reduces the total forage production, compared with rotational grazing (Burton *et al.*, 1952; Stephen, 1977). These recommendations are particularly valid if the crop is to subsequently produce hay or grain; overgrazing as well as late grazing in spring could seriously weaken the oat stand. Four cutting regimes were imposed on a crop sown with INIA LE Tucana (Table 4). Forage production in autumn/winter was lowest with one early cut (July 1st) and highest when the crop was cut until the end of August. Spring performance was excellent for all cutting regimes, except for the latest cut (August 28th), where the plants were shorter and the straw weight was significantly lower. However, grain yields were similar for all treatments, indicating the good recovery of the cultivar after defoliation.

Table 4. Effect of the cutting regime on forage and straw yield (t DM/ha), and grain (t/ha) for INIA LE Tucana. Sowing date: 13 April 1993

Cut.	Date	Forage yields					Harvest	
Number	Last Cut	July 1	July 28	August 12	August 28	Total	Straw	Grain
4	28 Aug	0.8	0.4	0.6	0.8	2.5a[1]	7.0b	4.0
3	12 Aug	1.0	0.5	0.4		2.0b	10.1a	3.8
2	28 Jul	0.8	0.4			1.2c	10.4a	3.9
1	1 Jul	0.7				0.7d	10.8a	4.0

[1] values within a column not sharing a common letter differ at $P<0.05$

The cultivars 1095a, INIA Polaris and INIA LE Tucana are all suitable for forage production, although they contrast in many characteristics such as heading date, growth habit, tillering capacity, leaf size. INIA LE Tucana is an erect cultivar and tends to produce more forage early in the autumn, whereas INIA Polaris produced more in winter and less in autumn (Table 5). This is particularly true for the more frequent defoliation regime (5 cuts), showing its good recovery after cutting and winter tolerance.

Frequent cuts favored tillering, increasing hay yields of all three cultivars. INIA Polaris grain yield and test weight were consistently high, independently of cutting treatments, whereas the low grain yields of INIA LE Tucana was caused by the high infection of crown rust. The cultivars 1095a and RLE 115 tends to lodge easily due to its fine stems, and this problem increases when managed for harvesting hay or grain after grazing in autumn/winter. Nitrogen fertilization should be managed carefully for these cultivars. Grain yield of cultivar 1095a were good; although 70-95% of the plots were lodge.

Table 5. Effect of defoliation frequency on the production of autumn, winter and spring forage (t DM/ha), hay yield (t DM/ha), grain yield (t/ha) and grain test weight (kg/hl) for three cultivars. Sowing date: 29 March 1995.

Cultivars	1095a		INIA Polaris		INIA LE Tucana	
Cut number	2	5	2	5	2	5
Autumn	2.2	2.3	2.2	2.3	2.6	2.4
Winter	1.9c[1]	2.2ab	2.0bc	2.5a	1.6c	1.8c
Spring	5.6	5.2	4.9	4.4	5.5	5.4
Hay	6.5bc	7.4ab	5.7c	7.7ab	6.5bc	8.4a
Grain	2.5ab	2.3b	2.8a	3.0a	2.3b	1.6c
Test Weight	39c	41c	54a	53a	49ab	47b

[1] values within a row not sharing a common letter differ at $P<0.05$

MIXTURES WITH ANNUAL RYEGRASS

Oats have the advantage to offer forage 20 to 30 days before other annual species. When . cultivated for forage, they are usually in mixture with annual ryegrass, either sown in mixture or due to ryegrass natural reseeding. The combination of the early autumn growth of oats and late winter ryegrass growth maximizes forage yields, improves seasonal distribution of forage and gives more stability to animal production. Oats are the prevalent component in autumn and early winter, whereas ryegrass dominate the mixture in late winter and spring (Table 6). Warm autumn favored oat yields, and cold ones favor ryegrass; greater stability throughout years is another advantage of the use of this mixture.

Table 6. Forage yield (t DM/ha) for pure stands of oat INIA LE Tucana and annual ryegrass cv E284 and its mixture; contribution of oat in the mixture, expressed as % of total DM.

Cutting Date	Oat	Ryegrass	Mixture	
	t DM/ha	t DM/ha	t DM/ha	% oat
2 Jun	0.6a[1]	0b	0.6a	100
25 Jun	0.6b	1.2a	0.6b	66
27 Jul	0.6	0.9	0.8	62
27 Aug	1.3b	1.8a	1.8a	39
22 Sep	1.5	1.7	1.8	17
28 Oct	2.9	2.3	2.6	13
Total	7.5	7.9	8.2	34

[1] values within a row not sharing a common letter differ at $P<0.05$

There is a large variation in morphological characteristics of the oat cultivars suitable for forage production and, therefore, main cultural practices should be tested when new cultivars are released.

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SELECTION AND MANAGEMENT OF OATS FOR FORAGE PRODUCTION IN THE SOUTHEASTERN UNITED STATES

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ABSTRACT

Southern USA oat breeding programs are predominantly affiliated with major universities. Active programs concentrate breeding strategies on winter hardiness, disease resistance, forage and grain yield. Most southeastern oats are grown as a winter forage crop or for silage, however grain yields are important for feed and seed purposes. Nutritional quality of oats as a forage or silage crop is dependent on the growth stage that is harvested. Recent data from Florida has shown that total per hectare dry matter yield and yield of digestible nutrients for oats was found to be highest at the dough state of growth. Conversely, percent CP (crude protein) and percent IVOMD was lowest at that stage. Quality of oats for grazed forage, hay or silage is an important aspect of southern oat breeding efforts. Cooperative efforts between southern oat breeders exists in the free exchange of germplasm, and regional testing of breeding lines and varieties.

INTRODUCTION

Oats are grown primarily for forage and feed grain production in the warm, humid southeastern USA There are no oat milling operations in the area and the oats are used primarily on the farms where they are grown. Although no acreage estimates are available, oats are not widely used because of relatively low grain prices compared to other crops and the poor government support program. Oats find their best use in winter grazing programs for cattle. Only winter oats are grown and they are normally fall planted in October-November and are grazed by mid-December through most of the winter months. Oats grown for grain or seed are harvested in late May-June.

BREEDING

Breeding programs for winter oats are conducted in a number of states in the area with the most active programs being in Texas, Louisiana, Arkansas, Georgia, South Carolina, North Carolina, and Florida. These breeding programs are considered to be public programs, conducted by personnel who also breed other small grains and have state university appointments. Very little breeding working on oats is being done by the private seed companies. At one time the Coker-

Northrup King company had a very large winter oat breeding program but it was discontinued in 1988, and after several years their breeding material was donated to the USDA. Many of the public breeders in the area have obtained this material and are actively working with it.

Temperatures well below freezing occur sporadically throughout the winter over most of the Southeastern United States, so one of the primary breeding goals is winter hardiness since growers do occasionally suffer losses due to winterkill. But overall, the winters are relatively mild and good growth of a winter crop usually occurs.

Breeding for winter hardiness is difficult because killing freezes occur rather infrequently particularly in the southern portion of the Southeast. So breeders in the southern portion of this region must send their material to more northerly locations in order to get reliable data on the winter hardiness of their material. One problem in breeding for additional winter hardiness is that you change the distribution of seasonal forage production. The more winter hardy types produce very little of their potential forage in the early portion of the growing season since they go through a dormant period and are not actively growing during this period. The fact that they are not actively growing is one of the reasons that they are winter hardy. The more winter hardy types also have a tendency to be later in maturity. It is difficult to have an early maturing winter hardy variety. So we have to compromise and sacrifice some winter hardiness to obtain good forage production in the earlier portion of the growing season. Most of our producers do not want their small grains lying dormant when we have temperatures available for good growth and development. The late maturing types do not produce good seed yields because they are filling their grain later in the spring after temperatures have increased significantly. The later maturing types are also exposed to disease epidemics over a longer period and are more likely to suffer seed yield losses from disease damage.

The very early upright growth types are also unsatisfactory for forage production since they do not produce their forage over as long a period as needed and do not regrow well when cut or grazed. They also are more susceptible to cold temperature damage. So most of our efforts are directed at selecting an intermediate growth type with medium maturity as an all purpose type oat.

The mild temperatures do favor diseases and insect pests so most of breeders' efforts are spent in developing resistance in new cultivars. Crown rust (caused by *Puccinia coronata* Cda.) receives the most attention and it can be a very devastating disease particularly in the southernmost states. This is the disease that causes most growers to abandon older varieties for new ones. Numerous genes for resistance are available (see the following website for a list: http://www.crl.umn.edu/Res_Gene/ocr.html). It is difficult to stay ahead of the crown rust races and have resistance varieties available when growers need them. Most breeders in the area try to accomplish this by releasing new varieties fairly often and utilizing diverse sources of resistance in their breeding programs. Developing varieties with stacked resistance genes could be done utilizing molecular markers but the importance of oats as crop in the area has not warranted the large expenditure of research funds that would be required to successfully accomplish this.

Stem rust (caused by *P. graminis* Pers. f. sp. *avenae* Eriks. & P. Henn.) also is a serious problem but is generally restricted to south Texas and Louisiana. New varieties must have resistance to stem rust to be successfully grown in that area. Leaf spot [caused by *Drechslera* *avenacea* (Curt. ex Cke.) Shoemaker] and Barley Yellow Dwarf Virus are also serious diseases and cause considerable damage.

Grain or seed yield is the primary breeding goal and very little work is done on milling characteristics or chemical composition of the grain by breeders in the Southeastern USA Many of the breeders do evaluate their advanced lines for forage production since this is the primary use of the crop. Seed yield is important even in a forage crop since livestock growers want to pay relatively low prices for seed used as forage, especially when cattle prices are low.

Very cooperative relationships exists among the breeders in the area. Germplasm is exchanged freely. Quite often bulk populations, as well as advanced lines, are exchanged. Several regional nurseries are conducted to help breeders evaluate their breeding material.

New breeding lines are usually first entered in a Regional Oat Screening Nursery that is coordinated by Dr. Steve Harrison at Louisiana State University at Baton Rouge, Louisiana. It requires only about 40-50 grams of seed to enter a line in this nursery that usually contains 150-200 entries. Dr. Harrison puts about 4-5 grams of seed of each entry in a envelope and cooperators plant each entry in single one meter rows. This nursery is planted in 8-10 locations and data is obtained on disease resistance and winter hardiness. Cooperators are free to use any entries in this nursery for crossing but no seed increases are made without permission of the owners of the lines.

Every year each breeder puts his most promising lines in a Uniform Winter Oat Yield Nursery that is coordinated by Dr. David Livingston of the USDA at Raleigh, North Carolina. This nursery usually contains about 25 entries and they are grown in replicated yield trials at 16 locations throughout the area. About 5,000 grams of seed are required to enter a line in this nursery. Each cooperator plants 3 or 4 replications in plots that are about 3-5 meters square. Data is collected on grain yield, test weight, heading date, plant height, lodging, winter survival and resistance to various diseases. Cooperators sends their data to the other cooperators at the end of the season. A summary report is prepared by the coordinator of the nursery.

Both of the previously mentioned regional nurseries are discussed and check varieties are selected when the breeders meet at the Southern Small Grain Workers Conference which meets every other year. A tour of a local breeding program including field nurseries are a portion of this meeting. It is also quite common for breeders to visit each others field nurseries during the course of a growing season.

The Cooperative Extension Service conducts variety trials in each state in the region and performance information is published and available to farmers. Variety recommendations for the year are also published and updated each year. So when a breeder has a new line that is ready for release, it is entered in state trials to test its performance against other varieties. Most states conduct both forage and grain yield trials in order to provide farmers information about newly released varieties.

In the past most varieties were released to the public with no requirement that those who benefited from the new improved varieties provide monetary support to the research program that developed the new varieties. But this has changed in recent years. Public breeding programs have suffered from reduced funding from public sources so most breeding programs now require that those who most directly benefit from the new varieties provide some monetary support back to the breeding program. Various programs are used to accomplish this but most involve some type of exclusive release that requires a royalty based on seed sales. There are private seed companies in the area who market proprietary oat varieties that they have obtained from various sources. Most oat breeders do apply for plant variety protection to the USDA Plant Variety Protection Office for new varieties that they develop.

Breeders generally are not involved directly in the distribution of seed of new varieties. Each state has a Foundation Seed Organization which is responsible for taking the publicly developed varieties and making seed stocks available to producers.

MANAGEMENT

Most of the research we have done with oats in recent years relates to its usefulness as a silage crop. We recently completed a study that was reported at the 1997 American Society of Agronomy Meeting held at Anaheim, California (Mislevy *et al.*, 1997). Oats were compared for yield and quality to wheat, rye and triticale when harvested at four physiological stages. Tables 1-5 summarize the data obtained in this study which was conducted in south-central Florida. Two different oat cultivars were compared to single cultivars of rye, wheat and triticale. A split plot design was used with cultivar as the main plot and physiological stage as the subplot.

Percent crude protein and in vitro organic matter digestion (IVOMD) were lowest and dry matter yield was highest at the dough stage. With the exception of rye and triticale, IVOMD yield was also highest at the dough stage. Crude protein yield per ha was always highest when the small grains were harvested at the boot to anthesis stages. In general, delaying small grain harvest from vegetative to dough stage results in a very significant increase in dry matter yield. This delay in harvest results in a decrease in crude protein and IVOMD percentage. Yield of digestible forage were highest when oats and wheat were harvested at the dough stage. This data does suggest that oats are an excellent silage crop since high yields of digestible forage can be obtained.

Management factors for oats when grown for silage are very similar to when the crop is being grown for grain production. Normally when oats are used for winter grazing they are planted about one month earlier than for grain production. Also in grazing programs, the nitrogen top dressing should be split into at least two applications, whereas for grain only one split is normally used. It is quite common in winter grazing programs to blend various small grain seed in mixtures with ryegrass and clovers. These blends work very well to extend the grazing season and provide some stability to the forage productivity. Production can be limited by various production hazards but these can be minimized by blending the various forage crops.

Oats have one advantage over the other small grains in that they can be planted earlier because of their resistance to seedling diseases. In our area the earliest recommended seeding date for oats is September 15 whereas for wheat, rye or ryegrass it is October 15. One of the hazards to early seeding is increased likelihood of significant disease and insect pressure. We recommend early planting only where early forage production is needed. We have had considerable damage from Barley Yellow Dwarf Virus and there is much need for improvement in variety resistance particularly for early planting.

Table 1. Crude protein concentration of small grain cultivars harvested at various stages of growth, 1995-96.

Cultivar	Stage			
	Vegetative	Boot	Anthesis	Dough
	g kg^{-1}			
Chapman oat	290 a A	100 c B	80 b BC	70 a C
Florida 401 rye	290 a A	140 a B	110 ab C	60 a D
Harrison oat	270 a A	110 b B	80 b C	70 a C
Morey wheat	290 a A	110 b B	130 a B	70 a C
Sunland triticale	270 a A	140 a B	100 ab C	70 a D

Lower case letters indicate significant differences within columns and upper case letters indicate significant differences within rows.

Table 2. In vitro organic matter digestion of small grain cultivars harvested at various stages of growth, 1995-96.

Cultivar	Stage			
	Vegetative	Boot	Anthesis	Dough
	g kg^{-1}			
Chapman oat	860 a A	660 c B	580 bc C	560 b C
Florida 401 rye	850 a A	710 b B	550 c C	440 c D
Harrison oat	870 a A	670 c B	600 b C	540 b C
Morey wheat	840 a A	720 b B	700 a B	570 b C
Sunland triticale	860 a A	780 a B	660 a C	610 a D

Lower case letters indicate significant differences within columns and upper case letters indicate significant differences within rows.

Table 3. Dry matter yield of small grain cultivars harvested at various stages of growth, 1995-96.

Cultivar	Stage			
	Vegetative	Boot	Anthesis	Dough
	Mg ha^{-1}			
Chapman oat	1.3 a D	7.2 a C	10.1 a B	12.3 a A
Florida 401 rye	1.6 a C	4.5 b B	5.6 c AB	6.5 d A
Harrison oat	0.9 a C	6.7 a B	6.9 bc B	9.6 bc A
Morey wheat	0.9 a C	6.5 a B	6.9 bc B	10.8 b A
Sunland triticale	1.6 a C	5.8 a B	7.8 b A	8.7 c A

Lower case letters indicate significant differences within columns and upper case letters indicate significant differences within rows.

Table 4. Crude protein yield of small grain cultivars harvested at various stages of growth, 1995-96.

Cultivar	Stage			
	Vegetative	Boot	Anthesis	Dough
	kg ha^{-1}			
Chapman oat	409 ab B	722 bc A	810 a A	849 a A
Florida 401 rye	438 a B	616 c A	599 b A	386 c B
Harrison oat	236 c C	740 ab A	563 b B	693 b AB
Morey wheat	288 bc B	737 abc A	870 a A	726 b A
Sunland triticale	394 ab C	847 a A	795 a A	620 b B

Lower case letters indicate significant differences within columns and upper case letters indicate significant differences within rows.

Table 5. In vitro organic matter digestion yield of small grain cultivars harvested at various stages of growth, 1995-96.

Cultivar	Stage: Vegetative	Boot	Anthesis	Dough
	kg ha^{-1}			
Chapman oat	1235 a D	4714 a C	5904 a B	6834 a A
Florida 401 rye	1295 a B	3220 b A	3093 d A	2821 c A
Harrison oat	750 a C	4517 a B	4108 c B	5242 b A
Morey wheat	824 a C	4655 a B	4710 bc B	6205 a A
Sunland triticale	1261 a C	4582 a B	5134 b AB	5333 b A

Lower case letters indicate significant differences within columns and upper case letters indicate significant differences within rows.

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FACTORS AFFECTING GROAT BREAKAGE AND BRAN YIELD DURING OAT MILLING

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ABSTRACT

Both groat breakage during dehulling and oat bran yield appear to be influenced by groat hardness. Groat hardness, as measured by an automated kernel hardness tester or by the particle size index, was correlated with groat breakage. Correlations of groat hardness with groat β-glucan suggest a structural basis for hardness. By definition, the particle size index, a measure of hardness, is equivalent to bran yield. Increased grain moisture reduced groat breakage and increased bran yields, presumably by affecting hardness. Oat bran produced by roller-milling or hammer-milling groats, and sieving to isolate larger particles, was enriched in protein and β-glucan. A product isolated by pearling away the outer layers of the groat was not enriched in β-glucan, indicating that oat bran is not primarily derived from the outer layers of the groat, but is derived from cell wall distributed throughout the groat.

INTRODUCTION

Oats must be dehulled before they can be milled in preparation for human consumption. The dehulling process involved impacting the groats against a surface, which separates the hull from the groat (Gan8mann and Vorverk, 1995). Groats that break during dehulling subtract from the economic yield of the oat milling process and often need to be removed.

Grain hardness is a concept that has been extensively developed for maize (Wu, 1992), and wheat (Pomeranz *et al.*, 1988), but not for oats. Numerous methods have been developed to measure hardness in wheat, including direct measurement of the force required to cut or crush kernels, measurement of the time or energy to mill grain, particle size resulting from a grind (particle size index), and near-infrared reflectance of ground wheat. Several automated hardness analyzers also have been developed. Unfortunately, hardness as determined by these different measures are not always related, and precise definitions of kernel hardness are not available (Wu *et al.*, 1990).

Oat bran is a value-added oat product produced by grinding clean oat groats and separating out the larger sized particles. In this respect oat bran yield is equivalent to the particle size index (Yamazaki and Donelson, 1983), which is a measure of kernel hardness in cereal grains.

Thus, it is reasonable to expect that oat bran yield is related to groat hardness. Oat bran is enriched in protein and β-glucan, which enhances its economic value.

In this report, studies investigating groat hardness and bran yield in oat are discussed.

MATERIAL AND METHODS

Oat (*Avena sativa* L.) cultivars Bay, Dumont, Hytest, Marion, Troy, and Whitestone used for the hardness experiments were grown in Fargo, ND in 1995. Groats from the breeding line ND910117 grown in Fargo in 1995 were used for the milling study.

Oats were dehulled with a Codema Laboratory Oat Huller (Eden Prairie, Minnesota, USA). For the hardness study, moisture of oats was controlled at dehulling by measuring moisture of a sample, then adding water to the grain enclosed in a jar, and allowing the moisture to equilibrate for 48 hr. Percent groat was calculated as the mass of crude groats recovered from the dehuller as a proportion of the mass of the whole oats dehulled, times 100. Crude groats were cleaned by hand sorting. Broken groats, hulled oats remaining, and whole groats were each quantified. Milling yield was defined as the mass of whole groats recovered after cleaning crude groats, as a proportion of the mass of the whole oats, times 100. Hardness studies and milling experiments were conducted on whole groats. Groats were steamed for 20 min in a vegetable steamer before being subjected to milling studies to inactivate lipid-degrading enzyme activities.

Hardness was evaluated with a texture analyzer, an automated Single Kernel Characterization System (SKCS), and by particle size index (PSI). The TA-XT2 Texture Analyzer (Texture Technologies Corp, Scarsdale, NY) had a TA-42 cutting blade probe with a 45° cutting edge. Individual groats were positioned under the blade, crease facing down, situated so that the blade would come in contact with the groat 1-2 mm distal to the embryo. The blade was initially positioned 4 mm above the platform. The instrument measured the resistance to the blade movement as it cut through the groat. The maximal resistance reached just before the groat fractured was taken as a measurement of the groat hardness. The SKCS (Perten Industries, Reno, Nevada, USA) was designed for characterizing the force required to crush wheat. Samples of groats were placed into the sampling hopper and the instrument automatically measured groat width, groat weight, and hardness index (HI). Typically, samples of 300 kernels were taken. The PSI was determined from 20 g groat samples ground with a Retsch model ZM-1 centrifugal mill with a 2.0 mm collar screen (Brinkmann Instruments, Westbury, NY). Ground samples were sieved over 250 μm screens. Mass retained on the screen, as a proportion of the total mass, times 100, was defined as the PSI.

For bran production experiments, cleaned steamed groats were milled with either a roller mill, a hammer-type mill, or a pearling mill. For roller milling, a Brabender Quadramat Junior mill was used. Bran was defined as particles retained by a 500 μm screen. Coarse flour was defined as particles retained by a 250 μm screen. Particles that passed through the 250 μm screen were defined as the fine flour. Some bran preparations from the roller mill were further processed with a Buhler Bran Finisher. For hammer-type milling, a Retsch ZM-1 centrifugal mill (Brinkmann Instruments, Westbury, Massachusetts, USA) was used, with 0.5, 1.0, 2.0, or 3.0 mm grinding screens. For these experiments bran was defined as particles retained by a 250 μm screen. For the pearling mill, a Satake Bench-Scale Pearling Mill (Model TM-05, Philip Rahm, Inc, Houston, TX) assembled with a 30 grit stone was used to pearl outer layers from oat groats. Samples (200 g) were loaded into the milling chamber, and milled for 2, 3, 4, and 6 min, to achieve different levels of bran removal.

For tempering experiments, groats were first dried overnight in a convection oven at 40°C. This lowered the groat moisture to about 7%. Water was then added to the groats, enclosed in jars, to bring the final moisture up to 9, 10, 11, 12, and 13%. Jars were sealed, and shaken vigorously, then allowed to incubate for 20 min, 6 hr, and 18 hr, before roller-milling groats.

Chemical composition of groats and milling fractions was determined by methods described in Doehlert and Moore (1997). Statistical analyses, including analysis of variance, Tukey's honestly significant difference (HSD) multiple range test, and correlation analysis were performed with the Statistix (Analytical Software, Tallahassee, FL, USA) computer software package.

RESULTS

To test genotypic effects on groat breakage, replicated samples of 6 oat cultivars were dehulled and groat breakage measured (Table 1). The cultivar Dumont had the highest groat breakage, which contributed to its low milling yield. Although the cultivar Bay had the lowest breakage of any cultivar tested, because it had a lower groat percentage than any other cultivar, its milling yield was slightly higher than Dumont. The cultivar Troy had the highest milling yield, due to its high groat percentage and low breakage.

Table 1. Genotypic effects on oat dehulling characteristics.

Genotype	*% Groat*	*% Broken Groats*	*% Hulls Remaining*	*% Milling Yield*
Bay	58.1	2.87	1.78	55.4
Dumont	66.6	12.96	6.13	53.9
Hytest	68.5	7.06	0.31	63.4
Marion	65.8	3.11	2.53	62.1
Troy	69.6	3.37	0.27	67.0
Whitestone	64.7	4.27	3.84	59.5
HSD (0.05)	2.0	1.9	2.4	2.8

Groat hardness was measured by 3 different methods for the 6 cultivars examined (Table 2). The texture analyzer indicated that Troy was the softest cultivar and Hytest was the hardest. The SKCS indicated that Bay was the hardest cultivar and Dumont was the softest, which corresponded well with the breakage results. The PSI results suggested only that Marion was harder than the other cultivars. A correlation analysis (Table 3) indicated that all 3 hardness measures correlated with each other, but only the SKCS and the PSI correlated with groat breakage. An analysis of groat composition (not shown) indicated that hardness and groat breakage were correlated with the β-glucan concentration in the groat. Groat weight was also correlated (positively) with groat breakage and with groat hardness (Table 3). Although this genotypic sampling was too small to draw any firm conclusions, the results suggest a structural basis for groat hardness.

Table 2. Groat hardness measured by three different methods.

Genotype	*Texture Analyzer* *N*	*Single Kernel Analyzer* Hardness Index	*Partic le Size Index* Units
Bay	17.39	-45.3	44.4
Dumont	16.69	-55.8	42.8
Hytest	18.96	-48.6	43.7
Marion	18.78	-46.5	55.5
Troy	14.34	-51.2	44.8
Whitestone	15.67	-54.7	41.0
HSD (0.05)	2.67	4.8	6.6

Table 3. Correlations among groat hardness measures, groat breakage and groat composition.

	Texture Analyzer	**Single Kernel Analyzer**	**Particle Size Index**	**Broken Groats**	**Groat Weight**	**Groat Protein**	**Groat Lipid**
Single Kernel Analyzer	0.570**						
Particle Size Index	0.557**	0.625**					
Broken Groats	0.012	-0.594**	-0.366*				
Hulls Remaining	-0.086	-0.601**	-0.274	0.688**			
Groat Weight	0.692**	0.059	0.378*	0.544**			
Groat Protein	-0.144	-0.034	0.394*	0.081	-0.402*		
Groat Lipid	0.243	0.032	0.375*	0.001	0.540**	-0.893**	
Groat β-glucan	0.672**	0.730**	0.783**	-0.413	0.283	-0.039	0.076

The effect of moisture on groat hardness was evaluated by equilibrating whole oats to different moisture levels before dehulling. Increased moisture resulted in less groat breakage (Fig. 1), although more hulled oat remained in the crude groats after dehulling at higher moistures as well. Because remaining hulls increased more than broken groats decreased at increasing moisture, the milling yield decreased at moistures over 9% (not shown). Groat percentage was not affected by moisture (not shown).

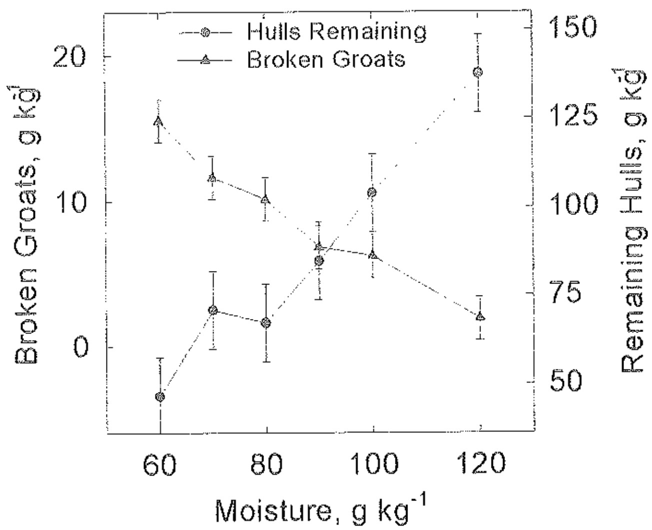

Figure 1. Effect of moisture on groat breakage and hulls remaining after dehulling.

It is interesting to note that the PSI is, by definition, equivalent to oat bran yield. Both are the proportion of larger particle flour obtained by sieving a ground groat flour. Because oat bran is an important value-added oat product, it was of interest to see what factors affect bran yield in oat milling. However, industrial protocols for oat bran production are not well publicized, so oat milling procedures were independently developed.

Initial oat milling experiments simply involved roller-milling groats at 12% moisture, and sieving the products over 35 and 60 mesh screens. The bran obtained resembled that obtained commercially, in that it was enriched in protein and β-glucan, but yields were very low. In contrast, the flour was enriched in starch. (Table 4).

Table 4. Yield and composition (%) of oat milling fractions of ND910117 with no tempering.

Fraction	*Yield*	*Starch*	*Protein*	*Lipid*	*β-Glucan*	*Ash*
Groat	---	66.5	15.8	4.73	3.88	1.98
Bran	18.1	48.6	22.1	4.81	8.37	3.74
Coarse	34.9	57.6	19.1	4.59	5.14	2.85
Flour	42.5	82.7	11.1	3.89	1.25	0.80
HSD	4.4	7.1	1.3	0.73	0.41	0.26

Tempering is a process used routinely in wheat milling, where water is added to grain, and moisture is allowed to equilibrate for a specified period of time before milling. In wheat, tempering improves the separation of bran and flour. Oat tempering experiments indicated that increased moisture resulted in increased bran yields, as did decreased tempering time (Table 5). Bran composition was changed very little, although β-glucan concentration tended to decrease with higher bran yields (not shown). Table 6 shows composition of bran after tempering. Again, protein and β-glucan concentrations are enriched in the bran. The composition of the milling fractions is similar to that in the untempered bran, but the bran yield is much higher with tempering, and the coarse fraction yield is reduced. The β-glucan concentration is slightly lower in the tempered milled bran. To obtain a bran more highly enriched in β-glucan, further processing the bran with a bran finisher significantly increased both protein and β-glucan concentrations (Table 7). The bran finisher provides additional physical agitation which knocks flour particles loose from bran.

Table 5. Effects of moisture and tempering time on bran yields

Final Moisture	Bran Yield (%) for 3 tempering times		
%	20 min	6 hr	18 hr
9	20.0	13.5	10.7
11	31.3	22.5	22.1
12	33.7	26.2	25.7
13	31.6	31.4	29.3

Table 6. Yield and composition of oat milling fractions after tempering to 12% moisture for 20 min.

Fraction	*Yield*	*Starch*	*Protein*	*Lipid*	*β-Glucan*	*Ash*
Groat	---	67.3	15.6	4.62	4.08	1.97
Bran	34.9	47.8	22.7	5.28	7.78	3.65
Coarse	18.8	65.7	16.3	4.91	3.96	2.19
Flour	45.4	84.0	10.1	3.50	1.46	0.56
HSD	2.2	2.8	0.4	0.40	0.62	0.15

Table 7. Composition of Oat Bran Processed with a Bran Finisher.

Component	Concentration
Starch	34.5
Protein	26.6
Lipid	5.8
β-Glucan	11.0
Ash	5.1

Bran was also made by grinding groats with a hammer-mill. Groats were ground with screen sizes ranging from 0.5 to 3.0 mm. As expected, bran yields increased with increasing grinding screen size. As bran yield increased, bran protein and β-glucan concentration decreased (Table 8).

Table 8. Effect of grinding screen size on yield and composition of oat bran retained on 250μm sieve.

Screen, mm	*Yield*	*Starch*	*Protein*	*Lipid*	*β-Glucan*	*Ash*
Whole	---	66.7	15.6	4.63	4.04	1.96
0.5	27.4	45.5	20.8	5.29	8.85	3.38
1.0	29.6	47.7	21.1	5.25	8.25	3.37
2.0	45.6	50.9	19.9	5.28	6.76	2.98
3.0	51.5	55.1	19.3	5.09	6.28	2.81
HSD	7.9	3.9	0.7	0.66	0.78	0.16

Finally, groats were milled with a pearling mill, that sequentially pearls off the outside of the groat. If the β-glucan is concentrated in the outer layers of the groat, one would expect to find this pearled bran enriched in β-glucan. However, no β-glucan enrichment in the pearled bran was found (Table 9), although the pearled bran was more highly enriched in lipid and ash than other brans. This indicated that oat bran is not primarily derived from the outer layers of the groat, but is derived from cell wall material distributed throughout the groat. During milling, the cell wall material apparently adheres in larger pieces with protein and ash. Tempering toughens the cell walls, hence, larger pieces are produced. Physical agitation of the bran with a bran finisher further separates the starch, which enhances concentration of β-glucan in the bran.

Table 9. Yield and composition of oat bran obtained from pearling mill.

*Fraction**	*Yield*	*Starch*	*Protein*	*Lipid*	*β-Glucan*	*Ash*
Groat	---	66.5	15.8	4.73	3.88	1.98
17%	9.3	51.0	18.8	6.30	4.73	4.10
25%	16.9	58.0	18.2	6.12	4.82	3.56
30%	22.9	59.9	17.7	6.64	4.64	3.27
57%	52.8	62.8	16.2	4.62	4.06	2.33
HSD	1.8	4.5	0.5	0.60	0.42	0.11

*Proportion of groat removed by pearling.

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A STEP FORWARD IN GROAT PERCENTAGE IN OATS BY NIRS

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SUMMARY

Oat milling industry considers groat percentage as an important grain quality criteria. Is desirable oats for grain to have a relation hull/ grain as lowest as possible.

Since 1978 many intents have been done to determine the percentage of groat of the experiment material landed in our Estación Experimental.

Many difficulties with the application of the traditional chemist method made it been left away.

In 1993, at the II South American Congress of Oat held in Port Alegre, Brazil, we reported a work about the method for estimating groat percentage in oat grain by NIRS technique.

This one does not use corrosive chemicals and proved to be simple, rapid, non-polluting and economical.

The NIRS instrument was an InfraAyzer 400 (Technicon, New York). We selected 44 samples representing a range of oat percentage between 58,6% and 77,2%. The reference date were got dehulling by hand. The correlation coefficient was R^2= 0,88.

This report shows the results and problems with the application of the NIRS method. However we are going to report the percentages of groat and protein got in lines and witness samples in 1978/79/80 and 1981. We will compare them with the last years results.

In 1996 an unfavorable climatological situation affected the normal grain development and materials with low percentage of grat were given. This permitted to expand the range of the sampling and obliged us to set up a new calibration. We selected 32 samples with an oat percentage range between 52.8% and 77,2%. The coefficient of multiple correlation and the posterior tests to check the new calibration were right.

CONTENT OF TOTAL AND SOLUBLE DIETARY FIBER IN OAT GROAT IN CHILE

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ABSTRACT

In this research, the content of total and soluble dietary fiber in the groat of oat and the relation between total and soluble dietary fiber were investigated. This study was carried out in Carillanca, Regional Research Center, of the Agriculture Research Institute (INIA), located in the Province of Cautín, IX Region, Chile. Eigth varieties and seventeen advanced lines of oats were evaluated in a complete blocks design with four replications (the treatments returned to each one of the 25 genotypes).

From the results obtained it was concluded that the content of total dietary fiber, the 25 oat genotypes, had a fluctuation between 6.42 % and 8.63 % and the fluctuation of the soluble dietary fiber was 4.60 % and 5.90 %. The actual commercial oats varieties: Urano, Nehuén and Llaofén, showed higher amounts of total and soluble dietary fiber, the same thing occurs with the next oat advance lines: AVE 85.101 and Ave 12.87, which had a high functional quality. Also, a high association was determined between the total and soluble fiber content of the groat oat.

INTRODUCCIÓN

Según Broca (1993), la avena se puede clasificar como un alimento funcional, conocidos como "alimentos para uso especifico en salud humana", entre otros, por su contenido de fibra dietaria.

La fibra dietaria total es una importante fracción de los alimentos, definida como "el conjunto de componentes de las paredes celulares de los vegetales que no son digeridas por enzimas de origen animal" (Burrows, 1992). El concepto de fibra dietaria total incluye dos tipos de fracciones : la fibra insoluble en agua o fibra cruda y la fibra dietaria soluble (Schmidh y Hebbel, 1981; Vetter, 1984; Scheneeman, 1986, 1987; Olson *et al.*, 1987; Hoseney, 1991).

Esta es la fracción activa de la fibra dietaria total que, por su alto porcentaje de ß-glucanos, presenta una actividad fisiológica importante (Peterson, 1992).

En la mayoría de las variedades de avena, la proporción más alta de fibra dietaria soluble se encuentra en el salvado, producto formado por: el pericarpio, la aleurona y subaleurona. La harina de avena, que es un subproducto de la obtención del salvado, también presenta importantes valores de fibra dietaria soluble (Lockhart y Hurt, 1986; MacArthur-Grant, 1986; Hoseney, 1991; Pak y Araya, 1991).

Los componentes de la fibra dietaria total, en especial la fibra dietaria soluble, ejerce un rol fisiológico importante en la prevención y tratamiento de enfermedades crónicas, asociadas al bajo consumo de fibra (Anderson, 1984; Pak y Araya, 1991; Burrows, 1992; Peterson, 1995), lo que conlleva la reducción de enfermedades cardiovasculares y diabetes; regulación de las funciones gastrointestinales y en el contenido de azúcar en la sangre; prevención de diabetes melitus, cálculos biliares y obesidad; inhibición del cáncer al colon y de la secreción de insulina y glicógeno; efecto hipotensivo y mejoramiento de la flora bacteriana (Pak y Araya, 1991; Brock, 1993). Además de confirmar la propiedad hipocolesterolémica de la fibra dietaria soluble, en forma general y específica, del salvado de avena (Vetter, 1984; Scheneeman, 1987; Pak y Araya, 1991).

Esta investigación preliminar tiene como objetivo preliminar evaluar el contenido de fibra dietaria total y fibra dietaria soluble de variedades comerciales de avena en Chile y de líneas avanzadas del programa de fitomejoramiento genético nacional.

MATERIALES Y MÉTODOS

El ensayo se realizó en el Centro Regional de Investigación-Carillanca, perteneciente al Instituto de Investigaciones Agropecuarias (INIA, Chile), ubicado en la IX Región, Provincia de Cautín, Comuna de Vilcún, a 38°41' lat. S y 72°25' long. W., a 200 m.s.n.m. Se estudiaron 8 variedades comerciales chilenas y 2 extranjeras, más 17 líneas avanzadas, que incluían material del programa nacional y de la Quaker Oat Company.

La siembra se realizó el 22 de mayo de 1995, con una dosis de semilla de 120 kg/ha. Se fertilizó con 150 kg de N/ha., en forma de salitre sódico: 1/3 a la siembra y los 2/3 restantes a la mitad de la macolla fisiológica y 180 kg de $P_2 0_5$/ha., como superfosfato triple, todo aplicado al surco al momento de la siembra. Las malezas se controlaron con una mezcla de 0.25 lt/ha. de Banvel-D, 35 gr/ha. de Granstar y 1 lt/ha. de MCPA. La cosecha se realizó el 19 de enero de 1996.

Se utilizó el diseño de bloques completos al azar, con cuatro repeticiones y 25 tratamientos (variedades y líneas avanzadas). Las variables estudiadas fueron sometidas a análisis de varianza y a la prueba de rango múltiple de Duncan. El análisis estadístico y los cálculos matemáticos fueron realizados con los software Harvey y Excel, respectivamente.

La fibra dietaria total se determinó por el método enzimático gravimétrico (A.O.A.C., 1984). La fibra dietaria soluble fue determinada por diferencia, entre el contenido de fibra dietaria total y el contenido de fibra cruda. Para determinar el contenido de fibra cruda se utilizó el método de hidrólisis ácido- alcalino (Schmith y Hebbel, 1981).

RESULTADOS Y DISCUSIÓN

Sin descuidar los avances obtenidos en aumentos de rendimiento y mejoramiento de la calidad física e industrial de las variedades de avena, en esta investigación se estudian principalmente, dos parámetros de calidad funcional: la fibra dietaria total y soluble, de las que se carece de información nacional.

Los valores de fibra dietaria total del grano pelado (Cuadro 1) obtenidos en este estudio, en los veinticinco genotipos analizados, fueron relativamente similares a los determinados por otros investigadores. Pak *et al.* (1990), obtuvieron tenores de fibra dietaria total en granos desnudos de avena de 7.1 %, valor inferior al contenido de fibra dietaria total promedio de 7.6 % determinado en este estudio. Sin embargo, éste fue ligeramente menor que el valor obtenido para grano pelado, extrapolado de los contenidos de fibra dietaria total en granos cubiertos informados por Aman y Hesselman (1984), Wood (1986), Aman (1987) y Pak y Araya (1991).

Cuadro N° 1. Fibra dietaria total (%) del grano pelado de 25 variedades y/o líneas avanzadas de avena (CRI-Carillanca, temporada 1995/96).

Variedad o línea avanzada	**Promedio de F.D.T. (%)**	
AVE 85.101	8,63	A
Urano	8,40	AB
AVE 85.103	8,32	AB
AVE 12.87	8,22	AB
Zeta	8,03	AB
AVE 14.87	7,95	ABCDE
OT 224 X W 78.181 (B)	7,92	ABCDE
Trafalgar	7,89	ABCDE
AVE 78.87	7,88	ABCDE
Nehuén	7,81	ABCDE
227 X ORA X 66-25 X TAM 301 (sel 1)	7,75	ABCDE
Llaofén	7,71	ABCDE
OT 224 X W 78.181 (A)	7,70	ABCDE
AVE 44.90	7,70	ABCDE
W 78.258 (D)	7,69	ABCDE
AVE 37.91	7,62	ABCDE
AVE 79.231	7,61	ABCDE
AVE 31.92	7,40	BCDEF
América	7,39	BCDEF
AVE 73.90	7,07	CDEF
AVE 56.87	7,02	CDEF
Omihi /10	6,80	DEF
Porter	6,75	DEF
Pony	6,45	F
AVE 80.115	6,42	F
Promedio	**7,60**	
Desviación estándar	**0,57**	
Coef. de variación (%)	**7,83**	

Letras en sentido vertical señalan diferencias estadísticas por variedades y/o línea avanzada, prueba de Duncan ($P < 0.05$).

Los mayores contenidos de fibra dietaria total corresponden a AVE 85.101 y Urano, con 8.63 % y 8.40 % respectivamente, y los menores contenidos a Pony (6.45 %) y AVE 80.115 (6.42 %). El promedio general de fibra dietaria total fue 7.60 %, y diecisiete variedades y/o líneas avanzada sobrepasan este valor.

Se propone una clasificación de las avenas, en tres categorías, en base al contenido de fibra dietaria total (Cuadro 2). Dieciocho variedades y/o líneas avanzadas superaron al promedio de los veinticinco genotipos y, cinco de éstos tuvieron tenores sobre un 8 %, con un máximo de 8.6 % de fibra dietaria total. Con excepción de América y Pony, las restantes variedades comerciales se ubican en una categoría media (Nehuén y Llaofén) y alta (Urano y Zeta), en contenido de fibra dietaria total. En el caso de Urano y Zeta esta situación era desconocida y, tiene importancia puesto que incorpora la calidad funcional, como una característica agregada a los atributos agronómicos, especialmente, de Urano que tiene altos, elevado peso de hectolitro y alta extracción de grano pelado (Beratto, 1996).

Cuadro N° 2. Escala de clasificación de 25 variedades y/o líneas avanzadas de avena, en base a su contenido de fibra dietaria total (%) en el grano pelado.

Categoría	**Fibra dietaria total (%)**	**Variedades y/o líneas avanzadas**
Alta	8,00 - 8,99	AVE 85.101, Urano, AVE 85.103, AVE 12.87, Zeta.
Media	7,00 - 7,99	AVE 14.87, OT 224 X W 78.181 (B), Trafalgar, AVE 78.87, Nehuén, 227 X ORA X 66-25 X TAM 301 (sel. 1), Llaofén, OT 224 X W 78.181 (A), AVE 44.90, W 78.258 (D), AVE 37.91, AVE 79.231, AVE 31.92, América, AVE 73.90, AVE 56.87
Baja	6,00 - 6,99	Omihi / 10, Porter, Pony, AVE 80.115

Además, la fibra dietaria total tuvo una correlación alta (r2 = 0.98*), con el contenido de fibra dietaria soluble (Cuadro 3), la que tiene un rol fisiológico importante en la prevención y tratamiento de enfermedades crónicas, asociadas al bajo consumo de fibra, lo que conlleva a la reducción de enfermedades cardiovasculares y diabetes, entre otras, según Anderson (1984), Pak y Araya (1991), Burrows (1992).

Cuadro N° 3. Coeficientes de correlación

Parámetros	**Fibra dietaria total (%)**	**Fibra dietaria soluble (%)**
Rendimiento	0.30	0.36
F.D.T.	----	0.98
F.D.S.	----	----

* Coeficientes de correlación en destacado son significativos a un 0.05

Se puede concluir que entre los veinticinco genotipos estudiados (Cuadro 4), hay diferencias en contenido de fibra dietaria soluble. Los mayores contenidos de ésta, corresponden a AVE 85.101 y Urano, con 7.03 % 6.87 % respectivamente y, los menores contenidos se obtuvieron con Pony (4.73 %) y AVE 80.115 (4.60 %). Nueve variedades y/o líneas avanzadas tienen valores de fibra dietaria soluble superiores al promedio de las 25 variedades estudiadas (5.9 %).

Cuadro N° 4. Fibra dietaria soluble (%) del grano pelado de 25 variedad y/o líneas avanzadas de avena (CRI-Carillanca, temporada 1995/96).

Variedad o línea avanzada	**Promedio de F.D.T. (%)**	
AVE 85.101	7,03	A
Urano	6,87	AB
AVE 12.87	6,67	AB
OT 224 X W 78.181 (B)	6,33	ABC
AVE 78.87	6,30	ABC
Nehuén	6,24	ABCD
Zeta	6,23	ABCD
AVE 37.91	6,22	ABCD
AVE 85.103	6,22	ABCD
227 X ORA X 66-25 X TAM 301 (sel 1)	6,16	ABCD
W 78.258 (D)	6,12	ABCD
AVE 44.90	6,08	ABCD
AVE 14.87	6,05	ABCD
Llaofén	6,03	ABCD
OT 224 X W 78.181 (A)	6,02	ABCD
Trafalgar	5,92	ABCD
AVE 31.92	5,75	BCDE
AVE 79.231	5,73	BCDE
Omihi /10	5,40	CDEF
Porter	5,28	CDEF
AVE 73.90	5,27	CDEF
AVE 56.87	5,19	CDEF
América	5.09	CDEF
Pony	4,73	F
AVE 80.115	4,60	F
Promedio	**5,90**	
Desviación estándar	**0,60**	
Coef. de variación (%)	**10,10**	

Letras en sentido vertical señalan diferencias estadísticas por variedades y/o línea avanzada, prueba de Duncan ($P < 0.05$).

Pak *et al.* (1990), obtuvieron valores de fibra dietaria soluble en granos desnudos de avena de 2.4%, inferior al contenido promedio de 5.9 % determinado en esta investigación. Debido, probablemente, a que los valores de fibra cruda que ellos obtuvieron fueron de 4.7 % en grano desnudo, valor muy alto para este tipo de grano que, normalmente fluctúa entre 1.2 % a 1.7 %, según lo establecido por Schmith y Hebbel (1981) y Hoseney (1991). Además que, éstos corresponden a una sola variedad, y no al promedio de veinticinco genotipos, como se determinó en este estudio.

Se propone una clasificación de las avenas en tres categorías, en relación a su contenido de fibra dietaria soluble (Cuadro 5). En esta investigación, diecisiete genotipos superaron al promedio (5.9 %), y nueve de éstos tuvieron tenores sobre 6.2 % con un máximo de 7.03 % de fibra dietaria soluble. Infiriéndose que, al igual que en fibra dietaria total, América y Pony se ubican en la categoría más baja y Llaofén en la categoría media; mientras que, Urano, Zeta y Nehuén se ubican en la categoria alta.

Cuadro N° 5. Escala de clasificación de 25 variedades y/o líneas avanzadas de avena, en base a su contenido de fibra dietaria soluble (%) en el grano pelado.

Categoría	Fibra dietaria total (%)	Variedades y/o líneas avanzadas
Alta	6,50 - 7,50	AVE 85.101, Urano, AVE 12.87
Media	5,50 - 6,49	OT 224 X W 78.181 (B), AVE 78.87, Nehuén, Zeta, AVE 37.91, AVE 85.103.227 X ORA X 66-25 X TAM 301 (sel.1), W 78.258 (D), AVE 44.90, AVE 14.87, Llaofén, OT 224 X W 78.181 (A), Trafalgar AVE 31.92, AVE 79.231.
Baja	4,50 - 5,49	Omihi / 10, Porter, AVE 73,90, AVE 56.87, América, Pony, AVE 80.115

CONCLUSIONES

(1) Se determinó que el contenido de fibra dietaria total del grano pelado de veinticinco genotipos de avenas fluctúo entre 6.42 % y 8.63 %; mientras que el contenido de fibra dietaria soluble varió desde 4.60 % a 5.90 %.

(2) Entre las variedades de avena comerciales en Chile, Urano tiene altos rendimientos de grano, peso de hectolitro (calidad física), extracción de grano pelado (calidad industrial) y contenido de fibra dietaria total y soluble (calidad funcional), seguida de Nehuén y Llaofén.

(3) Entre las líneas avanzadas de avena destacaron por su alto contenido de fibra dietaria total y soluble las que se indican: AVE 85.101 y AVE 12.87.

(4) Se propone una clasificación de las avenas de acuerdo a sus contenidos de fibra dietaria total y fibra dietaria soluble.

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PLANT BREEDING IN *Avena Sativa* L RESISTANT TO GREENBUG

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The greenbug (*Schizaphis graminum* (Rond)) characterized by ciclic attacks to cultivated and/or natural gramineous is world widely found.

In Argentina, it was detected in 1914 and since 1937 a great damage was observed on small grains in the Pampa region. In the last years its influence has increased. Thus, intensive and frequent attacks were observed in the central part of Santa Fe, Córdoba, La Pampa and south west of Buenos Aires Provinces.

In this area winter cereals, cultivated grassland and early fresh fodder sowing, specially oat has increased in the last years up to 2.000.000 ha, 70% being used as fodder.

Development of resistant varieties is considered a very useful way to avoid greenbug´s effects. Because it is highly consistent with biological, cultural and even chemical control. Such alternative is easy to be carried out, lowering cost and pesticide risk. Besides it improves environmental conditions.

Development of resistant varieties also means grain and herbage yield, grassing fitness, tolerance to biotic factors and commercial quality.

To reach this aim, a crossing programme is done using well know resistance sources and local varieties. The progenies are bred by pedigree selection in different locations and in the greenhouse artificially infested under controled conditions. At a time, other biological and genetical aspects as resistance mechanism and aggressivess are considered.

Two oat varieties, Tambera F.A (1988) and Boyera F.A (1993) were obtained with this metodology. At present they are in their distribution programme. Both cultivar have resistance genes from oat PI 186270. Likewise, both offers a high early herbage production that was not available in the other commercial varieties up to their release.

At the present time, there are advanced later lines, arose from PI 251580, PI 251581, JHG1, JHG8, etc., may be released soon.

Even if biological control has a lot of advantages, there are also some problems: resistance loss because of the new biotypes or physiological races, with a different virulence rate for different crops or different cultivars of the same crops. So, resistance level may change in different regions according to distribution and frequency of physiological races or biotypes.

In greenbug, at least 9 biotypes and more than 30 isolations were identified. Each of them characterized by different virulence expression. Due to this fact, the development of resistant cultivars is the principal aim in order to obtain stable tolerance to biotypical changes, heterogeneous population and changing environment.

In Argentina there are at least 3 biotypes, appearing certain homology with USA. However, the performance of several resistant genotypes suggests some differences and variability in those isolations of different origin. This aspect is nowadays under study by means of the biotypical and biological characterization of greenbug populations of different origins.

IMPORTANT NOTES ABOUT SUSTAINABLE RESISTANCE

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Crown rust epidemics has been the chief effect in reducing oat yields in Brazil. Besides, it may reduce the cultivated area, by generating unstable harvests and inadequate economic condition to the farmers. To maintain this disease at desirable levels, isolated methods, like the use of resistant varieties with major, race-specific genes, and fungicides, have been employed. Nevertheless, losses in effectiveness and the need for varieties reposition are frequent due to rapid changes in the population of the pathogen. Even if progresses have been obtained, the resistance levels present in available cultivars are not enough to face the pressure present in important growth areas. Chemical control of diseases leads to a more expensive culture, due to the purchase of products, machinery and human resources. It also brings risks to human and animal health and disrupts the ecological equilibrium. Acquired experience points that a sustainable resistance demands a new approach, with the knowledge and integration of more promising practices. The aim of this paper, therefore, is to present some aspects of resistance as it is seen today and the challenge to keep it durable.

Resistance can be defined as the ability of the host o hinder growth and development of the pathogen (Parlevliet, 1997). It is often used in a qualitative sense; a cultivar is resistant or susceptible. But this is far from the reality since complete susceptibility is rather rare in nature and the degrees of resistance/susceptibility frequently observed in many varieties represent the various levels of quantitative resistance.

Resistance is often controlled by major genes which frequently inherit dominantly, less frequently recessively (Parlevliet, 1997). In the interaction oat x crown rust, major genes appear to operate in a gene-for-gene system with avirulence genes of the pathogen and it has been typically non durable. The expression of resistance genes, however, can be modified by the action of other genes, the developmental stage, the tissue of the plant or the environment.

Host resistance has been described in wide array of terms, which can be grouped according to the: 1) Expression of resistance (complete, partial, quantitative, residual, field, seedling, adult plant and overall resistance). 2) Inheritance of resistance (major gene, minor gene and polygene resistance). 3) Specificity of resistance (race-specific, race-non-specific, pathogen-specific and broad resistance). 4) Mechanism of resistance (hypersensitive, non-hypersensitive, post-hautorial and pre-haustorial resistance). The term durable resistance has been described as the resistance that remains effective during its prolonged and widespread use in an environment favorable to the disease (Johnson, 1981; 1984).

According to Parlevliet (1997), complete, seedling, overall and adult plant resistance usually refer to simply inherited, major gene types of resistances. Partial, field and residual resistance are terms describing quantitative resistance. Partial resistance of wheat to *Puccinia recondita* (Broers and Jacobs, 1989) is based on a few additive genes whereas in barley to *Puccinia hordei* (Parlevliet, 1978) is of the polygenic type. Although this polygenic resistance in barley to leaf rust showed small race-specific effects, it was very durable (Habgood and Clifford, 1981; Parlevliet, 1993), giving no indication that polygenic, quantitative types of resistances with small race-specific effects could not be durable (Parlevliet, 1997).

Quantitative resistance is often considerably more durable than complete or near-complete resistance but there are exceptions (Toriyama, 1975). Typical non-durable resistance is largely restricted to the major gene type of resistance to specialized fungal and some bacterial pathogens, that are air or splash borne (Parlevliet (1993). However, monogenic resistance is not always elusive, showing durability, with and without known corresponding races of the pathogen, in a number of interactions (Parlevliet, 1990; Meiners, 1981). Apparently durability and race-specificity can go together. Unfortunately, up to date there is not any simple test that could help to indicate potentially durable resistances.

Mechanisms of broad resistance such as the phytoalexins are highly durable but with the durability of pathogen-specific resistance the situation is more complex. The resistance so easily overcome, predominantly found among the specialized biotrophic fungi, is based on the hypersensitivity reaction (Parlevliet, 1997). On the other hand, partial resistance does not evoke a hypersensitive type of response. Parlevliet (1979) found that partially resistant barley cultivars to leaf rust had less uredia, that appeared later and produced fewer spores. Germination, penetration, vesicle formation and the formation of the primary infection hyphae are not affected by the partial resistance. According to Niks (1986), the partial resistance becomes effective as soon as haustoria mother cells are formed, a pre-haustorial resistance.

In evolutionary sense all resistance is transitory. The constant arms race between the attacking parasite and the defending host, resulted in a remarkable coevolution (Parlevliet, 1997). Despite that no resistance lasts forever, large differences in the ease by which the pathogen can neutralize a resistance can exist. Whether a resistance is elusive or quite durable is primarily determined by the mechanism of the resistance (Parlevliet, 1995).

Another strategy advocated to achieve sustainable resistance was the gene pyramiding in a particular variety (Shanner, 1983). Ideally it would combine effective resistance genes to all races and some residual resistance too. For Johnson (1988), this strategy of combining race-specific genes, particularly those for which matching pathogenicity is rare, might provide a more satisfactory control of disease in climates that are less favorable to the pathogen. In same cases, however, like in wheat and leaf rust, it seems that some specific gene combination is more important than the number of genes pyramided in order to provide durability (Leonard, personal communication).

It is likely that there is much potentially durable resistance to crown rust in oat germplasms but the genetic basis of much of this resistance is not well known as yet. Certainly much more data will be accumulated on the scale of cultivation of cultivars and the evidence of durability of their resistance. According to Johnson (1988), the best way to enhance the probability of achieving durable resistance in new cultivars is to transfer resistance from sources already identified as durable. He also suggests that resistance could be accumulated from crosses between moderately susceptible cultivars, which could readily be achieved within pedigree programs and does not require resort to recurrent mass selection methods. Although there is no guarantee that such resistance would be durable, the method seems more promising than the introduction of single major genes or combining already known race-specific genes into new groups. The accumulation of resistance from crosses of locally adapted cultivars could sometimes be attractive as an alternative to attempting to derive durable resistance from known but unadapted sources (Johnson, 1988). It should be kept in mind, however, that if the breeding programs are very large, it is difficult that either of these methods could be applied consistently to all crosses and although they might increase the probability of producing cultivars with durable resistance, they are not such as to guarantee future durability.

Under these circumstances, it seems very important to monitor the disease resistance of all new cultivars and to maintain systems for detecting changes in pathogen populations. The risks of genetic uniformity should be continually kept in view and systems to reduce widespread dependence on single uniform cultivars should be encouraged (Wolfe, 1985; 1997). To manage resistance in a integrated way seems to be of fundamental importance to avoid surprises by the forces of evolution (Martinelli, 1993).

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A PROPOSED NORTH AMERICAN SYSTEM OF NOMENCLATURE FOR *Puccinia coronata* f. sp. *avenae*

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A nomenclature system for designating virulence combinations of oat crown rust (causal agent *Puccinia coronata* f. sp. *avenae*) isolates is proposed. Sixteen oat lines, with seedling resistance genes *Pc38, 39, 40, 45, 46, 48, 50, 51, 52, 54, 56, 58, 59, 62, 64,* and *68* occurring singly in each of them, are used as primary differentials. The host lines are arranged into groups of four (subset 1 = *Pc40, 45, 46, 50*; subset 2 = *Pc38, 39, 48, 68*; subset 3 = *Pc51, 52, 58, 59*; subset 4 = *Pc54, 56, 62, 64*). Avirulence and virulence of isolates on each line are indicated by low and high infection types, respectively. The consonants B through T are used to indicate the 16 possible infection type patterns on each subset (Table 1). Virulence combinations are assigned with a four-letter Pca code for races of *P. coronata* f. sp. *avenae*. Local differential series are separated from the Pca code by a slash, followed by a listing of the ineffective host genes in the local differentials on which the race was virulent.

The identification of virulence phenotypes has been and will continue to be an important part of the program to develop resistant host cultivars, as well as for determining regional virulence differences for the purpose of gene deployment in North America. The proposed Pca nomenclature should simplify the designation of complex virulence combinations. The new nomenclature also should facilitate the study of evolution of virulence in the oat crown rust populations. The previous use of frequencies of avirulence/virulence phenotypes made it difficult to follow trends involving complex virulence combinations. The proposed nomenclature permits the calculation of individual virulence frequencies as well as the determination of any virulence combinations in the oat crown rust population.

Table 1. Code for the 16 North American differential hosts for *Puccinia coronata* f. sp. *avenae* in ordered sets of four

		Infection type[b] produced on single-gene Pc line			
	Pc gene subset 1:	40	45	46	50
	Pc gene subset 2:	38	39	48	68
Pca	Pc gene subset 3:	51	52	58	59
code[a]	Pc gene subset 4:	54	56	62	64
B		L	L	L	L
C		L	L	L	H
D		L	L	H	L
F		L	L	H	H
G		L	H	L	L
H		L	H	L	H
J		L	H	H	L
K		L	H	H	H
L		H	L	L	L
M		H	L	L	H
N		H	L	H	L
P		H	L	H	H
Q		H	H	L	L
R		H	H	L	H
S		H	H	H	L
T		H	H	H	H

[a]Pca code consists of the designation for subset 1 followed by that for subset 2, etc. For example, race LQBB = subset 1 (L), virulent to *Pc40*; subset 2 (Q), virulent to *Pc38, 39*; subset 3 (B), avirulent; subset 4 (B), avirulent.
[b]L = low infection type (avirulent pathogen), H = high infection (virulent pathogen).

BREEDING FOR DURABLE RESISTANCE TO WHEAT LEAF RUST: AN OVERVIEW

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INTRODUCTION

Wheat leaf rust, caused by *Puccinia recondita* f. sp. *tritici* is one of the major diseases of wheat worldwide. Uruguay is located in a large epidemiological unit which also comprises Argentina, lowlands of Bolivia, Brazil and Paraguay. Within this region, there are no geographical barriers for spore movement. Uruguay has a subtropical climate, very favorable for the disease (average yearly rainfall of 1000 mm and mean temperature of the coldest month slightly above 10C). First pustules are generally detected in August but in some years these have been observed in April and May, on volunteer plants or early planted crops, indicating the fungus probably oversummers locally. Late and early maturity wheats are planted from April to August and harvested in December, determining a very long growing season which provides green tissue for many leaf rust infection cycles. Under these conditions, severe epidemics of leaf rust frequently develop on susceptible cultivars, causing severe losses (Germán *et al.*, 1986).

Traditionally, the control of leaf rust has been based on the selection of resistant cultivars. However, the resistance if often eroded due to selection of rust races virulent to resistance genes in the cultivars. As a consequence, the high level of resistance of released cultivars has been short lived worldwide (Roelfs, 1988) and in Uruguay (Germán, 1995). The objective of breeding for wheat leaf rust resistance must be not only obtaining effective resistance but also that this resistance should be long lasting.

This communication intends to give information about how breeding for durable leaf rust resistance has been approached and provide some basic information of the wheat-leaf rust system including host reaction and pathogen virulence, structure and dynamics that relate to the identification and development of germplasm with this characteristic. Other interesting approaches to control the disease by increasing genetic diversity will not be considered.

THE HOST

Resistance to wheat leaf rust

The control of leaf rust has traditionally been based on the use of race specific genes (mayor or hypersensitive) genes. Forty six genes determining leaf rust resistance (*Lr* genes) at 40 different loci have been identified to date and given official designations. The characteristic infection type, chromosome location and linkage relationships are known for most genes (McIntosh *et al.*, 1995; Kolmer, 1996). Most of these genes are available in single gene lines in the Thatcher (Tc) uniform susceptible background, developed at Agriculture and Agri-Food Canada Winnipeg Research Centre by Dr. Peter Dyck (Kolmer, 1995). These near isogenic lines have been very valuable tools to study pathogen virulence patterns and genetic studies of host lines.

Twenty five resistance genes were originally present in wheat (most in *Triticum aestivum*) and 21 have been introgressed from related species within the tribe *Triticeae*. Most identified leaf rust resistance genes are expressed from the first leaf stage (seedling resistance genes), but others are optimally expressed at a later stage of plant development (adult plant resistance or APR): *Lr12, Lr13, Lr22a, Lr22b, Lr35, Lr37* (McIntosh *et al.*, 1995). Genetic studies have indicated that the same leaf rust resistance genes were present in wheat collections that had very different origins (Shang *et al.*, 1986; Claude *et al.*, 1986), indicating that the leaf rust resistance gene pool may be nearly exhausted. Specific virulence in *P. recondita* can be found to most leaf rust resistance genes deployed in wheat cultivars (McIntosh *et al.* 1995).

Durable wheat leaf rust resistance

Durable resistance has been defined as resistance that has been adequate for a number of years over a range of environments (Johnson, 1981). Wheat land races and cultivars that have demonstrated durable resistance are the obvious source for this characteristic to be used in breeding programs.

The combination of genes *Lr13* + *Lr34* has been identified as one of the most durable sources of leaf rust resistance (Roelfs, 1988). These genes are present in Frontana, a Brazilian cultivar which has been widely used as a source of resistance in wheat breeding programs in North America and CIMMYT due to its durable resistance. *Lr13* + *Lr34* are probably present in Americano 44 d, a selection from a landrace made in Uruguay in the 1910's, and other old South American wheats (Roelfs, 1988). The fact that durable resistance to leaf rust has been related to the presence *Lr13* and *Lr34* suggests that it may be associated to APR. However, some of the APR genes, namely *Lr12, Lr22b,* are only partially effective or even completely ineffective in some regions, where there is specific virulence to them. *Lr13* is still effective in Australia, and is an important component of the resistance in many North American wheats, in combinations with *Lr16, Lr34*, etc. (Kolmer, 1996).Therefore APR does not always imply durable resistance.

*Lr*34

On the contrary, APR gene *Lr34*, has no specific virulence reported in spite of being widely distributed (it has been found in old cultivars and landraces, South and North American cultivars, CIMMYT germplasm, and in accessions collected from different origins). *Lr34* was initially described as a modifier of the APR genes *Lr13* in Frontana and *Lr12* in Exchange (Dyck *et al.*, 1966). *Lr34* was given final designation when mapped on chromosome 7D (Dyck, 1897).

Lr34 best expresses its resistance in the adult plant stage (Dyck and Samborski, 1982). In the field, *Lr34* is expressed as variable pustule size and low severity of infection (Dyck, 1987).
Lr34 resistance is affected by environmental conditions and genetic background. It is best expressed under cool temperature (Dyck and Samborski, 1982; Singh, 1992), reason why it

probably plays an important role delaying the epidemic build up during winter or early spring. *Lr34* resistance is associated with longer latent period, decreased number and size of uredinia, starting at the fourth leaf stage (Drijepondt *et al.*, 1991). Rubiales and Niks (1995) found that these characteristics were due to reduced rates of haustorium formation in early stages of infection, not associated to cell death.

Germán and Kolmer (1992) demonstrated that *Lr34* interacts with other genes for enhanced resistance when the additional gene conditions some degree of resistance. This suggest that this gene has more an additive than an epistatic gene action. All the characteristics described, as well as the durability of the resistance conferred by *Lr34*, are characteristics of partial resistance.

Partial resistance (considered here as synonymous to slow rusting) is characterized by a slow disease development in the field, despite a susceptible infection type (Caldwel, 1968; Parlevliet, 1979). It is the consequence of the interaction of reduced infection, longer latent period and lower spore production (smaller pustules and shorter infectious period) (Parlevliet, 1979).

Partial resistance to wheat leaf rust: inheritance and potential for selection

The inheritance of partial resistance to wheat leaf rust or its components have been conducted by a number of authors (Table 1).

Table 1. Summary of studies on the inheritance of partial resistance to wheat leaf rust.

Characteristic evaluated	Number of genotypes	Gene action	h2 (%)	Minimum Ner of genes	Author
Severity	2	additive		2 or +	Singh and Huerta-Espino (1995)
Severity	4	additive		3 or 4	Singh and Rajaram (1992)
AUDPC	5	predom additive	45-92		Das *et al.* (1992)
Receptivity	1		47	3 or 4	Das *et al.* (1993)
Latent period	1		57	3	Das *et al.* (1993)
Uredinium size	1		63	3 or 4	Das *et al.* (1993)
Latent period	7	recessive or partially		1 o 2 to 3	Lee and Shaner (1985)
Latent period	3	predom additive recessive of partially	80	1 or 2 to 3 or +	Jacobs and Broers (1989)
Latent period	3			2 or 3	Broers and Jacobs (1989)
Latent period	1	partial dominance		2	Kuhn *et al.* (1980)

Partial resistance or slow rusting and its components performed as quantitative traits. The inheritance was oligogenic, with one to three or four genes involved. These genes were recessive, partially recessive or partially dominant, and had additive or predominantly additive effects. Heritability estimates were medium to high, indicating that selection for the resistance or the components should be effective to increase the level of partial resistance. The recessive or partially recessive and additive nature of the resistance implies that selection for resistance should be mild in early generations.

When two or more materials were studied, the authors claim that some or all the genes present in the different materials were different. Singh and Rajaram (1992) found *Lr34* was one of the genes in some of the wheats they studied. It is possible that other materials studied by other authors also have this gene. Using chromosome substitution lines R. Singh was able to isolate and locate on chromosome 1B one APR gene from Pavon 76. This gene was named *Lr46* (R. Singh, personal communication). Highly resistant CIMMYT lines with combinations of more than 3 genes have been obtained recently (R. Singh, personal communication).

Many cultivars have combinations of seedling resistance and APR, possibly including partial resistance, which should be exploited. *Lr34* has been selected unconsciously in many breeding programs since it enhances the resistance conferred by other genes (Dyck *et al.* 1966; Dyck and Samborski, 1982). Due to their additive action, this may also be the case for other genes determining partial resistance.

The knowledge of the genetic basis of leaf rust resistance of locally adapted advanced lines or cultivars (Table 2) also provides very valuable information, not only to identify materials that may carry useful genes, but also to properly manage the segregating populations derived from crosses of these materials with those carrying partial resistance (Table 2).

Table 2. *Lr* genes present in seven Uruguayan wheat cultivars

Cultivars	Year of release	Seedling resistance	APR
Early maturity			
E.Tarariras	1974	*Lr 3bg*	*Lr 13, 34*
E.Benteveo	1989	*Lr 3, 14a, 26*	*Lr 13, 34?*
E.Pelón 90	1990	*Lr 1, 17, 26*	*Lr 34*
I.Boyero	--	*Lr 26*	*Lr 13, 34, -*
Late maturity			
E.Calandria	1986	*Lr 3bg, 16, 24*	*Lr 34?*
E.Federal	1987	*Lr 10 +*	-
E.Halcon	1991	*Lr10, 16, 14?*	

Leaf rust resistance is conditioned by combinations of seedling resistance with APR in six of the seven cultivars examined. APR genes present were *Lr13*, *Lr34* and possibly unidentified APR genes in I.Boyero and E.Federal (Germán, 1996).

Breeding for partial resistance has to be approached differently depending on whether mayor genes are present or not. If there are no mayor genes in any of the parents included in crosses, the process will be straight forward and the resistance selected will be partial resistance. But most probably elite germplasm carry race specific resistance, since this resistance has been widely used. In this case, because it is impractical to eliminate the mayor genes from the segregating populations, races of the pathogen virulent to the specific resistance should be used to select for partial resistance since mayor gene resistance is epistatic and hides the expression of partial resistance.

THE PATHOGEN

Availability of appropriate pathogen isolates and, for field studies, knowledge of the pathogen population, acquire relevance in the situation described above. Surveys of the leaf rust population in Uruguay begun in 1989. Results for the last three years are presented in Table 3.

Table 3. Percentage of virulence phenotypes of *Puccinia recondita* in Uruguay, 1994-1996.

	Year			
Ptr code*	1994	1995	1996	previously
LCG-10	4,2	8,6		*
LDG-10			3,3	
LFG-10		1,4	4,9	
LFG-10,20			1,6	
LFH-10			3,3	
MBG-10	4,2	2,9	1,6	*
MBG-10,20	1,4			*
MBM-10			1,6	
MBR-10		2,9	14,8	*
MCG-10	1,4	5,7	9,8	*
MCH-10			1,6	
MCR		1,4		*
MCR-10	54,2	44,3	14,8	*
MCR-10,20			1,6	*
MFB-10,20	8,3			
MFR	26,4	7,1		
TBJ-10,20			4,9	
TCD-10,20		2,9		
TDD-10,20		22,9	13,1	
TDJ-10,20			23,0	
Number	72	70	61	203

* Long and Kolmer (1989)

Virulence phenotypes were determined using the 12 differential lines with *Lr* genes *1,2a,2c,3,3ka,9,11,16,17,24,26,30* (Long and Kolmer, 1989) and *Lr10* and *Lr20* as supplementary differentials. Virulence phenotypes were denominated by the *Prt* code, followed by the gene number of the supplementary differentials if the isolate was virulent on these.

Twenty different virulence phenotypes were found in the three year period. **The leaf rust population was dominated by few races**, as has been shown for other regions (Medeiros and Barcellos, 1994; Kolmer, 1994; Singh, 1991). Seven, 10 and 14 different virulent phenotypes were identified during the three year period. Two to four races predominated in the leaf rust population with over 10% prevalence. In 1994, MCR-10 accounted for more than 50% of the isolated tested, followed by MFR. MCR-10 caused a severe epidemic on Estanzuela Federal, sown in about 10% of the wheat area that year. In 1995, the area of E. Federal was reduced drastically, but still 44% of the isolates corresponded to MCR-10. The second prevalent race was

TDD-10,20, which caused high infections on Buck Yapeyu, planted in Argentina and in about 3% of the Uruguayan wheat area. In 1996, TDJ-10,20, also virulent on B. Yapeyu, accounted for 23% of the isolates. MBR-10, MCR-10 and TDD-10,20 also had over 10% prevalence. (Germán and Abadie, 1997).

The structure of the population was studied using multidimensional scaling, based on the virulence phenotypes (Figure 1). From the biplot it is apparent that the population is formed by a more distant group of races (races T) and two other more related groups that include races L and M. Many of the races within the groups had only one or two gene difference, and have virulence to similar groups of lines and cultivars.

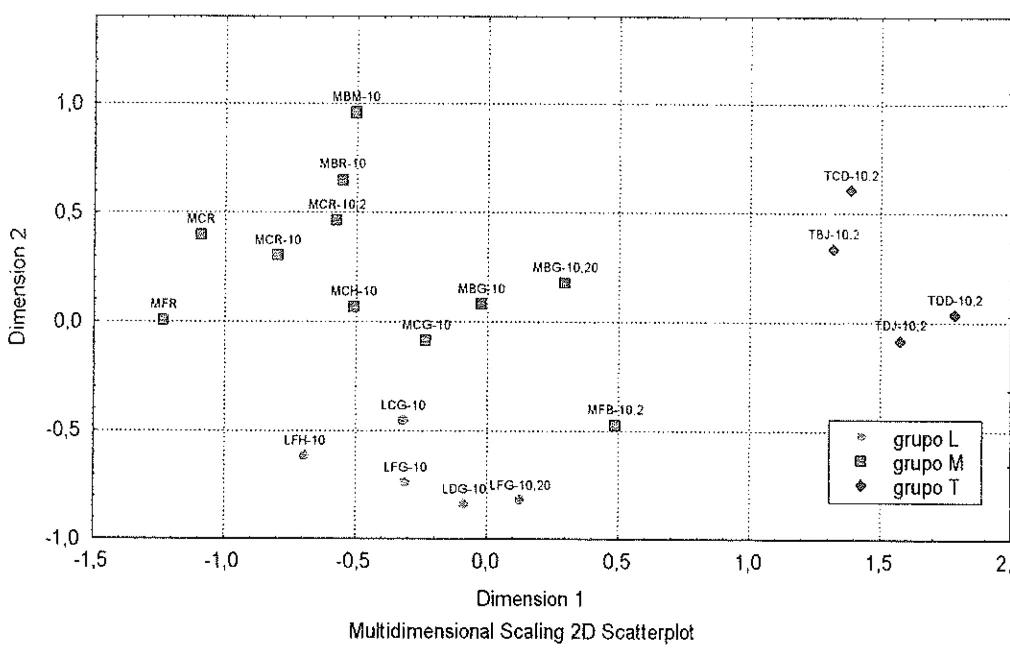

Figure 1. Two dimension similarity scatterplot of *P. recondita* isolates based on virulence/avirulence on 14 *Lr* genes,.

The leaf rust population is very dynamic. Only three races were found during the three year period, and 12 were found only in one year. From the twenty races identified, eight had been previously found in Uruguay and eight had been reported in Brazil until 1996. Seven were new different virulence phenotypes. The dynamics of the leaf rust population is better exemplified by the change in virulence frequencies on some single genes (sum of the frequencies of all isolates virulent on that gene), as shown in Figure 2.

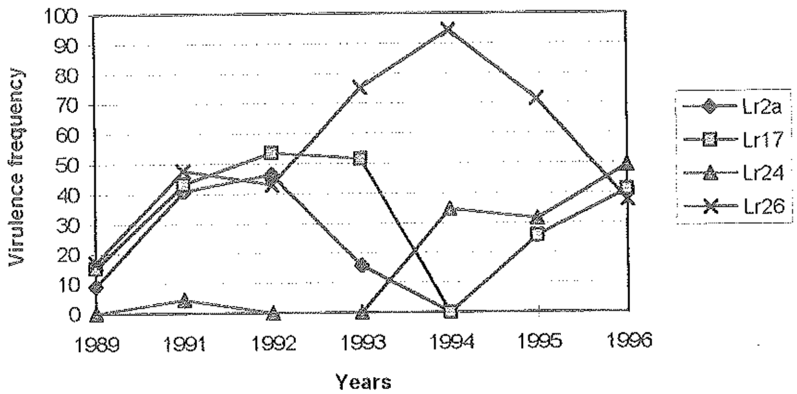

Figure 2. Virulence frequency to four *Lr* genes during 1989-1996.

Virulence to *Lr26* increased up to 95%, due to the widespread use of CIMMYT lines with the 1B/1R translocation, which carries this gene. Virulence to *Lr2a* and *Lr17* increased to medium levels, decreased to 0 in 1994 and increased again to medium levels in following years. Virulence to *Lr24* was low until 1994 and increased in 1995 and 1996. This is explained by the increase in area planted with cultivars with this resistance in Argentina and Brazil. Population shifts are due to host selection.

It is also important to know the virulence of different races to race specific APR genes that are present in the breeding germplasm, and are not included in rutinary surveys for practical reasons. This is the case of *Lr12* and *Lr13* (Table 4). There are races with combined virulence to both, *Lr12* and *Lr13*, races virulent to only *Lr*12 or *Lr*13, and races which are polymorphic for virulence to these genes.

Table 4: Reaction of different leaf rust isolates on lines with APR gene *Lr*12 and *Lr*13

Prt code*	No aisl	*TcLr12*	*TcLr13*
LCG-10	4	R**	S
MBG-10	2	S	S
MBR-10	1	S	R
MCG-10	1	R	S
MCR-10	4	S	R
	2	S	S
MFB-10,20	1	S	S
	1	R	S
MFR	2	S	R
	1	S	MRMS
TDD-10,20	3	S	S
	1	S	MRMS

* Long and Kolmer. 1989

** R: resistant. MR: moderately resistant. MS: moderately susceptible. S: susceptible

THE HOST-PATHOGEN INTERACTION

Since the pathogen population is highly variable and dynamic, lines with partial resistance, or genes isolated in single gene lines (as *Lr46*) should be tested to different to different pathogen populations and/or races with different virulence combinations, to assess race-specificity, since the pathogen may adapt to some of the components (Broers, 1989).

The two characteristics of the pathogen population (few prevalent races and dynamic population) have two implications in the identification and selection for partial resistance:

1. The pathogen population should be surveyed yearly.
2. Field data, compared to seedling infection type to the most prevalent races gives information about the presence of APR in wheat lines susceptible at the seedling stage to these races. If the prevalent races are also virulence to mayor APR genes commonly present in the germplasm, the APR identified is caused by other different genes, possibly conferring partial resistance (Table 5).

MCR-10 and MFR were the two most prevalent races in 1995. Little Club was used as the susceptible check. Virulence levels to *Lr12* is high since Tc*Lr12* does not express any resistance under field conditions, but may condition resistance in some lines, in combination with other mayor genes . Virulence to *Lr13* was probably intermediate, since this gene expressed intermediate resistance in field tests, and may be contributing to resistance in some of the lines with APR. In fact, *Lr13* is present in E. Cardenal, I. Boyero and probably MEC 6528.

Table 5. Seedling infection type to two leaf rust races and field reaction of some wheat cultivars and lines. La Estanzuela, 1995.

	Seedling infection type to leaf rust isolate		
Wheat line	**MCR-10**	**MFR**	**Field reaction**
Little Club	3*	33+	90**S*
LE 2210	0;	1-;	0
E.Halcon	2-cn	0;	40 MS
E.Cardenal	23-	3-	30 S
I.Boyero	2-;	32	T M
MEC 6528	3=	3=	2 M
LE2221	3	3	0
TcLr12	-	-	80 S
TcLr13	3	33+	30 MS
TcLr34	2-3	3+2	40 MS

* Stakman *et al.*, 1960

** Modified Cobb scale. Peterson *et al.*, 1948.

The comparison of these two sets of data allows different conclusions relative to considering only field data. Field infection of E. Halcón, E. Cardenal and Tc*Lr34* were similar. However, they are the result of very different resistance. E. Halcón's field resistance is due to the seedling gene *Lr16*; E. Cardenal has *Lr13 which*, and of course, Tc*Lr34*, carries *Lr34*. Careful observation allows to see some necrotic tissue around the pustules in the case of *Lr16* and *Lr13*.

No information about the presence of APR resistance can be derived for materials resistant in the seedling stage to prevalent races (LE 2210). Other cultivars or lines with susceptible seedling infection type had very low leaf rust infection in field tests, indicating they carry APR. Higher resistance than that conferred by *Lr13* probably indicates the presence of additional APR resistance in I. Boyero (confirmed by genetic studies), MEC 6528 and LE 2221. The use of isolates with virulence to *Lr13* in addition to the seedling resistance, should provide stronger evidence for the presence of other APR genes.

The effect of the resistance on components of partial resistance may be assessed to further characterize the resistance, but the ultimate proof of its nature has to be determined by genetic studies. Once appropriate sources of resistance have been determined, and different genes identified in different wheat lines, these can be crossed with highly productive cultivars, and the resistance selected, provided the appropriate races of the pathogen are available.

Other practical considerations in field tests and evaluation of partial resistance were reviewed by Shaner (1996):

- How to evaluate to evaluate partial resistance
- Maturity: it is difficult to compare the level of slow rusting in materials of different maturity, therefore, susceptible checks with different maturity types should be included if available.
- Interplot interference.

In summary, the steps to be followed to breed for partial resistance could be:

- Identification of accessions with partial resistance
- Inheritance studies (number of genes involved, gene action)
- Isolation of genes if possible (backcrossed lines or chromosome substitution lines)
- Characterization of the resistance, to diverse pathogen populations or components, under different environmental conditions
- Use the resistance for breeding purposes, considering it is inherited oligogenically, genes have small additive effects and variable expression under different environments
- For selection consider using the appropriate races of the pathogen to test it, considering seedling hypersensitive genes present, and checks with different maturity.
- **Maintain genetic diversity, within partial resistance or combinations of partial resistance with selected race specific genes since the pathogen may adapt to some of the components.**

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MOLECULAR MARKERS: HOW CAN THEY HELP OAT BREEDERS?

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Plant breeders have traditionally selected plant variability based on phenotype. This has been successful for high heritable traits, but not necessarily for traits of low heritability. Because many of the important traits for breeding are of quantitative nature, breeders have used progeny tests or advanced line selection to partially overcome the difficulties of selection. These, however, have not decreased genotype x environment interaction effects. Because the phenotype is the expression of a genotype under a specific environmental condition, it can change. To work with the phenotype is like to work with a moving target across environments. One way to avoid this would be to impose selection on the genotype, which would not be dependable on the environment. Although this may seem difficult, with the new molecular marker technologies, breeders have now the instruments to reach and select genetic variability at the DNA level. The objective of this paper is to present the main types of DNA markers available and their particularities, and to discuss how can they help oat breeders.

There are many types of DNA markers available now and they all differ for their ability to detect polymorphism, cost, easiness of use, consistency and reproducibility. While RFLP markers have been used for comparative mapping studies because of their consistency, these tend to be more expensive and are not so easy to use in a breeding program. On the other hand, PCR markers, specially RAPDs, are easy to handle and less expensive, although are not as reproducible. Other markers as microsatelites and AFLP reveal more polymorphisms and have become the best option for species were polymorphism is limited. Because many aspects are involved in choosing the type of DNA marker to use, there is not one kind that can be considered superior in all aspects. For this reason, breeders should look for the options available before deciding which one to use.

There is much information in the literature as how breeders may use markers in their breeding programs (Lee, 1995). These include in general to monitor and organize genetic variability, for marker assisted selection and for variety protection. These applications, of course, will not have the same importance in all plant species, because the mode of reproduction, traits of interest, value of the selection unit, breeding status and other pertinent aspects differ greatly from one species to the other. So, oat breeders have to identify traits of interest and clear objectives before they ask: what can I do with DNA markers?

The answer for the question "how can markers help oat breeders?" may be answered with some other questions as: 1) Will indirect selection using DNA markers lead to higher genetic gain? 2) Will the equation [time saved x (1/cost of selection) x efficiency] give a significantly higher number by using markers instead of plant phenotype as the selection criteria? 3) Are we exploring properly the genes from the oat wild relatives? 4) Do we know enough about the most important oat traits we deal with so breeding strategies for best genetic gains can be drawn from our current knowledge? 5) Are we content with the time spent and the efficiency to release new competitive varieties?

Predictions and answers for these questions are hard to get because they will vary with the breeding reality and the status of the oat breeding program. However, it is important to keep in mind what is the status of markers in oat. Certainly, the construction of the hexaploid oat map (O'Donoughue *et al.*, 1995), a very ambitious project financed mainly by Quaker Oats and undertaken by five groups from USA and Canada, was a big step for oat in the world of markers. Many important genes have been placed on this map or associated to molecular markers since then. The list includes the Pg9 and Pg13 genes for stem rust resistance (O'Donoughue et al, 1997); Pc38, Pc39, Pc68, Pc91 and Pc92 genes for crown rust resistance (Penner *et al.*, 1993; Rooney *et al.*, 1994); height genes (Milach *et al.*, 1997), grain quality genes (Kianian *et al.*, 1996) and other agronomic traits (Siripoonwwiwat *et al.*, 1996). Other important genes have been, are and will probably be associated to markers and traits of interest in oat in the near future. But marker assisted selection may not contribute to oat breeding programs very soon. Meanwhile, our understanding of complex traits is improving and breeders are indirectly benefiting from this. At the Federal University of Rio Grande do Sul, we have started working on mapping slow rusting resistance in oat. Two mapping populations were made from crosses between slow rusting and susceptible genotypes; DNA is being extracted and phenotypic scoring is underway. Mapping will be done using AFLP and RAPD markers. The main objective of this project at the moment is to answer important questions about partial resistance in oat, as if it is race-specific or not; if there are genomic regions which have major contribution to this trait and have stable expression over environments. The answers for these questions will help us to plan the strategies to obtain crown rust resistance which may be more durable.

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WHAT OAT BREEDERS REALLY NEED FROM BIOTECHNOLOGY

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My purpose today is to help the breeders in the audience to answer the question posed in the title. To do so I suggest you rephrase the question as follows. If only I could do ________; then suggest you engage your biotech colleagues to determine the interface or intersection between your needs and what biotechnology has to offer in the way of tools to better do the job of crop improvement.

Secondly, engage your colleagues in dialog to learn about information generated by biotechnology in its various forms which will give you greater insight into more efficient modification/ improvement of crop plants, specifically for this group -- oats. I also challenge you to do these considerations using not only current paradigms, but also imagine again what new paradigm possibilities there could be if some of the answers you gave above were turned into reality.

According to Sorrells and Wilson (1997), breeding progress depends on (i) discovery and generation of genetic variation for agronomic traits and (ii) accurate selection of rare genotypes that possess new or improved attributes due to superior combinations of alleles at multiple loci, or simply stated (1) genetic variability and (2) selection applied on the phenotypic expression of that variability to advance the more desired genotypes.

Regarding the discovery and generation of genetic variability, several things come to mind. First, the new variation should be directed, not random. That direction may be accomplished by (1) the use of specific donor genes to either fix a broken situation or enhance a suboptimal one. Another possibility (2) is to modify an existing gene to produce a better genotype and then phenotype. Further, there are some gene products that when eliminated by (3) gene suppression might result in a more useful phenotype. Also, as we learn more about specific loci interaction we may be able (4) to custom design new gene combinations that as a composite produce an improved genotype/phenotype. All of these examples could be accomplished with sexual recombination, albeit in a mostly random fashion.

With the advances in genetic engineering that Sandra discussed earlier, successful transformation essentially allows access to any source of genes which could accomplish any of the first four items. We might first look to species and genera whose genomes share many DNA segments or base sequences with oats. However, we probably should also look beyond these relatively closely aligned genomes to any organism which contains a gene which could modify the phenotype in a desired manner. Especially as these transfers bridge wider evolutionary distances, isolating the gene of interest and transferring it with a maximum expression potential will increase breeding efficiency. When there is suboptimum expression, using promoters which provide for tissue specific expression may effectively enhance the expression of the desired trait.

The other major consideration regarding using genetic engineering to achieve directed or non random variability is the cost/benefit ratio. Because the biotechnology will probably be more costly than conventional procedures, the benefits must be proportionately greater to compensate for the increased inputs. Part of the cost consideration includes minimizing the selectivity of genotypes on which the new technology can be effectively used. Said another way, novel processes which work only on a limited number of genotypes have reduced attractiveness and actually work at cross purposes with expanding genetic variability.

Moving to the second point (selection) from Sorrells and Wilson (1997), it can be summed to say increasing the heritability so that the phenotype better predicts the actual genotype. Remember the simple equation P=G+E+GE. We want to highlight the G term because improvement comes from retaining and increasing the frequency of better genotypes. Using genetic engineering to intensify the genetic control of the trait will also elevate the value of G.

For improving selection, the goal is to use better evaluation methods which more effectively identify the actual genotype by relatively reducing the E and the GE components of the above equation. A better understanding of how the genes within a genotype act singly and, in combination, to produce a given phenotype will obviously contribute to more effective selections, as well as the construction of new directed gene combinations.

Molecular markers, pieces of DNA, whose sequence composition is not influenced by the environment in which they exist either directly (the E term) or indirectly (the GE term) increase the capacity for more precise prediction of a genotype than are predictions based only on phenotypic observations. Such identification of superior genotypes provides for the continued improved phenotypic expression.

Another useful feature of markers is the ability to detect heterozygotes when the markers are codominant. Fixing a favorable dominant allele can be done in one generation.

Marker Assisted Selection (MAS) is obviously most useful when the marker trait association exists in many populations. If the marker trait associations are unique for individual populations, then the investment necessary to determine the relationships for each breeding population is probably not justified in most breeding situations.

Assuming multiple population associations, those having either tight or flanked linkages can be used to track subtle or minor genes once identified. In other words, QTLs can be manipulated as though they were major qualitative loci.

Finally, it may be that using MAS for parent rather than progeny selection will be more cost effective since 100 molecular analyses may be manageable while 5,000 to 20,000 may not be.

The other item beyond tools which plant breeders can use from biotechnology is information. Much of this information could come from what I call genetic dissection. This information would tie directly to the directed variability and to the increased heritability both discussed earlier. Pairs of NILs could assist in estimating the size of each locus effect. Currently, when analyzing quantitative data we assume equal sizes of locus effects that make the mathematics manageable even though we use terminology of major and minor genes.

Secondly, multiple pairs of NILs could allow detection and estimation of various forms of epistasis in other than aggregated statistical terms such as AXA, AXD, and DXD. That information would facilitate design of selected new gene combinations which as a composite would produce new phenotypes.

In conclusion, biotechnology has the potential to assist plant breeders by facilitating directing the creation of desired variability and secondly by providing tools to increase the connection between the observed phenotype and the actual genotype which produced that phenotype. That connection is heritability. It will also allow differentiating genotypes among individuals with similar phenotypes to increase the chance of exploiting transgressive segregation. The fundamental question to be asked to identify these tools won't change, but the answer, the tools and therefore the paradigms will change as we learn more over time. Keep an open mind!

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FEDERAL UNIVERSITY OF RIO GRANDE DO SUL OAT BREEDING PROGRAM

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INTRODUCTION

The importance of oat as a crop in Southern Brazil is increasing every year. The agriculture in that region is based on two crops per year, and the summer crop is economically more important. On the other hand it is important for Brazilian farmers to have a profitable winter crop. Wheat has been the main cold season crop but oat becoming an important alternative, specially as the no-till system increases. Besides being destined to human and animal feeding, oat is an excellent cover crop.

To establish oat as a crop was crucial to develop genotypes widely adapted to different regions of Southern Brazil. In this way, in 1974 the Plantas de Lavoura Department of Federal University of Rio Grande do Sul (UFRGS) started its oat breeding program. By then, Dr. Fernando Carvalho received a collection of pure lines and segregating populations from Dr. Shands from Wisconsin University. Until that moment the varieties used in Brazil were introductions from USA or Argentine.

GERMPLASM

The germplasm used in UFRGS oat breeding program is based on that of Quaker Oat International Nursery, coordinated by Texas A&M and Wisconsin Universities. The contract with that program started in 1976 and every year new pure lines and F2 or F3 segregating populations were introduced. More recently, germplasm exchange has been made with other research institutions as the ones from South (Adelaide) and West (Perth) Australia, University of Minnesota (USA) and Guelph and Winnipeg Universities (Canada).

OBJECTIVES

Oat varieties used in Brazil before 1980 were tall, late maturity and not well adapted. The UFRGS oat breeding program main objective is to develop high grain yield and grain quality varieties with wide adaptation to the Southern Brazil environments. The program has obtained short height oat genotypes, with less than 100 cm e good lodging resistance. The UFRGS breeding program has made available oat varieties with 140 days cycle, which allowed farmers to grow two crops per year, including oat in the rotation system. This was an important achievement since old oat germplasm available in Brazil used to have 180 days cycle. Earliness is becoming even more important as some farmers are getting interested in cultivating three crops per year.

Serious damages have been caused to oat crop in the Southern Brazil by diseases, where springs are wet and hot. Crown and steam rusts are the main diseases, caused by *Puccinia graminis* f. sp. *avenae* and *Puccinia graminis* f. sp. *avenae*, respectively. Others diseases as that caused by *Dreschlera avenae* and *Bipolaris sorokiniana* have increased their importance because of the no-till system adopted by farmers. Rust epidemics are very severe in Southern Brazil and rust resistance of oat varieties are not durable. A resistant variety remain so by periods of less than 5 or 6 years. New strategies to obtain durable rust resistance are now been studied in the program.

The UFRGS oat breeding program is concerned to develop genotypes with cold resistance, hence frost damage is more dramatic in higher altitude, besides the potential expansion of cultivation to southern areas in Argentine and Uruguay.

In addition to high grain yield, selection to oat grain physical quality has been an important goal in the oat breeding program. Strong selection has been made for test weight and visual grain appearance. Selection for oat grain chemical quality has not been made because of the difficulties and cost of analyses for the breeding routine.

HYBRIDIZATIONS

In recent years artificial hybridizations made by the UFRGS oat breeding program have increased in number. The parental genotypes are organized in four gene pools and are conducted in two ways: 1) for germplasm development (future parent genotypes); 2) for variety development. The composition of the pools are: 1) Pool "A" - elite genotypes with excellent adaptation to target environments. Crosses made to release new varieties in general involve pool "A" genotypes. 2) Pool "B" - genotypes with good adaptation carrying genes of interest like short height, early cycle, disease resistance and good grain quality. Genotypes from Pool "B" are preferentially crossed with pool "A" genotypes. 3) Pool "C" - pure lines introductions. These introductions are of great interest, specially as gene sources for desirable traits. Simple and fast tests are conduct to eliminate most part of genotypes introduced every years. Hybridizations to pool "A" are made to transfer desirable traits to adapted genotypes. 4) Pool "D" - segregating populations which may eventually be used in crosses, specially to get better agronomic traits. The UFRGS oat breeding program has focused on simple crosses between complementary parents.

BREEDING METHOD

A modified pedigree method has been used in the UFRGS oat breeding program. Progenies are sown at normal density of cultivation to allow competition among plants and selection of more competitive ones. Instead of individual plant selection, the best rows are selected and the best four to eight panicles are chose within them. Each selected panicle will originate a new row next year, allowing to follow the population changes for desirable traits.

SELECTION CRITERIA

Genotypes are compared to check varieties and the selection is practiced in four different plant developmental stages: 1) around 40 days after emergency (plants with 6 or 7 expanded leaves) selection is for high vigor and apparent phytomass; 2) during the milk-stage grain selection is for height within rows with high vigor and phytomass; 3) on physiological maturity selection is practiced for general plant type, disease resistance and general fertility and grain quality; 4) in the laboratory grains from each selected panicle are visually analyzed comparing within population and with check genotypes. Screening is made for larger grain size and general visual grain quality.

As grain quality is essential for the industry, the UFRGS oat breeding program is conducting the first studies of physical grain quality through digital image analysis. Images are captured by a video camera and traits like area, length, width and grain shape factor are analyzed. The goal is to elect those traits that better correlate to characters related to trade value like test weight, groat percentage and milling yield.

Selection for resistant genotypes, specially to crown rust, has been very important. This trait has been easily selected when resistance is controlled by major genes. Nevertheless, resistance from these genes has been overcome by the pathogen in a short time. In fact, the UFRGS oat breeding program is working on selecting genotypes with more durable resistance. Particular attention has been paid on early telia and partial resistance. On partial resistance, we are studying traits that may be used as selection criteria in the breeding routine. However, analysis like area under progress disease, pustule size, number of spores per pustule and infected leaf area are still extremely laborious to perform. So digital image analysis is been used to identify partial resistant genotypes, but it is still not been used in the breeding routine.

PERSPECTIVES

Oat grain yield potential may be considered high in Southern Brazil. Farmers using high technology have reached yields of 3,000 to 4,000 kg/ha. According to Federizzi *et al.* (1997) oat grain yield have been increased 28 kg/ha/year or 1.1% /year in the last 15 years, whereas the check varieties have increased 78.55 kg/ha/year or 4.33%/year at the same time. Because the check varieties have been the top yield ones, it has been a difficult task to select new lines that have higher yield potential, besides having high grain quality, short stature, earliness, lodging resistance, cold and disease resistance.

New techniques that allow more precise selection of traits that are difficult to screen may increase efficiency of oat breeding, as the use of image analysis for selection of grain quality and more durable disease resistance. Biotechnology may take an important place in this context. Techniques like plant transformation may not have great impact in next few years, because of the wide genetic diversity of oats, except for some special characters. Marker assisted selection may help breeders in selecting quantitative traits as partial resistance to oat crown rust and to pyramid major genes for disease resistance. In the other hand, the availability of this technique will depend on the gene mapping for agronomic traits in adapted populations.

To obtain crown rust partial resistant genotypes, in general controlled by many genes which low phenotypic effect, it will probably be necessary to use other breeding method to conduct the segregating populations. The SSD method may contribute to select genotypes with partial resistance, by screening pure lines with better adaptation.

In 1996, the area cultivated with oat in Rio Grande do Sul was about 400,000 ha and there is potential to expand it. However, trading oat grain is not easy, as it is mainly for human consumption or to race horse feeding. On the other hand, milk producing farmers may use oat grain or ensilage for feeding cattle. Besides that, these farmers are interested in early oat varieties, so they can harvest oat and sow corn in the beginning of spring.

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OAT BREEDING IN ENTRE RIOS

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ABSTRACT

Since 1986 the Cooperativa Agrária is developing oat research. But only since 1995, oat crossings have been made. This paper was written to describe the oat breeding program conducted at this location. The priorities are grain yield, straw strength, test weight, frost tolerance, resistance to diseases. The pedigree method is used during inbreeding. When the homozygosity is reached, test lines are bulk harvested. Lines that have performed well in the replicated preliminary trial can be proposed to multi-location replicated elite tests. After evaluation, the lines can be suggested and approved as a new oat cultivar. Not only the number of matings of this program was increased, but also the seed set has improved. Although some lines took part in the multi-location replicated elite tests, none of these lines have become a cultivar so far. Thus the challenge of releasing an improved oat cultivar in the future, still remains.

INTRODUCTION

Since 1986 the Cooperativa Agrária Mista Entre Rios is taking part in the program "Breeding Oats Cultivars Suitable for Production in Developing Countries". Pure lines have being evaluated and segregating populations have being conducted using the pedigree method. Since 1995, oat crossings have been made at this location. The objective of this paper is to briefly describe the Oat Breeding Program, conducted at FAPA (Fundação Agrária de Pesquisa Agropecuária) in the State of Paraná, South Brazil.

MATERIAL AND METHODS

Grain yield, straw strength, test weight, frost tolerance, resistance to crown rust, and to oat helminthosporiose are the top-priorities of this program.

Selection of parents

Cultivars and oat lines selected as parents, that were used in the 1995, 1996 and 1997 hybridizations are presented in Table 1. These parents were selected based on the objectives of the program. According to Forsberg, 1994, it is essential that the breeder knows the agronomic performance and disease reactions of the breeding stocks, so that parental combinations are based on intelligent decisions and provide reasonable chances for breeding success.

Table 1. Oat lines and cultivars used as parents in the 1995, 1996 and 1997 hybridizations. FAPA, Entre Rios, Guarapuava, PR, Brazil, 1997.

1995		1996		1997	
Lines	Cultivars	Lines	Cultivars	Lines	Cultivars
ER 87253-1 †	CTC - 5 #	ER 87253-1	CTC - 5	ER 88144-1	Entre Rios
ER 88144-1	UPF - 15 ††	ER 88144-1	UPF - 15	ER 20926-5-2-2	CTC - 5
IER 88198 ‡	UPF - 16	IER 88198	UPF - 16	ER 90148-2-1-1	UPF - 15
ER 89144-1-3	UFRGS-14	ER 89144-1-3	UFRGS-14	ER 92130-2-1-1	UPF - 16
HS 89007-1 §	UFRGS-15	NC-Dwarf-Dw-7 ‡‡	UFRGS-15	ER 92148-2-3-1	UFRGS-15
UFRGS-884068 ¶		Dw-8 ‡‡	UFRGS-17	ER 93247-2	UFRGS-17
UFRGS 901717			UFRGS-18	IER 95006	UFRGS-18
			Echidna ‡‡	UPF- 86243-1	Echidna
				UFRGS-911740	
				UFRGS-93572	
				UFRGS-93598-4	
				NC-Dwarf-Dw-7	
				Dw-8	
				ERCV96 §§	

† Segregating lines derived from Quaker segregates. ‡ Pure lines derived from Quaker Nursery. § Pure line from Germany. ¶ Lines and cultivars from the Universidade Federal do Rio Grande do Sul. # Cultivar from Cotrijuí. †† Lines and cultivars from the Universidade de Passo Fundo. ‡‡ Dwarf lines. §§ Segregating lines derived from FAPA 96 crosses.

Population formation

Due to the large number of parents and consequently large number of crossings that would be necessary in a complete diallel, the mating procedure preferred is the partial diallel mating design. An advantage of this procedure is the flexibility in terms of the number of matings that can be accomplished within a season. If the breeder has enough available time or can count on the help of another person, and a wide range of flowering time opportunities, he or she can make a larger number of matings. On the contrary, with less time or no help and with a short range of flowering opportunities, the breeder can still make matings, though fewer, without feeling frustrated. The approach-crossing method has been used in making these crosses inside a greenhouse.

Inbreeding and selection among progenies

In order to increase germination, F1 seeds have to have their dormancy reduced. F1 plants have been grown off-season, during the summer time, in a shadow protected place. In order to do that, initially the seed hull has to be removed. After being treated with fungicide, individual entries of F1 seeds are stored in a high moisture and cold environment (refrigerator) for seven days. After one day at normal environmental conditions, F1 seedlings are ready to be transferred to the pots. In the following season, FAPA F2 seeds are space planted in the field, along with the checks and with the Quaker segregating population. Since the 1997 season, F2 plants are also grown inside the greenhouse, in order to take part as parents in the crosses. The pedigree method is used during inbreeding. The selection begins in the F2 population for traits like early maturity, plant height and disease resistance. The selection pressure exerted in the F2 and later generations within a year depends on the environment conditions and time available for selection. All field selected panicles are individually threshed and go through a visual lab selection. Seeds are inspected for quality traits like hull and groat color, and the presence of strong awns. Some are discarded, and a few individual progeny rows are grown in the next season. When the homozygosity is reached, the F6, F7 or F8 head rows of the test lines are bulk harvested. Before test lines go to the expensive replicated preliminary trials, they are evaluated in an observation nursery. These nurseries are used to compare test lines with the currently grown cultivars (checks) and to increase the seed amount.

Replicated testing

Test lines conducted in the observation nursery, that are similar or better than the checks, in terms of grain yield and agronomic type, are then promoted to the replicated preliminary trial. Any test line that has performed well in this trial and that has been superior to the checks, can be proposed to the Brazilian Oat Research Commission to take part in the multi-location replicated elite tests. The best lines from different programs are evaluated together on several locations in these elite trials. After three years of evaluation, the lines which yield five per cent more than the best checks can be suggested and finally approved as a new oat cultivar.

RESULTS AND DISCUSSION

Number of matings and average seed set percentage accomplished at FAPA, during the years of 1995, 1996 and 1997 is presented in Table 2. According to Brown and Forsberg, 1987, an experienced hybridist working under near-optimum conditions should expect at least 25 % seed set in the field and 50 % in the greenhouse. Considering this information, the work done during these three years obtained satisfactory results. Not only the number of matings was increased, but also the seed set has improved along the three years. Planting parent lines in at least four different planting periods and making the crosses until no later than the end of October (cooler temperatures are more appropriate), are the practical procedures learned along the years in order to get the best results. There have been 5794 segregating progeny rows evaluated during the 1989-1997 period, including Quaker, UFRGS, and FAPA segregates (Table 3). After the homozygous lines were evaluated at the replicated preliminary trials, 11 best lines took part in the multi-location replicated elite tests (Table 4). However, none of these lines have become a cultivar so far. In conclusion, the FAPA Oat Breeding Program has been facing a new challenge in the past three years. It is developing its own breeding stock, which may originate an improved oat cultivar in the future. Furthermore, FAPA is looking forward to using this germplasm, and its own facilities, in a cooperative work among institutions in order to make the Brazilian oat research more interactive and efficient.

Table 2. Number of matings and average seed set percentage accomplished at FAPA, during the years of 1995, 1996 and 1997. FAPA, Entre Rios, Guarapuava, PR, Brazil, 1997.

	1995	1996	1997 †	Total
Number of matings	20	34	30	84
Average seed set (%)	43.6	45.8	76.6	55.3

† Done until October 6, 1997.

Table 3. Segregating populations conducted at FAPA during the period 1989 to 1997. FAPA, Entre Rios, Guarapuava, PR, Brazil, 1997.

Year	Generations							Total
	F2	F3	F4	F5	F6	F7	F8	
1989	-	100	197	121	-	-	-	418
1990	-	90	221	177	112	-	-	600
1991	-	100	123	108	40	20	-	391
1992	121	70	49	14	64	-	-	323
1993	-	642	275	92	60	126	-	1 195
1994	83	155	208	139	21	26	40	672
1995	36	154	222	182	-	222	-	816
1996	73	147	106	294	82	1	-	703
1997	34	128	189	192	125	8	-	676
Total	347	1 586	1 590	1 324	504	403	40	5 794

Table 4. Frequency of the ER and IER lines at the oat multi-location replicated elite tests. FAPA, Entre Rios, Guarapuava, PR, Brazil, 1997.

Year	Regional trial	South Brazilian trial
1989	-	-
1990	-	-
1991	4	-
1992	1	-
1993	-	1
1994	2	1
1995	3	-
1996	1	3
1997	-	1
Total	11	6

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OAT GENETIC IMPROVEMENT FOR ALUMINUM TOLERANCE

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ABSTRACT

An oat breeding project to improve the crop's aluminum tolerance has been carried out at the University of Passo Fundo since 1986. From 1986 to 1994, the experiments were conducted in a field having aluminum values varying from 3,8 to 4,5 meq/100 ml of soil. Ten oat genotypes tolerant to aluminum and many promising segregating populations were selected. From 1988 to 1993, growth chamber trials for evaluation of oat genotypes were conducted for 11 days in nutrient solutions. The Al level used to screen known tolerant oat genotypes, 156 other white oat (*Avena sativa* L.) genotypes, and 14 black oats (*A. strigosa* Schreb) was a concentration threshold of Al of 7,5 mg/liter in solution, previously found not to seriously damage tolerant oats. It was concluded that the white oat group showed a high variability for Al reaction, and was less tolerant than the black oat group. The white oat genotype UPF 82079 (1563 CRcpx/C75-12/SR cpx), UPF77394-1 (Auto Tetraploid Saia), UFRGS 6 (Unknown), UPF86006 (79 Barrow seln.), UPF81360 (MN1107/Dal), UPF86160 (Coker 62-26/EEA10//X2503/X2299), UPF86112 (Steele), UPF81359 (MN5320/diamante), UPF 2 (X2505-4), introduced from the Quaker Nursery, showed the best tolerance and responsiveness over Al levels up to 15,0 mg/liter. Both might be useful in breeding Al-tolerant oat cultivars. Another future objective of this research is to study the physiological causes of Al tolerance in oat genotypes.

INTRODUCTION

Acid soils are found extensively throughout the South Brazilian regions where oat is cultivated. Aluminum toxicity is a growth-limiting factor for crop production in these areas. The toxicity can be prevented by liming to raise soil pH to 5,5 - 6,0, or to grow cultivars that have greater tolerance to Al. However, the Al tolerance of Brazilian oat cultivars and oat germplasm collections was not known. At the First South America Oat Congress was presented de results of oat tolerant genotypes selected in the field trials. This paper presents the results obtained from trials conducted in growth chamber. The main goal of this work, carried out at ESALQ/USP, Piracicaba, SP, was to study the responses of white (*Avena sativa* L.) and black oat (*A. strigosa* Schreb.) genotypes to various levels of aluminum in nutrient solution. This study was undertaken to select tolerant genotypes, as well as to study the possible causes of nutritional and physiological effects of the aluminum toxicity. The main results from field trials were presented at the First South American Oat Congress (Floss *et al.* 1991).

MATERIALS AND METHODS

The following oat genotypes were grown for 11 days in nutrient solutions (Furlani and Hanna, 1984) in a growth chamber at 25 °C. The level of Al in nutrient solution suitable for selection of Al-tolerant oat genotypes was determined (7,5 mg/liter), and 156 white oat genotypes and 14 black oat accessions were screened for tolerance. The main parameter evaluated was seminal root growth (SRG); those values were correlated with other parameters of root growth and with dry matter (DM) yield. Two tolerant white oat cultivars (UPF82079 and UPF86AL169-2b) and the most tolerant black oat genotype (UPF77434) were compared with two sensitive oat genotypes (UPF 7 and UPF79239-1) over 21 days for their reactions in nutrient solutions containing 0, 5, 10, 15 and 20 mg Al/liter.

RESULTS AND DISCUSSION

As previously mentioned, the concentration threshold of Al in nutrient solution was found to be 7,5 mg/liter for Al-tolerant oat genotypes. This level promoted a reduction of 50% in the SRG of the most sensitive genotypes. Initial seminal root length (ISRL) did not correlate significantly with SRG, relative seminal root growth (RSRG), length of seminal root (LSR) or relative length of seminal root (RLSR); however, sometimes the ISRL correlated with LSR. SRG showed highly significant correlations with RSRG, LSR and RLSR (Table 1). The SRG showed better correlations with DM yield for the whole plant (PDM, r = 39,18**) and shoots (SDM, r = 38,96**) and lower correlations with DM root yield (RDM, r = 30,73**) and relative root (DM - RRDM, r = 35,15**). The best correlations were observed with SRG and the relative shoot (DM - RSDM, r = 56,31**) and relative whole plant (DM - RPDM, r = 59,3**).

Table 1 - Linear correlation coefficients for various traits in oat genotypes growth in a nutrient solution containing 7,5 mg Al/liter

	RSRG	LSR	RLSR	ISRL	PDM	SDM	RDM	RRDM	RSDM	RPDM
SRG	64,6**	94,1**	65,7**	ns	39,1**	39,9**	30,7**	35,1**	56,3**	59,3**
RSRG	-	67,0**	98,5**	ns	66,6**	64,7**	55,4**	44,2**	77,3**	81,2**
LSR	-	-	63,2**	30,3**	38,4**	38,2**	30,0**	32,8**	54,2**	56,5**
RLSR	-	-	-	ns	66,7**	65,2**	54,9**	42,1**	76,6**	79,5**

** significant at the 1% probability level.

At the 7,5 mg Al/liter concentration, the white oat genotypes UPF82079 (1563CRcpx/C7512/SRcpx), UPF86Al198-5-4b (QR336=X2051-6/X1913-3/3/DC9/Coker74C17/OTEE), UPF3 (Coronado/X1779-2), UFRGS 6 (Unknown), UPF86Al068 (C5-2, 1563 CR cpx/T312/Srcpx), UFRGS 1 (DAL/CDA 292), UFRGS 4 (DAL/CDA 292), UPF 15 (QR306=COKER82-33//IL3376/OA338), UPF86120 (COKER 85A85), UPF84297 (X2051/X2670//X2300/ X2682/3/CORON/BCLA), UPF84125 (X2795/X2682/2/C62-26/3/C62-26), UPF87070 (OT224/W78181), UPF84321 (CORON/BCLA//PA7804), UPF87128 (X2795-2/X2682-3/COKER 62-26 2), CTC 1 (BCLA/COKER234//RLE83), UPF79302 (X2681-1/(74C17/X2888-2), CTC84412-3 and UPF79159 734470-2/CI8360), showed tolerance (SRG) and responsiveness (RSRG). The line UPF86AL169-2b (QR305=Coker 82-33//C5-2, 1563CRcpx/SRcpx) showed tolerance but not responsiveness. The genotypes UPF82079 (1563CRcpx/C7512/SRcpx), UPF77394-1 (Auto-Tetraploid Saia), UFRGS 6 (Unknown), UPF86006 (79 Barrow Seln.), UPF81360 (MN1107/DAL), UPF86160 (COKER 62-26/EEA10//X2503/X2299), UPF86112 (Steele), UPF81359 (MN320/Diamante) and UPF2 (X2505-4), showed tolerance by the relative tolerance index (RAITI) at the level of 15 mg Al/liter.

The black oat genotypes UPF77434 (CD3820), UPF84AP01 (Unknown), UPF77066 (PI244471), UPF77436 (CD7847-CI9035), Argentina Black Oat , UPF77352 (K2588/URSS), and UPF85AP01 (Unknown), were tolerant/responsive at the concentration of 30 mg Al/liter.

The length of seminal root (LSR) of the black oat genotypes were significantly higher than those of the most tolerant white oat genotypes (UPF 82079 and UPF 86 AL169-2b) only at the 15 and 20 mg Al/liter levels (Table 2). However, the black oat UPF 77434 the length of seminal root (LSR) was superior those of the sensitive white oat genotypes (UPF 7 and UPF 79239-1) at all levels of Al.

Table 2 - Effects of levels of aluminum in nutrient solution on the seminal root length of oat genotypes

Genotypes	Levels of Aluminum (mg/liter)				
	0	5	10	15	20
	cm				
BUPF 77434	40,4 a A	30,0 a B	26,8 a B	26,2 a B	25,3 a B
TWUPF 82079	34,6 a A	30,0 a A	21,3 a B	16,8 b B	14,0 b B
TWUPF 86AL169-2b	42,2 a A	27,6 ab B	19,0 a C	12,0 bc CD	8,6 b D
SWUPF 7	26,0 b A	19,5 bc A	9,9 b B	6,3 c B	6,1 b B
SWUPF 79239-1	39,2 a A	16,3 c B	9,1 b BC	7,7 c C	7,8 b C
Average	20,9				
C.V. Genotypes (%)	10,2				
C.V. Levels of Al (%)	16,7				

Means followed by the same letter, lower case in colluns and uppee case in rows, are not significantly different by Tukey's multiple range test (P<0,05), B= black oats; .TW =tolerant white oat; SW = sensitive white oat.

On the other hand, the black oat produced higher plant dry matter yield than Al-sensitive genotypes at all levels of Al, but did not differ from the dry mater yield of the white tolerant genotypes at the 5 mg concentration of Al/liter (Table 3).

Table 3: Effect of aluminum in nutrient solution on the plant dry matter (PDM) of oat genotypes

Genotypes	Levels of Aluminum (mg/liter) 0	5	10	15	20
			g		
BUPF 77434	3,1 c C	4,2 a AB	4,9 a A	3,7 a BC	3,8 a BC
TWUPF 82079	4,6 ab A	3,5 a B	3,0 b B	1,4 b C	1,1 bc C
TWUPF 86AL169-2b	5,2 a A	4,2 a B	2,8 b C	1,5 b D	1,4 b D
SUPF 79239-1	5,0 a A	2,1 b B	1,2 c C	0,6 c C	0,6 bc C
SUPF 7	3,96 bc A	2,1 b B	1,3 c BC	0,9 bc CD	0,5 c D
Average 2,7					
C.V. Genotypes(%) 4,1					
C.V. Level of Al (%) 12,7					

Means followed by the same letter, lower case in colluns and upper case in rows, are not significantly different by Tukey's multiple range test ($P<0.05$).

Better correlation of the length of seminal root (LSR) with shoot dry matter (SDM) and plant dry matter (PDM) than with root dry matter (RDM) were observed in this trial (Table 4).

Table 4 - Linear correlation coefficients (r) for various traits in oat genotypes growing in different Al levels in nutrient solution from (0, 5, 10, 15 and 20mgAl/liter)

	RLSR	RDM	RRDM	SDM	RSDM	PDM	RPDM
LSR	0.91**	0.83**	0.71**	0.87**	0.79**	0.87**	0.79**
RLSR	-	0.80**	0.73**	0.84**	0.77**	0.85**	0.77**
RDM	-	-	0.85**	0.90**	0.85**	0.93**	0.87**
RRDM	-	-	-	0.83**	0.94**	0.85**	0.96**
SDM	-	-	-	-	0.94**	1.00**	0.91**
RSDM	-	-	-	-	-	0.91**	1.00**
PDM	-	-	-	-	-	-	0.91**

** significant at the 1% probability level.

It was concluded that the white oat showed a high variability for reaction to Al toxicity, and was consistently less tolerant than the black oat. The white oat genotypes UPF82079 showed the best tolerance and responsiveness considering the Al levels used and might be used for breeding purposes.

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OAT BREEDING PROGRAM AT THE UNIVERSITY OF PASSO FUNDO

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ABSTRACT

The oat genetic breeding in development at the University of Passo Fundo has the objective to develop new genotypes with high adaptability to several regions of Southern Brazil. The goal of this paper is to comment the situation of the oat genetic breeding from 1995 until nowadays. The breeding method used is the genealogic. The crosses are made normally in growth chambers and the parents used are locally adapted germplasm. We have been obtaining about 48% in average of seed set. In 1995/96 were conducted 786 populations being selected 487 populations, being 3488 panicles and 126 uniform lines. The program has been growing principally for the crosses however, is each time more difficult to overcome the actual plateau yield for the last cultivar released like UPF16 and UPF17. These cultivars had shown excellent performance in grain yield and others characters, in all the trials and in farming level too.

INTRODUCTION

The oat genetic breeding in development at the University of Passo Fundo (UPF) since 1977, released 17 cultivars. Nowadays six are recommended for cultivation in several regions of Southern Brazil. The objective of the program is the development of new genotypes with high adaptability to the different regions of the country.

We showed in the Second South American Oat Congress, 1994, a regression analysis considering trials data from 1980 until 1993, that estimated the genetic gain in grain yield of oat at UPF program. The results displayed yield increase of 7% per year on average indicating that the oat breeding program had made continuous progress.

This paper has the objective to comment the situation of the oat genetic breeding from 1995 until nowadays.

MATERIAL AND METHODS

The breeding method used is the genealogic. The crosses are made normally in growth chambers and the parents used are locally adapted germplasm. In 1995 were made crosses with 19 differents parental combinations and in 1996 with 16 combinations. The technique used to cross consist in extracting the anthers from the primary floret after having discarded the secondary floret. The pollination was doing normally 3 days after emasculation, shaking the male panicle, with the top of the spikelets cut on the female panicle.

The selection in segregating material obtained from these crosses and from introducted populations from the Universities of Wisconsin, Minnesota and Texas A&M (U.S.A.), was done in order to obtain plants with early maturity, short plant height, compact panicle types and with resistance or tolerance to the most important diseases such as crown rust, stem rust and Barley Yellow Dwarf Virus. For the quantitative characters, the selection was done in preliminary tests, with 3 replication. In 1995, were evaluated 43 lines and in 1996, 88 lines. Besides this, the performance of the 200 pure lines from Quaker nursery introduced in 1995 (100 lines) and 1996 (100 lines) was studied.

RESULTS AND DISCUSSION

In relation of the crosses, it was obtained 48% in average of seed set. This percentage is the same that we have been obtaining since 1990.

The results of the selection are in the Table 1. In 1995 and 1996 were conducted 786 populations being selected 487 populations, being 3488 panicles and 126 uniform lines.

The evaluation of pure lines introduced in 1995, showed 5 distinction genotypes in grain yield and 6 lines in 1996 (Table 2).

Table 1. Populations conducted and number of panicles and uniforms lines selected in the respective populations in 1995 and 1996

Years	Populations Conducted	Populations Selected	Panicles Selected	Uniforms Lines Selected
1995	449	293	1993	68
1996	337	194	1495	58
Total	**786**	**487**	**3488**	**126**

Table 2. Distinction lines from Quaker nursery introduced in 1995 and 1996

Genotypes	Pedigree
UPF95S024	(C16 CRcpx/C75-12/SRcpx/74C8014) = 1987SA028
UPF95S033	Don/2/N569-42-51/Froker/3/ogle
UPF95S089	79 Bord./Kenya SR/TAMO 386//TAMO 386/833/87^{A}.S.37
UPF95S091	Coron^{2} / CTZ^{3}/ Pendek/ME1563/TAMO 386/T386^{2}/87AS.10
UPF95S100	A.S./ ME 1563
UPF96S047	TAMO386^{2}/87^{A}. S.37//Coron^{2}/Ctz/Pendek/NE563/TAMO386
UPF96S038	A.S./ 1563
UPF96S039	TX93B3567

The results of the preliminary test in 1995 showed that in total 43 lines, 4 lines (UPF 89181-2, UPF89167-6, UPF90H400-2 and UPF90VS154-2) were superior in grain yield of the best check, the cultivar UPF 16. In 1996, from the 88 lines, only 4 lines were better in yield grain when compared with the best check UPF 16, (UPF 92129-2, UPF951704, UPF91Al100-1-4-3 and UPF89H809-2). The genotypes were being evaluated in preliminary yield trials in this year, when 92 lines are been evaluated.

The oat breeding program at UPF has been growing principally for the crosses, however, is each time more difficult to overcome the actual plateau yield for the last cultivars released like UPF 16 and UPF 17. These cultivars had been shown in all the trials and in farming level too, excellent perfomance in grain yield and others agronomic characters.

The overall analysis about national oats cultivars trials made in 1996, showed that UPF 16 had 3505 kg/ha in average for the 5 environments at Rio Grande do Sul (RS) and 3703 kg/ha in average for the 10 environments at Santa Catarina (SC), Paraná (PR) and São Paulo (SP). For the UPF 17 the yield was 3997 kg/ha at RS and 3472 kg/ha for SC, PR and SP (Floss *et al.*, 1997).

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PRESENTE Y FUTURO DEL MEJORAMIENTO DE AVENA PARA GRANO EN LA EEA BORDENAVE

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Desde enero de 1995, me encuentro a cargo del CVT INTA-QUAKER. Durante este período se implementó por primera vez la siembra en conjunto de material de avena para grano; durante el invierno de 1995, se sembró un E.C.R. de Líneas Avanzadas, integrado con material proveniente de la EEA Bordenave, la Chacra Experimental de Barrow y la Universidad Federal de Río Grande Do Sul (UFRGS). El Vivero de Quaker, compuesto por 100 entradas homocigotas y 190 poblaciones segregantes en F2 y F3. Un Crossing-block compuesto por padres recurrentes adaptados a la zona de la EEA Bordenave y posibles fuentes de resistencia a royas. Un Screening Cono Sur, integrado con líneas de Bordenave, Chacra Experimental de Barrow y la UFRGS; material segregante entre F2 y F6 que se venía conduciendo. En la campaña 1996 se repite el E.C.R. de Líneas Avanzadas, el Vivero de Quaker y el resto del programa de mejoramiento.

Los años 1995 y 1996 se caracterizaron por escasas precipitaciones fluviales. En la presente campaña se siembra nuevamente un E.C.R. de Líneas Avanzadas Cono Sur Avena y un E.C.R. Preliminar; el Vivero de Quaker 1997 y material segregante; un Crossing-block con líneas resistentes a las nuevas razas de roya del tallo y de la hoja con padres recurrentes; líneas en SSD.

Este año se producen abundantes lluvias durante el ciclo, no sufriendo hasta este momento la falta de agua. El futuro lo veo como un gran desafío para los fitomejoradores de avena, no solo para grano sino también para doble propósito. Aunque este futuro nos encuentra mas organizados, con objetivos definidos y relacionados entre los mejoradores de los distintos centros de mejoramiento.

OAT BREEDING AT BARROW RESEARCH STATION

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ABSTRACT

In Argentina oat is grown in a large area, about 2 to 3 million hectares. It is used primarily as forage for cattle. In our country it is possible to obtain pasture, hay and grain. This is the reason why the sown of oats has increased in Argentina, while it is declining in the rest of the world (even though the harvested area showed a different behavior). Oat is a less profitable crop than wheat or barley, but it is planted because of its multipurposes.

The main objectives of the Barrow program are the development of new cultivars with higher yield potential (forage and/or grain), better adaptability to different regions, better grain quality, resistance to the most important diseases, such as crown rust (*Puccinia coronata* Cdo.), stem rust (*Puccinia graminis* f.sp.*avenae*), tolerance to aphids, tolerance to frost, etc. We know it is difficult to obtain a cultivar with all of this treats.

The program has an annual introduction of genetic material from the Universities of Wisconsin and Texas A & M (USA), trough the project "Breeding Oat Cultivars Suitable for Production in Developing Countries", and in 1994 we received some material (pure lines and segregating populations) from the University of Rio Grande do Sul (Brazil). Local selection has been made and crosses with adapted parents were made too. The entries from UFRGS with crown rust resistance and grain quality were used in crosses to improve grain yield.

The most important problem of oat crop are the rusts, crown rust in forage oats and stem rust in grain oats. Both of them cause high damage, lowering yields and quality.
Since 1993 to 1996 the presence of stem rust was very important, and a great part of the material (pure lines and population) had to be discarded .

Between 1989 to 1992 the 90 % of the entries of the Quaker Nursery had good performance to *Puccinia graminis*, with few entries with maximum datas of 7 or 8 (scale 0-9). Since 1993 until today only the 27% of pure lines and 44% of segregating population had good behavior, the maximum values registered in 1993 and 1994 were 9. In 1992 a new race of stem rust appeared and broke down the resistance of Bonaerense Paye, the only resistant cultivar till this moment.

Crown rust was not very important in this period at Barrow field, but we had the datas from Castelar (Ing. Antonelli) and Parana (Ing. Formento) that were very helpful to discard material. We lost lots of good materials because of the rust. Now we have lines with good agronomic traits, good grain quality and yield, some of them with possibilities of realizing.

The mean yield of the best lines was higher than the mean of Bonaerense Paye, Cristal INTA and Suregrain (13% in 1995 and 33% in 1996). They were better also in groat percentage,

protein percentage, although in hectoliter weight and weight per 1000 kernels were slightly lower.

We think therefore that oat breeding program at Barrow has made continuous progress in increasing the yield of oat and that this trend will likely continue. But we are conscious that in despite of breeder's efforts to increase yield, the realization of this potential is being continually restricted by evolution of pathogens able to overcome the resistance of the new varieties. The neighborhood of the cultivated areas in Argentina, Brazil and Uruguay and the increase of oat sowing in Brazil made us worry about the dynamic of rusts.

INTRODUCCION

La avena es un cereal que se siembra en Argentina básicamente para la producción de forraje, en una amplia zona de su geografía. El área de influencia de nuestra experimental, es la que concentra dentro de la provincia de Buenos Aires la mayor superficie cosechada de grano.

Es sabido que de la avena se puede obtener forraje en diversas formas y también grano. Nuestra región nos da la posibilidad de hacer un uso doble de este cultivo, forrajero y granífero con casi todos los materiales difundidos y es proveedora de semilla para otras áreas que la emplean como forraje. Los múltiples destinos de éste cereal, han permitido que la superficie sembrada con avena en Argentina creciera, contrastando con la tendencia mundial decreciente, soslayando así la escasa rentabilidad de este cultivo. Aunque no sucede lo mismo con el área cosechada que también en Argentina ha disminuido.

La sanidad es hoy el principal problema del cultivo. En las siembras para forraje, la roya de la hoja es la que causa más perjuicios, mientras que en los cultivos para grano los rendimientos y la calidad del grano se ven afectadas seriamente por la roya del tallo. Esto ha quedado evidenciado claramente en nuestra región, ya que desde 1992, con intensidad variable pero de considerable importancia, se ha registrado la presencia de roya del tallo en avena, disminuyendo el potencial de rendimiento de las mejores variedades.

OBJETIVOS

La CHEI Barrow conduce un plan de mejoramiento de avena, iniciado hace muchos años, y que se ha mantenido con altibajos tratando de dar respuestas a las necesidades del productor, no solo de la región sino también de otras zonas que utilizan a la avena como verdeo de invierno en la cadena forrajera.

Atendiendo a ello se destacan como objetivos principales el desarrollo de cultivares de mayor productividad (de forraje y/o grano). Se trabaja sobre los siguientes parámetros: capacidad de rebrote, comportamiento a fitoparásitos (royas, septoria y bacteriosis), tolerancia a pulgón verde (*S. graminum Rond.*), comportamiento a vuelco y desgrane, comportamiento a factores climáticos adversos, calidad molinera del grano con destino a la industria del laminado. Se evalúan también las posibles áreas de difusión comercial de materiales inéditos.

Como se comprenderá no es sencillo lograr en una única variedad tantos y algunos tan diversos aspectos, que además tiene posibles usuarios en ambientes muy distintos.

RESULTADOS

El programa cuenta con material que se recibe anualmente de las Universidades de Wisconsin y Texas (USA) a través del proyecto Breeding Oat Cultivars Suitable for Production in Developing Countries, y en 1994 se introdujo material del programa de la Universidad Federal de Río Grande do Sul (Brasil). Se realizan cruzamientos de materiales propios adaptados con algunos introducidos de buen comportamiento a royas.

Desde el año 1993 a 1996 han sido constantes y de mucha magnitud los ataques de roya del tallo (*Puccinia graminis*) a campo en Barrow, siendo mucho menor la incidencia de la roya de la hoja (*Puccinia coronata*). Esto motivo la eliminación de gran parte del material avanzado que se poseía, resultando en una disminución de la variabilidad genética, efecto no deseado. Ello se puede ejemplificar brevemente, diciendo que entre 1989 y 1992, el 90 % o más de las entradas del Quaker Nursery tenia buen comportamiento a roya del tallo (en 1990 fue algo inferior), con pocas entradas con ataques máximo de 7 y 8 (en una escala de 0 a 9). Desde 1993 a la fecha esos porcentajes no superan el 27 % en las líneas puras y el 44 % en las poblaciones segregantes, habiendo alcanzado en el 93 y 94 valores de 9 en la escala, lo que confirma la gravedad del ataque. La aparición de una nueva raza de *P. graminis* que afectó al cultivar Bonaerense Payé, resistente a roya del tallo hasta 1992 (Antonelli, 1994), puso en evidencia la susceptibilidad de gran parte del material fitotécnico que se conducía.

En cuanto a roya de la hoja (*Puccinia coronata*), a pesar de que su presencia no fue importante en Barrow, se contó con datos de viveros realizados en INTA Castelar (Ing. Antonelli) y de INTA Paraná (Ing. Formento).

Otra enfermedad, de baja incidencia por el momento, pero que representa un peligro potencial es la bacteriosis (*Pseudomonas coronofaciens*, *P. striafaciens*) de aparición en invierno hasta mediados de primavera. Se ha observado en casos aislados la presencia de virosis. Las observaciones se realizan en el campo de la experimental y están sujetas a la ocurrencia natural de los patógenos, desconociéndose que razas o biotipos están presentes. Teniendo en cuenta los objetivos del plan, se ha realizado una fuerte selección desde generaciones tempranas frente a estos patógenos y debiendo descartar en éstas campañas material promisorio. Fenómenos climáticos adversos han permitido además la selección de materiales de buen comportamiento a vuelco y desgrane.

En cuanto a rendimiento de grano, el promedio de algunas líneas ha superado al promedio de los mejores testigos Suregrain, B. Payé y Cristal INTA en un 13% en 1995 y en 33% en 1996. Significando un progreso también en desarrollo de grano, contenido de pepita y de proteína, mientras que en PH y PMG los datos son ligeramente inferiores. Cuadros 1, 2, 3 y 4. Los datos de las líneas son comparados con el promedio de los mejores testigos para grano Bonaerense Payé, Cristal INTA y Suregrain.

Cuadro 1. Rendimiento y sanidad. Una fuerte granizada ocurrida el 14 de noviembre de 1994 hizo que no se evaluara rendimiento, sí otros parámetros.

Variedad	Rendimiento en kg/ha.		*Puccinia graminis* (0-9)		
	Año 1995	Año 1996	1994	1995	1996
Cristal-Payé-Suregrain	3152	2026	8	8	7
Otros testigos	2460	1685	8	7	7
Bw 16	3373	2596	6	2	1
Bw 6	3934	2576	2	Tr	Tr
Bw 5	3227	2451	Tr	Tr	Tr
Bw 13	3278	2828	3	0	0
Bw 25	3972	2600	1	1	1
Bw 28	3581	2933	5	1	0
C.V. %	10	17			

Cuadro 2. Ensayos Barrow 1994 (datos de 3 ensayos).

Variedad	Días G-P	PH	P.M.G gr	Desarrollo %	Pepita %	Proteína %	Altura Cm.
Cristal-Payé-Suregrain	94	48.60	35.6	89.6	70.3	16.6	92
Bw 16	95	45.80	34.1	92.5	74.8	17.2	91
Bw 6	96	47.05	33.3	94.9	73.8	17.0	71
Bw 5	95	45.20	36.4	92.4	69.9	17.3	94
Bw 13	94	48.75	33.3	92.8	72.2	17.5	78
Bw 25	94	46.20	35.8	96.0	68.3	16.7	79
Bw 28	91	47.90	32.9	80.7	70.9	16.9	85
Promedio líneas	--	46.80	34.3	91.55	71.7	17.1	83

Cuadro 3. Ensayos Barrow 1995 (4 ensayos).

Variedad	Días G-P	PH	P.M.G Gr	Desarrollo %	Pepita %	Proteína %	Altura cm.
Cristal-Payé-Suregrain	82	49.45	35.5	80.7	68.8	14.9	100
Bw 16	81	48.00	32.4	89.6	68.6	14.8	100
Bw 6	85	47.15	27.5	90.2	70.0	15.0	82
Bw 5	83	50.00	36.5	96.3	70.2	15.6	100
Bw 13	84	50.70	32.1	92.6	70.5	15.5	81
Bw 25	84	46.40	33.4	95.0	68.6	15.4	88
Bw 28	79	49.15	32.0	93.9	68.4	15.4	86
Promedio líneas	83	48.60	32.3	92.9	69.4	15.3	89.5

Cuadro 4. Ensayos Barrow 1996 (datos de 3 ensayos).

Variedad	Días G-P	PH	P.M.G Gr	Desarrollo %	Pepita %	Proteína %
Cristal-Payé-Suregrain	95	43.90	27.6	63.4	65.7	14.0
Bw 16	93	47.15	29.5	68.9	67.2	14.9
Bw 6	98	44.70	27.9	78.3	66.9	15.1
Bw 5	95	44.55	30.6	83.6	71.7	16.0
Bw 13	96	45.40	29.6	76.7	67.0	15.8
Bw 25	97	43.60	29.6	86.6	68.3	15.6
Bw 28	92	50.00	31.6	88.4	67.2	16.6
Promedio líneas	95	45.90	29.8	80.4	68.1	15.7

CONCLUSIONES

La búsqueda de materiales de mejor productividad implica que además de rendimiento deben tener buen comportamiento a los factores que limitan la expresión de esa productividad.

En la actualidad se cuenta con material avanzado de buenas características agronómicas, rendimiento superior a los testigos, y de parámetros de calidad aceptables.

La introducción de material proveniente del programa de Mejoramiento de UFRGS, de buena sanidad y con buena aptitud granífera, apunta a aumentar la variabilidad y fortalecer el desarrollo de variedades graníferas.

Como se puede observar en los cuadros, hay líneas de buen comportamiento a roya del tallo y con un potencial de rendimiento de grano superior a los mejores testigos.

De continuar con ésta performance, se estará en condiciones de contar con nuevas variedades en el corto plazo.

La vecindad de las áreas sembradas de avena en Argentina, Brasil y Uruguay, y el aumento de éste cultivo en Brasil debe motivarnos a realizar acciones conjuntas sobre la dinámica de los patógenos para tratar de evitar que se agraven los problemas sanitarios.

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WHEAT GERMPLASM DEVELOPMENT THROUGH REGIONAL COLLABORATION

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INTRODUCTION

Germplasm exchange has been one of the most critical aspects behind the development of modern plant breeding programs around the world. Cooperation at the global level among the breeders has not only resulted in successful creation of newer varieties, but also in the expansion of genetic variability in different crop species. In most cases, such collaboration among the breeding programs has also served as an alert system in epidemiologically homogeneous regions.

In the case of wheat, the Southern Cone region, with exception of Chile, is very homogeneous. The region does not have any physical barrier except the Andean range of mountains to curtail the movement of diseases and insect pests from one country to another. The movement of stripe rust spores between Argentina and Chile reported by Dr. Vallega over half a century ago, the arrival of the race 24 of stripe rust of barley from Colombia down to Chile and on to Argentina in the beginning of 1980s and the recent appearance of Russian grain aphid in Argentina demonstrate the critical role that Inter-Andean Valleys play in the movement and epidemiology of the diseases and insect pests on both sides of the range.

The wheat breeding programs of the Southern Cone, aware of this geographical reality, have utilized all opportunities to exchange germplasm among them and evaluate it in different parts of the region, both in formal and informal manner. Such exchanges have been done regularly since 1950s when the first regional and international nurseries were started. The International Rust Nursery (USDA), the Latin American Wheat Yield Trial organized by Dr. Norman Borlaug of the Office of Special Studies, Mexico, the Southern Cone Wheat Yield Nursery (ERCOS) organized by EMBRAPA and Latin American Disease and Observation Nursery (VEOLA) organized by CIMMYT have been some of the formal vehicles for regional evaluation of germplasm.

With the support from IICA-BID cooperative program among the countries, now PROCISUR, the annual exchange of wheat advanced lines was formalized in a nursery called LACOS. Since its inception in 1981, LACOS has been coordinated by the CIMMYT regional program with the help of the National Research Institution of the country it is based in.

OBJECTIVES OF THE LACOS

The regional exchange of high yielding and good agronomic type advanced lines is the principal objective of LACOS. However, the data collected on adaptation and resistance or tolerance to biotic and abiotic factors through multi-location testing helps the breeding programs make valuable decisions before the release of commercial varieties. In this aspect, LACOS has also served as a regional collection to generate specific information from outside the region and for the germplasm banks.

During the last few years, LACOS has been utilized to type pathogenic variability among leaf rust and septoria leaf blotch under field conditions in order to identify the superior sources of resistance at the regional level. It has also been used to study the stability of industrial quality parameters in the germplasm included.

COMPOSITION OF LACOS

LACOS includes approximately 300 advanced lines derived from around 20 wheat breeding programs of Argentina, Bolivia, Brazil, Chile, Paraguay and Uruguay (Table 1). All entries considered for LACOS are selected after one or two years of yield evaluation in the country of their origin.

Table 1. Number of lines and origin of germplasm in LACOS

Country	**1993**	**1994**	**1995**	**1996**	**1997**
Argentina	33	50	53	60	46
Bolivia	43	38	40	40	19
Brazil	94	65	60	42	51
Chile	57	61	61	66	53
Paraguay	41	40	40	45	39
Uruguay	32	40	26	39	35
Other		17	20	26	26
TOTAL	300	301	300	318	243

It is important to point out that between 1995 and 1997, approximately 70% of the lines included in the LACOS originated from the crosses and selections made in the region. This represents an increase of almost 25% of the local or regional material included in the LACOS compared to its earlier years. As a result, LACOS represents a fairly different set of genetic variability than distributed by CIMMYT and other institutions internationally.

With the objective of achieving homogeneous seed source, the advanced lines from each country are multiplied at one location, at present INIA La Estanzuela, Uruguay. Diseases and insect pests are controlled utilizing chemical applications during the seed multiplication in order to produce healthy and good quality seed. With an objective of comparing the performance of newer lines, approximately 20 check varieties are added to the nursery each year.

During the last few years, 50 sets of LACOS have been distributed regionally and internationally. Of these, five sets are sent specifically to the collaborators who have conditions to evaluate septoria leaf blotch under artificially inoculated conditions. Each collaborator receives approximately 20 grams of seed per line treated with a combination of Benomyl and Iprodione. In order to screen the germplasm for some specific characters, international collaboration outside the region is sought (Table 2).

Table 2. International collaboration in LACOS

Character screened	**Institution**	**Country**	**Collaborator**
Rust (seedling)	Cereals Rust Laboratory	USA	A. Roelfs
Stem rust	National Plant Breeding Institute	Kenya	P. Arana
Stripe rust	INIAP	Ecuador	M. Rivadeneira
Leaf rust	CIMMYT	Mexico	R. Singh
Septoria glume blotch	University of Georgia	EEUU	B. Cunfer
Septoria leaf blotch	INIFAP	Mexico	R. Garcia
Spot blotch	CIMMYT	Zambia	T. Payne
BYDV (seedling)	Department of Agriculture	Canada	A. Comeau
Russian grain aphid	Small Grains Institute	S. Africa	V. Tolmay
HMW glutanins	CIMMYT	Mexico	J. Peña

The data received from the cooperators are analyzed at the CIMMYT regional office for publication and distribution purposes. Only the data that represent an adequate selection pressure are utilized for analysis. Most of the disease data is converted into coefficients of infection in order to compare among the lines. During the last two years, the facilities of INIA-La Estanzuela have been most helpful in the publication of the results.

RESULTS AND DISCUSSION

The climatic variability found in the Southern Cone Region each year permits an excellent evaluation of LACOS at a regional level. Depending on the selection pressure, the collaborators are asked to evaluate only those characters of interest that can differentiate among the genotypes. Between 1991 and 1995, the percent of results returned have varied between 52 and 80%. While some countries such as Paraguay have returned 100% of the results each year, other have done it to a lower level due to the loss of the trial caused by climatic or other factors (Table 3).

Table 3. Percent of results received and analyzed in LACOS

Country	1991	1992	1993	1994	1995
Argentina	50	57	14	28	43
Bolivia	67	50	0	60	150
Brazil	50	42	50	66	27
Chile	75	80	60	80	80
Paraguay	100	100	100	100	100
Uruguay	100	67	67	100	100
Others	62	45	77	50	57

Over the last few years, the Brazilian collaborators have been forced to seed the trial a year later due to quarantine problems. This has caused a serious delay in the processing of the results and their reduced utility to the participating programs. Argentine collaborators have also had serious problems with climatic conditions during the last few years that has resulted in the loss of valuable data. Efforts are being made at the present time to reduce these problems in order to improve the value of information analyzed and distributed.

Analysis of the evaluations done on LACOS between 1991 and 1995 are presented in Figure 1. Considering that the major objective of LACOS is basically to exchange germplasm, selection of useful lines by a breeding program is the most important factor evaluated. The selected germplasm is not only utilized in the crossing program, but also tested for its yield potential. The data regarding selection of lines from LACOS by different countries and some specific breeding programs are presented in Tables 4 and 5. It is important to observe that some countries have been able to select as much as 38% of the germplasm included in LACOS which represents a significant increase in the genetic variability available to a breeding program. Although approximately 15% of the entries are selected by a program on an average, some breeders have been able to select over 25% of the germplasm regularly.

Table 4. Average percent of germplasm selected from LACOS

Country	13th LACOS	14th LACOS	15th LACOS
	SEL %	SEL %	SEL %
Argentina	20	14	14
Bolivia	-	26	14
Brazil	15	20	38
Chile	9	12	11
Paraguay	17	20	31
Uruguay	7	15	17
Mexico	18	18	28
Others	3	24	24

Table 5. Number of lines selected from 13th, 14th and 15th LACOS at key locations

Institution	LACOS 13th (300)*	LACOS 14th (301)*	LACOS 15th(300)*
INTA, M. Juárez, Argentina	59	51	67
CNPT, Passo Fundo, Brazil	27	53	
FUNDACEP, Cruz Alta, Brazil	41	56	65
INIA, Quilamapú, Chile	43	57	28
CRIA, Cap. Miranda, Paraguay	34	32	92
INIA, La Estanzuela, Uruguay	22	23	79
INIFAP, Patzcuaro, México	98	28	
CIMMYT, Obregón, México		102	62
CIAT, Saavedra, Bolivia		46	69

* Total number of entries in the trial

Among the agronomic data, most cooperators provide information on the plant height and days to heading. For some reason, the information on days to maturity is not evaluated by many wheat breeders in the region in spite of its critical value in determination of the crop cycle and that of genetic resistance to saprophytic diseases.

Among the diseases, leaf rust is the most common and evaluated disease in the region (Fig. 1). In spite of its variable severity amongst locations each year, Pergamino, Argentina; Cruz Alta and Passo Fundo, Brazil; Santiago and Chillan, Chile and La Estanzuela, Uruguay evaluate the disease every year. In an analysis done during 1993, Chillan, Chile represented a different leaf rust virulence picture than other locations in the region. Based on this analysis, Pergamino, Argentina and Chillan, Chile can be considered two key locations for leaf rust screening in the region.

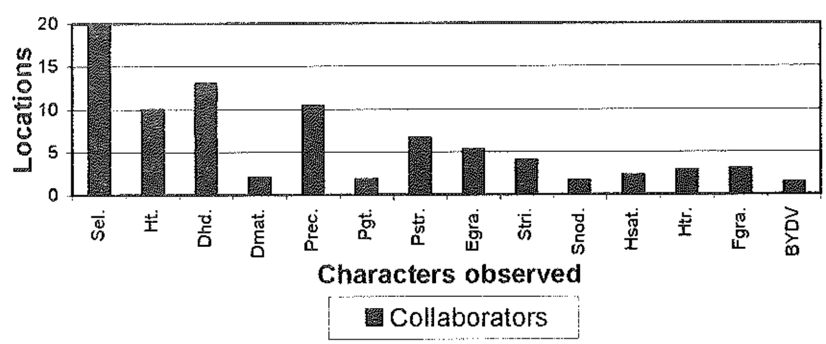

Figure 1. Characters evaluated by LACOS collaborators 1991/95.

On the other hand, the data of LACOS permits identification of low level of susceptibility to a disease in the region. Besides representing wide based resistance, some of these lines may be sources of durable resistance. (Table 6). Although the data presented in the publication is averaged over locations, a separate analysis of individual location data is done to identify valuable germplasm for the breeding programs.

Table 6. Variability of leaf rust reaction of selected lines of 15th LACOS at key locations

Location	Entry Number					Coefficient of Infection	
	104	2	258	282	254	Average	Maximum
Pergamino, Argentina	80 S	TR	20 M	70 S	20 MS	26.9	90
Barrow, Argentina	80 S	0	1 R	1 R	30 MR	5.2	80
La Estanzuela, Uruguay	40 MS	2 MR	10 MR	10 MR	15 MS	12.5	90
Young, Uruguay	60 S	0	60 S		10 MR	19.5	80
Santiago, Chile	0	0	0	0	TMR	0.9	54
Chillan, Chile	20 MS	0	10 MS	0	20 MS	6.6	72
Okinawa, Bolivia	20 MS	0	0	10 MR	0	4.5	80
El Batán, México	100 S	1 MS	10 MS	30 MSS	30 MSS	17.2	100
Cruz Alta, Brazil	80 S	0	0	0	10 S	3.6	80

Collaboration from the Cereals Rust Laboratory, USDA, USA; National Wheat Research Center, EMBRAPA, Brazil and CIMMYT, Mexico has been critical to generate data on seedling reaction to specific leaf and stem rust virulences. This information combined with the field observations has helped identify a set of germplasm for adult plant resistance to leaf rust which is being tested separately (Table 7).

Table 7. Seedling and field reaction of selected lines in 15th LACOS to leaf rust.

Entry number	Leaf rust isolate				Field reaction		Average Coefficient
	TBD/TM	MFB/SP	TCB/TD	MCJ/SP	Maximum	Location	Of Infection
104	3	3+	3+	3+	100 S	México	51.6
80	:	0:	0:	0:	1 MS	México	0.1
232	:	1+	:1	1+	60 S	Pergamino	18.1
45	3+	3+	3+	3+	15 MSS	El Batán	2.6
8	3+	3+	3+	3+	30 M	Pergamino	4.5
79	3	3+	3	3+	30 S	Okinawa	9.8

Similar variation in virulences to Septoria leaf blotch has been observed among Argentina, Uruguay and Mexico and probably among different locations within the country (Table 8). The Southern Cone region is well known for its wide pathogenic variability for Septoria leaf blotch fungus and the data from LACOS nursery can help to identify the stable sources of resistance.

Table 8. Variability in Septoria leaf blotch infection of selected lines in 15th LACOS under field conditions

Entry	Barrow	La Estanzuela	Toluca
58	86	87	89
1	53	88	88
50	85	63	63
94	31	31	86
128	86	88	83
93	52	T	32

In the recent years, there has been a significant increase in the presence of powdery mildew in the region. Given the narrow base of resistance to powdery mildew among the regional germplasm, it has affected the lines included in the LACOS seriously. The key locations such as Passo Fundo and Campinas in Brazil and Caacupe, Paraguay are being used to identify sources of resistance. However, due to the lack of accompanying study on pathogenic variability of this fungus, the stability of sources identified is not fully evaluated.

The spot blotch and tan spot caused by different species of *Helminthosporium* became important with the move of wheats to the warmer regions and the incorporation of conservation methods of tillage without adequate regard for rotations. Given the scarcity of data available on these diseases in the region, LACOS is being tested internationally to generate valuable information.

The collaboration of various programs in the region and that of CIMMYT Mexico has been very useful to develop a data base on the industrial quality characteristics and information on high molecular weight glutanin bands of the lines included in LACOS. The most important contribution of LACOS has been the identification of advanced lines by the national programs for their commercial release as varieties (Table 9). Some other widely adapted lines included in LACOS have been released as commercial varieties in the countries other than their origin. The contribution of LACOS in terms of increased genetic variability for agronomic characters and wide based disease resistance sources is even more valuable to the breeding programs.

CODE OF ETHICS

The collaborators in LACOS have followed a very simple code of ethics since the beginning of the trial. During the 1980s, collaborators could select a line suited for their environmental conditions and after adequate testing release it commercially, giving the required credit to the original institute. However, with the changing scenario of plant protection regulations in most of the countries during 1990s, the releasing institution is required to ask for the written authorization from the original breeding institution and reach an agreement on the conditions of release.

There have been no cases of abuse of these ethics so far and all participating institutions and breeders understand the value of the nursery to their respective programs. There is, however, a growing concern on the part of some breeding programs to see that their administrators are becoming highly involved with what can be exchanged and distributed freely and what can not. So far there has been little problem with the quantity and quality of germplasm exchanged through LACOS. But there is a need to regroup the participants and fan out any concerns there may be at the institutional level. In order to reach the administrative line of thinking, the recent publication of results of the 15th LACOS carries an executive summary explaining the objectives of the nursery and the value of the information generated through networking. The nursery results are distributed regularly to the hierarchy of each participating institution and other agencies interested.

Table 9. Some of the new varieties released after their testing in LACOS

Argentina	J 3636	PROINTA PUNTAL
	J 3153	PROINTA QUEGUAY
	J 91030	PROINTA ELITE
Bolivia	MOR/VEE	PAILON CIAT
	NDD/SEL101//PUN/SIS	GUENDA CIAT
	KEA/BUC	SURUTU CIAT
Brazil	CEP 8878	CEP 27
	IAC 120	CURUMI
Paraguay	E 8554	ITAPUA 40
	C 86240	IAN 9
Uruguay	LE 2189	INIA MIRLO

In conclusion, the exchange of wheat germplasm among the countries of the Southern Cone in the form of LACOS has been very successful. Besides providing increased germplasm variability to the national programs, LACOS has helped provide multilocation information on important agronomic and disease characters as well as served as an alert system on the presence of new virulences in the region. LACOS has also helped identify key locations with different pathogenic populations for diseases that can serve to identify wide based resistance of the germplasm included in this trial.

In general, the participating cooperators of LACOS have been able to select more material for the breeding programs than they have contributed. In spite of the fact that only few lines included in the LACOS have been released as commercial varieties, the majority of others have served well to increase the genetic variability necessary in the breeding programs.

ACKNOWLEDGMENTS

My sincere gratitude go to all the collaborators participating with their germplasm and information, who are really responsible for the successful continuation of LACOS. I would also like to thank the colleagues in PROCISUR, INIA Chile, DIA Paraguay, and recently, INIA Uruguay who have supported LACOS in different phases. Finally, my appreciations go to the personnel in CIMMYT regional office, Uruguay, for their assistance in distribution of LACOS as well as summarization of results.

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POSTER

WHY MAJOR CROWN RUST GENES DON'T LAST IN SOUTH AMERICA

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Our intent today is to lead a discussion to pursue answers to the question posed in the title of this presentation. Secondly, we want to explore alternative approaches to achieve a more durable rust resistance by looking at potentials and limits of several other resistance mechanisms.

In attempting to answer the question of why major crown rust genes don't last very long in South America, it is important to understand the disease situation there. There are a number of significant contributing factors which collectively exert considerable pressure on host (oat) resistance genes. First, crown rust of oats is probably the most variable pathogen of its kind. It has extremely high mutation rates which may be explained by its lighter colored spores. Both points are similar for yellow (striped) rust of wheat. Second, oats are growing every month of the year so there is no temporal barrier which may impede the pathogen in other areas. In addition to a lack of temporal barriers, there is also essentially no physical barriers to spore movement in southern Brazil, Uruguay and Eastern Argentina. Thus a successful mutant spore could spread quite easily. Another contributing factor is that most likely other host species present provide additional opportunities for the pathogen to achieve infection. Finally, the relatively long window for both infection and sporulation again increases the spore production potential. All of these factors can combine to significantly increase spore production throughout the entire year.

Many people immediately respond to this scenario by suggesting that combinations (pyramids) of major genes are an attractive alternative because the necessary simultaneous mutations at several loci of the pathogen will occur in relatively lower frequency than if only one host gene needs to be overcome. Thus the next question -- will major gene pyramids provide more durability? We suggest not really and also recommend that you think in terms of mutant survival and thriving rather than emphasizing the mutation even itself.

The following calculations will illustrate the analyses that produced our conclusion. To begin, we need to make several assumptions about relevant parameters which we believe are quite reasonable. The assumptions include 1) a 40-day sporulation period, 2) as many as 1160 spores per pustule per day (Martinelli, Personal Communication), 3) a 1% infection rating is equal to 10 pustules per plant, 4) currently there are 200,000 hectares of oats for grain in Brazil annually, and 5) a variable mutation rate of crown rust spores from as high as one per 2000 to one every 8000 spores.

Using the values given above, the number of rusted oat plants in Brazil annually with 10% infection is equal to 20,000 ha times 3 million plants per ha or 6 x 10^{10} rust infected plants each having 100 pustules. Continuing, each infected plant will have 5 x 10^{4} effective spores (100 pustules x 1000 spores each x 50% survival) producing 2 x 10^{6} spores over a 40-day period. Finally, multiplying the number of rusty plants, 6 x 10^{10}, times the number of spores from each infected plant 2 x 10^{6} produces 1.2 x 10^{17} spores of oat crown rust annually in Brazil.

We believe this estimate is conservative for the following reasons: 1) assume only 50% spore survival rate, however this value is relatively inconsequential unless it is less than 1%, 2) ignores all areas planted to "Black" oats, 3) includes only Brazil, however Uruguay and Argentina are also known to contribute to the spore load in the area, 4) doesn't include other Avena species which might be present and susceptible, and 5) also doesn't include any other grass species which would also support oat crown rust.

Turning our attention now to the protection afforded by combination (pyramids) of major genes, and assuming a mutation rate of 8 x 10^{-3} (the highest rate reported earlier), one host resistance gene would effectively match 8 x 10^{3} spores. A two- gene pyramid would match 6.4 x 10^{7} spores, a three-gene pyramid would match 5.12 x 10^{11} spores, and a four-gene pyramid would effectively counter 4.1 x 10^{15} spores. Remember the conservative estimate of annual spore count in Brazil was a minimum 1.2 x 10^{17}. Thus on average there would be about 30 mutant spores produced each year in Brazil alone which would be capable of attacking a four-gene pyramid.

How realistic is a four-gene pyramid? Currently there are no known virgin (non-rustable) major resistant genes for South America. Even if the genes were available, considerable breeding effort would be required to accumulate them into a single genotype and when grown, the pyramid would be vulnerable to any of those 30+ mutant spores. Further, when one of the mutant spores landed on any heretofore resistant plant, there would be no other rust spores present to compete with the mutant spore thus elevating the relative fitness of the mutant spore to nearly one. Not an attractive situation.

What then are our options? If we found virgin major genes, we could expend the effort to pyramid them. Or we could begin to consider different approaches which would provide the pathogen with much less selection pressure (assistance) to evolve new virulent types. One possibility is partial resistance genes or perhaps rate-reducing resistance genes. Through the use of recurrent selection we could begin the process of accumulating such genes. At Minnesota we now have such a program in progress and initial results are very promising.

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POSTER

PHYSIOLOGICAL SPECIALIZATION OF OAT LEAF RUST (*Puccinia coronata* Cda.) IN SOUTHERN BRAZIL

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ABSTRACT

Studies on population dynamics of oat leaf rust (*Puccinia coronata*) initiated in Brazil in 1949 were discontinued in spite of the importance of the disease. More recently, research on pathogenic specialization of *P. coronata* in southern Brazil has been developed in a cooperative work Embrapa Trigo/Universidade de Passo Fundo (National Wheat Research Center/University of Passo Fundo). Uredospore collections of oat species (*Avena sativa, A. fatua, A. strigosa*) and rye grass (*Lolium multiflorum*) from crop and experimental south Brazilian areas, over the period 1994-1996, were inoculated on seedlings of susceptible oat varieties (*A. sativa*) under greenhouse conditions. The identification of 22 races from 31 isolates provides evidence for the high level of virulence variability on *P. coronata* in southern Brazil. The genes *Pc 38, Pc 48, Pc 50, Pc 52, Pc 62, Pc 63, Pc 64*, and *Pc 68* conferred resistance to the Brazilian races, in this study. Oat seedlings (*Avena sativa*) were infected with rust from *L. multiflorum, A. strigosa*, and *A.fatua*.

INTRODUCTION

Leaf rust, the most destructive oat disease, is caused by *Puccinia coronata* Cda.). The fungus variability has limited the oat breeding progress. Changes on virulence have resulted in short time resistance. Continuous research on the dynamics of the pathogenic populations are necessary and influence the choice of the variety to be cultivated, the identification and use of genes combinations for the breeding programs for resistance, and disease control strategies.

The first references on physiologic specialization of *P. coronata* in Brazil indicated that the same races occur in Argentina, Brazil, and Uruguay, according to Vallega (1940), cited by Eichler *et al.* (1986). The survey on *P. coronata* races in Brazil initiated in 1949. Results were reported by Silva (1953), Bertoldi (1953), Souza (1956 to 1959), and Coelho (1972), as cited by Coelho (1976). On this publication race frequency in the state of Rio Grande do Sul, Brazil, during the period 959-1972 is presented. This research was discontinued and it was only in 1977, when the oat breeding program began at the University of Passo Fundo, that attention was again directed toward the problem of oat leaf rust (Eichler *et al.*, 1986).

More recently, studies on pathogenic specialization of *P. coronata* in southern Brazil were accomplished in a cooperative work Embrapa Trigo/Universidade de Passo Fundo (National Wheat Research Center/University of Passo Fundo). Information on the period 1994-1996 is discussed in this report.

MATERIALS AND METHODS

Uredospore collections of *Avena sativa*, *A. fatua*, *A. strigosa*, and *Lolium multiflorum* from field crop and experimental areas at the south Brazilian states Rio Grande do Sul, Paraná and São Paulo, over the period 1994-1996, were inoculated on seedlings of susceptible oat varieties (*A. sativa*), UPF 13, UPF 14, and UFRGS 7. Inoculum of 31 monopustule isolates were multiplied, under greenhouse conditions, at Embrapa Trigo, in Passo Fundo, RS, to obtain sufficient amount of inoculum to infect a differential series of races. The seeds of this series were provided by E. Antonelli, INTA, Castelar, Argentina. The differential series consisted of 21 genotypes carrying each one a *Pc* gene, besides the varieties La Prevision, Suregrain, Santa Fe n^{o} 3, Buck 152, Moregrain, Steele, and Saia. The avirulence/virulence formula (races) were determined by the identification of effective and ineffective genes in the host, through the resistance and susceptible reactions. The scale 0 (resistant) to 4 (susceptible) was used to determine the infection type of reaction.

RESULTS AND DISCUSSION

The results indicated 22 races of *P. coronata*. Virulence formula of the races and the number of isolates identified during the period 1994-1996 in southern Brazil are presented in Table 1. Comparing these races with those determined in Argentina, from 1990 to 1994 (INTA, 1994 e 1995), the variety Saia, as well as the *Pc 63* and *Pc 68* lines, maintained resistance. Steele, a cultivar that had become susceptible to one Argentinean race, in 1994 (INTA, 1995), reacted as resistant to the Brazilian isolates. In addition to *Pc 63* and *Pc 68*, the following genes conferred resistance to the Brazilian races, in this study: *Pc 38*, *Pc 48*, *Pc 50*, *Pc 52*, *Pc 62*, and *Pc 64*.

Oat seedlings were infected with rust inoculum from *L. multiflorum*, under greenhouse controlled conditions, and the races identified as R 2 e R 7 (Table 1). The R 2 race was also detected from *A. strigosa*. The inoculum of the R 15 race derived from *A. strigosa*. R 1 and R 6 races were detected from *A. sativa* and from *A. strigosa* and *A. fatua*, respectively. Under natural conditions, *L. multiflorum*, *A. strigosa*, *and A. fatua* are probably propagating *P. coronata* and increasing the inoculum pressure to infect crops of *A. sativa*.

The identification of 22 races from 31 isolates provides evidence for the high level of virulence variability on *P. coronata* in southern Brazil and that adequate strategies for oat breeding are non-specific resistance and genotype diversification.

Table 1. Virulence, number of isolates and source of inoculum of *Puccinia coronata* races, in southern Brazil, period 1994-1996

	Virulence		
Race	Ineffective *Pc* genes	Number of isolates	Inoculum source
R 1		4	*Avena sativa* *A. strigosa*
R 2		2	*A. strigosa* *Lolium multiflorum*
R 3	*40*	2	*A. sativa*
R 4		1	*A. sativa*
R 5	*51 56*	1	*A. sativa*
R 6	*60 67*	2	*A. sativa* *A. fatua*
R 7	*35 58*	1	*L. multiflorum*
R 8	*39 58 59*	1	*A. sativa*
R 9	*35 39 60*	1	*A. sativa*
R 10	*39 46 56*	1	*A. sativa*
R 11	*35 39 55 58 61*	1	*A. sativa*
R 12	*45 46 58 67*	1	*A. sativa*
R 13	*40 45 46 60 61*	1	*A. sativa*
R 14	*40 55 60 61 67*	4	*A. sativa*
R 15	*39 40 55 61 67*	1	*A. strigosa*
R 16	*35 39 40 45 46 55 60*	1	*A. sativa*
R 17	*37*	1	*A. sativa*
R 18	*40 45 46 55 61*	1	*A. sativa*
R 19	*35 39 40 46 55 61*	1	*A. sativa*
R 20	*55*	1	*A. sativa*
R 21	*39 40 55*	1	*A. sativa*
R 22	*45 55 61 67*	1	*A. sativa*

No virulence was detected for the following *Pc* genes: *38 48 50 52 62 63 64 68.*

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POSTER

DIALLEL ANALYSIS FOR TWO COMPONENTS OF QUANTITATIVE RESISTANCE TO OAT CROWN RUST

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ABSTRACT

Some of the genetic effects controlling pustule size and affected leaf area were studied using a partial diallel design from six oat genotypes (*Avena sativa* L.) representing a broad range of resistance to crown rust (*Puccinia coronata* f. sp. *avenae*). The results indicated that the effects of general combining ability were of major importance, so additive effects were more important than non additive effects for these two components of quantitative resistance to oat crown rust. Therefore, it should be possible to manipulate the quantitative resistance traits pustule size and affected leaf area in oat breeding programs.

INTRODUCTION

Crown rust of oats is an economically important disease in Southern Brazil. In susceptible varieties yield losses can be as high as 50% if heavy infections occur before anthesis and grain filling, affecting grain quantity and quality (Martinelli *et al.*, 1994).

Breeders have achieved high levels of resistance to this disease using major, race-specific genes. The pathogen, however, has been able to overcome these genes easily by producing new virulent races. Currently, more attention has been drawn to other forms of resistance, such as quantitative (or partial) resistance, which is typically polygenic and has showed to be durable in many host-pathogen systems (Wilcoxson, 1981; Parlevliet, 1993). Partial resistance is characterized by a slow epidemic build-up despite a high infection type indicating a compatible host-pathogen interaction. This slow rusting is explained by the combined effect of several resistance components such as longer latent periods, reduced pustule size and lower percentage of infection, resulting in a lower disease severity (Parlevliet and Zadoks, 1977; Parlevliet, 1979).

The screening for partial resistance to oat crown rust and the study of its components in Brazilian oat genotypes, started at the Oat Breeding Program of the Federal University of Rio Grande do Sul (UFRGS) in 1995. The objective of this study was to estimate the genetic effects for pustule size and affected leaf area, in order to begin to understand the genetics of these components of partial resistance to crown rust in Brazilian oat germplasm.

MATERIALS AND METHODS

Six oat genotypes belonging to the UFRGS Oat Breeding Program were intercrossed in a partial diallel mating design. The UFRGS genotypes chosen (7, 910906, 921260, 922003, 93576, 93641-13) were characterized for partial resistance before and represented a broad range for resistance to crown rust.

The parents and F1 progenies were grown in the field, at UFRGS Agricultural Station in Eldorado do Sul - RS, in a randomized block design with five replicates, in 1996. All genotypes were exposed to the natural inoculum of the rust fungus.

At grain filling stage the flag leaf was collected from the main culm of five plants per genotype. The length (representing pustule size) of 20 pustules per leaf was measured using a stereoscopic microscope. On the same leaves, the rust severity was assessed by measuring the percentage of affected leaf area on the upper surface, using the digital image analysis technique as described by Thomé *et al.* (1997).

Pustule size and affected leaf area data from parental genotypes were submitted to ANOVA, followed by Duncan's Multiple Range Test (P = 0.05). General and specific combining ability were estimated for parental and F1 genotypes through Method 2, Model I of Griffing (1956).

RESULTS AND DISCUSSION

The differences among parental genotypes (Table 1) indicated that there is genetic variability for both pustule size and affected leaf area, reinforcing the importance of this genetic study. Knowledge of genetic effects controlling the resistance components permits one to estimate the probable effects of selection on any generation, and diallel analysis is a powerful technique for obtaining a rapid estimate of the genetic parameters and relative dominance properties of the parents (Ghannadha *et al.*, 1995).

Table 1. Mean pustule size (length in mm) and flag leaf area affected by crown rust of six oat genotypes. Means of five replicates.

Oat Genotype	Pustule size (mm)	Affected leaf area (%)
UFRGS 7	0.80 A *	19.31 A
UFRGS 93576	0.66 B	4.88 C
UFRGS 921260	0.64 B	2.65 CD
UFRGS 922003	0.61 B	11.25 B
UFRGS 910906	0.52 C	1.69 D
UFRGS 93641-13	0.51 C	1.25 D
C.V.	7.01	26.21

*Means followed by the same letter are not significantly different by Duncan's Multiple Range Test (P=0.05).

Diallel analyses for both variables showed that the general combining ability (GCA), describing the average performance of a genotype in hybrid combinations, and which contains mainly additive effects, was the major component of genetic variation. The specific combining ability (SCA) was also significant. This is a measure of the deviation of crosses from the value expected on the basis of the performance of the parents, and it is composed of dominance plus interallelic interaction effects (Table 2).

Table 2. Estimates of general (GCA) and specific (SCA) combining ability effects for variables x_1 = pustule size and x_2 = leaf area affected by oat crown rust and its respective mean squares (MS_{GCA} and MS_{SCA}).

		UFRGS Oat Genotypes / SCA effects						
		7	910906	921260	922003	93576	93641-13	GCA effects
7	x_1	**0.069**	- 0.034	0.002	- 0.040	- 0.014	- 0.05	0.064
	x_2	**5.293**	- 5.365	0.932	0.1328	- 1.274	- 5.013	4.907
910906	x_1		**0.016**	- 0.048	- 0.006	0.031	0.025	- 0.050
	x_2		**2.383**	0.486	- 1.898	0.283	1.728	- 2.445
921260	x_1			**0.028**	0.005	- 0.063	0.048	0.001
	x_2			**0.082**	- 2.439	- 0.802	1.660	- 0.818
922003	x_1				**0.051**	- 0.018	- 0.042	- 0.023
	x_2				**4.692**	- 2.982	- 2.197	1.178
93576	x_1					**- 0.020**	0.105	0.036
	x_2					**1.924**	0.926	- 0.623
93641-13	x_1						**- 0.042**	- 0.027
	x_2						**1.448**	- 2.199
		$MS_{(SCA)}$	x_1 = 0.013	**		$MS_{(GCA)}$	x_1 = 0.073	**
			x_2 = 49.59	**			x_2 = 298.7	**
				Ratios*:	x_1=0.918	x_2=0.923		

*$2MS_{GCA}/(2MS_{GCA}+MS_{SCA})$ (Baker, 1978)

Genotypes UFRGS 910906 and UFRGS 93641-13 had the greatest GCA. Considering both the negative signal and the magnitude of the effects, it means that they probably have higher concentration of favorable alleles for reducing pustule size and lowering percentage of infection (Venkovsky and Barriga, 1992). In both cases the ratio proposed by Baker (1978), which compares mean squares (MS) of GCA with MS of GCA plus MS of SCA, was close to unity, also indicating that additive effects were more important than non additive effects for these two components of partial resistance to oat crown rust. The predominance of positive Sii estimates (bold numbers in Table 2) observed in this study for both variables (Table 2) indicate unidirectional dominance deviations. It resulted, consequently, in negative heterosis, i. e. reduction of partial resistance components in hybrid combinations of divergent parents.

The information provided by the analyses performed in this study indicated that it is possible, therefore, to manipulate the resistance factors controlling pustule size and affected leaf area in a breeding program because of the high level of additive effects. Also, the diallel analysis was an important tool for the identification of parents which will be used to develop germplasm for partial resistance to oat crown rust in Brazil.

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POSTER

DECOMPOSITION OF OAT RESIDUES AND SURVIVAL OF *Drechslera avenae*

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ABSTRACT

In trials carried out in the field and in the laboratory the time required for complete decomposition of oat crop residues, and the presence of the *Drechslera avenae* (Eidam) Sharif (imperfect form of *Pyrenophora avenae* Ito & Kuribayashi), causal agent of oat helminthosporiosis, in the form of conidia and ascospores, were determined. Oat crop residues broken down in an average period of 17 months and the fungus survival follow the same pattern of residue decomposition. After an average period of 16 months conidia were not more detected.

INTRODUCTION

In soil conservation is recommended to maintain crop residues at the soil surface as one of the most efficient ways to control erosion. Nevertheless, the benefits of this conservation practice may result in the increase of some diseases, due to the presence of necrotrophic parasites, which survive saprofhytically in crop residues (Reis, 1987; Summerell & Burgess, 1989). One of this fungus, which causes leaf blight, is *D. avenae* (perfect state *P.* avenae). This fungus survives saprophytically in oat residues which inoculum is presented in the form of conidia or ascospores (Sivanesan, 1987). South Brazilian farmers have reported an increased incidence of this leaf blight in the past years, probably due to the common practice of growing oat continuously in the same field. *D.* avenae is specific to *Avena* species and does not attack any other small-grain cereals such as wheat or barley. In this work the span of time required for complete break of oat residues was quantified in order to understand the pathogen survival in the absence of the oat green plant (parasitic phase).

MATERIALS AND METHODS

Experiments were carried out in Passo Fundo (RS) and Eldorado do Sul (RS) locations, during 1994 and 1996. Residues of white oat cultivar UPF 7 and UFRGS 15, and of common black oat were used.

In Passo Fundo the decomposition period of the white oat UPF 7 and black oat were performed. The cultivar UFRGS 15 was tested at the Eldorado do Sul location. Fifty grams of oat residues were weighted and maintained in nylon mesh bags (50 x 50 cm) with five replications. These residue samples were kept at the soil surface under similar condition from where they were collected. Residue samples were collected at monthly intervals. They were brought to the laboratory to be washed, dried, weighed, and later returned to the field (modified procedure from Summerell & Burgess, 1989). Decomposition was evaluated by weight difference through time and expressed as a percentage of the remaining residue in function of time.

The survival of the pathogen in its saprophytic phase was carried out in both locations using white oat residues of UPF 7 and UFRGS 15 cultivars. Residues were naturally maintained at the soil surface from where five samples of residues, at monthly intervals, were taken to the laboratory in order to assess the pathogen presence (conidia and ascospores). Five grams of residues were chopped in pieces of 2 cm long, added into an Erlenmeyer containing water (100 ml) with spreader and shaken during five minute to remove the spores. Spore counting in the water suspension was done under the microscope by counting all spores in a known drop of suspension. Data were expressed as the number of spores per gram of residue in function of time.

RESULTS

In Passo Fundo the white oat UPF 7 residues broke down in 18 months and black oat in 17 months. The pathogen (conidia of *D.* avenae) was not detected 17 months after harvest in this location. In Eldorado do Sul, the time for complete decomposition of the white oat UFRGS 15 was 16 months and the pathogen (conidia of *D.* avenae) was not detected 15 months after harvest.

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POSTER

STABILITY ANALYSIS FOR COMPARING OATS RECOMMENDED CULTIVARS

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ABSTRACT

Genotype-environment interactions are of major importance to the plant breeder in developing improved varieties and to recommend cultivars from specific or general locals. The goal of this paper is to test the stability of 15 oats cultivars in 4 locals and 2 years. The stability parameters were calculated according to the model proposed by Eberhart and Russel (1966). Results indicated a high genotype x environment interaction. The cultivar UPF16 was superior in grain yield and the cultivar UFRGS7 was the lowest. The cultivar CTC1 was the most stable, but did not show a good grain yield. The cultivar CTC5 would be indicate for the adverses environments and the cultivar UPF17 would be recommended to favorables environments.

INTRODUCTION

The knowledge of nature and relative magnitudes of the various types of genotype-environment interactions is important in making decisions concerning breeding methods, selection programs and testing procedures in crops. These analysis may show the necessity or not to recommend some genotypes for determinate environments. According to Carvalho et al (1983), most genotypes do not perform satisfactorily in all environments but some tend to be closer to the ideal than others.

This paper had the objective to test the stability of some oats recommended cultivars. It includes an estimation of the application and consideration of regression methods as applied to the study of the nature of genotype-environment interactions.

MATERIAL AND METHODS

Grain yield data were obtained from 15 recommended oat cultivars trials made in four locals (Passo Fundo and Vacaria-RS, Entre Rios and Ponta Grossa- PR) for two years (1995 and 1996). The experiments were layout in randomized complete block designs with three replications. The genotypes include UPF7, UPF13, UPF14, UPF15, UPF16, UPF17, UFRGS7, UFRGS10, UFRGS14, UFRGS15, UFRGS16, CTC1, CTC2, CTC3, and CTC5.

The data were first submitted to analysis of variance and after to a regression analysis where we considered the variables environmental index (X) and genotype yield (Y). The environmental index was calculated by substracting the geral mean of the experiment to the means of all cultivars in each environment. The linear regression coefficient (bi) shows how the cultivar behave (i) can be altered with the environment alteration (Ij). The stability parameters for genotypes were calculated according to the model proposed by Eberhart and Russell (1966). The grain yield was compared with the Duncan test and the significance of the deviation from regression was determinate by F-test. The hypothesis of the linear regression coefficient was not different to 1,0 (b=1), determinate by T-test.

RESULTS AND DISCUSSION

The variance analysis showed that the interaction components of genotypes x locations, genotypes x years and genotype x locations x years were highly significant ($p < 0,01$), being that genotype x local interaction had more effect. This indicated that the cultivars yields changed in function of environment conditions of years and locals.

The grain yield, the linear regression coefficient, the deviation from regression and the determination coefficient are showed in the Table 1. The cultivar UPF16 was superior in grain yield (3363 kg/ ha) for the four locals and for the two years when compared with the others genotypes, being that the cultivar UFRGS7 was lower.

Table 1 - Grain yield (x= kg/ha), regression coefficient (b), deviation from regression (S^2di)) and determination coefficient (R^2) of 15 oat genotypes tested in 4 locals and 2 years

Gentypes	x	b ± sb	sdi^2	R^2
UPF7	2081	1,065 ± 0,132	260626,783 **	0,75
UPF13	2159	1,213 ± 0,142	299842,134 **	0,77
UPF14	2265	0,930 ± 0,103	158010,908 *	0,79
UPF15	2609	0,894 ± 0,115	196474,976 **	0,73
UPF16	3363	1,115 ± 0,188	525581,385 **	0,61
UPF17	3077	1,322 ± 0,121 *	216380,615 **	0,84
UFRGS7	1790	1,000 ± 0,138	284229,273 **	0,70
UFRGS10	2184	1,195 ± 0,169	422760,458 **	0,69
UFRGS14	2786	0,995 ± 0,138	281167,965 **	0,70
UFRGS15	2876	0,762 ± 0,152	345194,621 **	0,53
UFRGS16	2930	0,737 ± 0,142	299565,288 **	0,55
CTC1	2114	1,038 ± 0,089	117036,484 NS	0,86
CTC2	2994	1,069 ± 0,138	284379,412 **	0,73
CTC3	2991	0,882 ± 0,144	309667,095 **	0,63
CTC5	2868	0,783 ± 0,097 *	139719,190 NS	0,75

* and ** indicate significance at the 5% and 1% level of probabillity, respectively. NS not significant.

In relation to the regression coefficient three groups of genotypes were obtained: b=1,0; b> 1,0 and b< 1,0.

- The genotypes UPF7, UPF13, UPF14, UPF15, UFRGS7, UFRGS10, UFRGS14, UFRGS15, UFRGS16, CTC1, CTC2, CTC3 showed values for b equal to one. These genotypes will be more appropriate to cultivation in function of theirs response to the increment of the environment.
- The only genotype with significant values for b < 1,0 was CTC5. This cultivar would be indicated for the adverses environments because it showed a good grain yield (2868 kg/ha).
- The cultivar UPF17 showed a significant b > 1,0 with a higher grain yield (3077 kg/ ha). According to these parameters the cultivar UPF17 would be recommended for favorables environments.

For the deviation from regression, the majority of cultivars were highly significant. These results are according to those obtained by Carvalho *et al.* (1983) and Federizzi *et al.* (1993). The cultivars CTC1 and CTC5 did not show the deviation from significative regression. Considering the parameter deviation from regression and regression coefficient, the cultivar more stable was CTC1. However this cultivar showed low grain yield.

According to the stability concept any cultivar would be denominated stable when the parameters yield, regression coefficient and deviation from regression are considered.

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POSTER

IDENTIFICATION OF ARGENTINEAN OAT VARIETIES WITH RAPD MARKERS

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INTRODUCTION

Varietal identification has an important role in plant breeder's rights regulation. Cultivar registration is traditionally based on visual distinctiveness evaluated over a period of time, by comparisons with standard or existing cultivars, under the same growing conditions. Evaluation of morphological features, though still extremely useful and used, has several limitations. They require the plant to be grown to a suitable developmental stage before certain characters can be scored. Besides, extensive observations of a large set of phenotypic and physiological data should be accomplished, and this is often difficult to assess, and sometimes variable due to environmental influences. Furthermore, with the continuous introduction of varieties into the marketplace, it is becoming increasingly difficult to discriminate among them with the use of morphological markers alone.

Several methods have been utilized in order to supplement observations on morphological data for establishing copyright and checking on the labeling or purity of seed samples. Among them, storage proteins and isozyme electrophoresis are the most widespread, and have been successfully utilized on oats (Singh *et al.* 1973; Almgård and Clapham, 1975). Nevertheless, because proteins are the product of gene expression, they may vary in different tissues, developmental stages and environments (Beckman and Soller, 1983). The major limitation of these techniques is, however, the low level of polymorphism among closely related cultivars, insufficient for discriminating among them (Yang and Quirós, 1993).

More recently, the advent of DNA markers, such as RFLPs (Restriction Fragment Length Polymorphism) provided new tools for genotype identification. This method has several advantages, including independence from environmental conditions, unlimited numbers and ubiquitous occurrence. O'Donoghue *et al.* (1994) were able to discriminate among 83 North American oat varieties using this technology. RFLPs are, however, relatively costly, technically demanding, and time consuming. As an alternative, RAPDs (Randomly Amplified polymorphic DNA) constitute a faster and easier approach for exploring genetic variation. Varietal identification, characterization and classification based on RAPDs have been carried out in several crop species. (Mori *et al.*, 1993). This presentation is a report of the ongoing work aimed at achieving a PCR-based methodology for oat cultivar identification in Argentina.

MATERIALS AND METHODS

Plant material and DNA isolation

In this study we analyzed 15 varieties of oats, 14 from Argentina and 1 from Chile (Table 1). For each genotype, 5 seeds were grown in the greenhouse at Agri Food Canada, (Ottawa) and DNA was extracted from one single plant, by the method of Saghai-Maroof *et al.* (1984). In order to assess intra-varietal uniformity, 15-25 seeds from several cultivars were germinated at room temperature in Petri dishes and DNA from the seedlings was extracted by the method of Edwards *et al.* (1991).

Table 1. Cultivars used in the present study.

Accession number	Country	Name
C-85-1290	Canada	Random
(purchased at Temuco)	Chile	Nehuén Imperial
94-719	Argentina	Boyera f.a.
94-750	Argentina	Bonaerense Gringa
94-812	Argentina	Bonaerense Payé
94-843	Argentina	Buck Epecuén
94-874	Argentina	Buck 152
94-905	Argentina	Cristal inta
94-936	Argentina	Don Víctor
94-967	Argentina	Millauquén inta
94-998	Argentina	Moregrain
94-5329	Argentina	Suregrain
94-5360	Argentina	Amarilla Tomé
94-5458	Argentina	Tambera f.a.
(Old cultivar)	Argentina	La Previsón 13
(Original Bordenave)	Argentina	Máxima inta

Polymerase chain reaction

PCR was performed as described by Baum *et al.* (1997). In order to obtain consistent results, careful attention was paid to DNA quality and concentration (Willams *et al.*, 1990). Amplification products were resolved on 1.6% agarose gels. The gels were stained with ethidium bromide, visualized with UV light and photographed with an FRC 10 camera (Fotodyne) using Polaroid 665 film.

Results and Perspectives

Cultivar ID

The level of polymorphism found was low compared to other crops (Yang and Quirós 1993). Only eleven out of the approximately 370 primers screened for the present study yielded polymorphic bands (OPAA11, OPAA17, OPAB1, OPAB2, OPAB5, OPAB18, OPD2, OPD3, Operon Technologies Inc., and G902, G904 and G907, Genosys, Inc.). Nevertheless, the 27 polymorphic bands produced by those 11 primers exceeded the 11 markers needed to allow distinction among any given two varieties of Argentinean and/or Canadian oats with an appropriately selected set of primers (Guillin and Baum, unpublished results).

No cultivar-specific band was detected for the Argentinean oat varieties analyzed. All of them were discriminated according to their RAPD profiles. For assessment of intra-variety uniformity, several primers were applied to PCR of individual plants of cultivars Random, Bonaerense Gringa, Nehuén Imperial and Boyera. All primers tested displayed total intra-variety consistency in the banding profiles of individual plants.

A key to identify all of the cultivars examined was elaborated based on their non-duplicated DNA profiles, and is provided below:

1(0). OPAA11 -600 absent.. 2
OPAA11-600 present.. 9
2(1). OPAB1 -850 absent... 3
OPAB1 -850 present.. 6
3(2). OPAA11 -855 absent.. 4
OPAA11-855 present.. 5
4(3). OPAB2 -250 absent... 15. Amarilla Tome
OPAB2 -250 present.. 14. Boyera FA
5(3). OPAB2 -250 absent... 2. Buck 152
OPAB2 -250 present.. 4. Cristal, INTA
6(2). OPAB2 -250 absent... 7
OPAB2 -250 present.. 8
7(6). OPAA11 -855 absent.. 6. Bonaerense Gringa
OPAA11-855 present.. 5. Don Victor
8(6). OPD2 -420 absent... 1. Bonaerense Paye
OPD2 -420 present.. 3. Buck Epecuen

9(1). OPAA11 -855 absent..........	10
OPAA11-855 present..........	12
10(9). OPAB1 -850 absent..........	11
OPAB1 -850 present..........	9. Nehuen Imperial
11(10). OPAA11 -250 absent..........	11. La Prevision 13
OPAA11-250 present..........	13. Maxima, INTA
12(9). OPD2 -420 absent..........	13
OPD2 -420 present..........	14
13(12). OPAA11 -860 absent..........	12. Tambera F.A.
OPAA11-860 present..........	10. Suregrain
14(12). OPAB1 -850 absent..........	7. Millauquen, INTA
OPAB1 -850 present..........	8. Moregrain

RAPD analysis, pros and cons

The advent of PCR based technology for cultivar identification might become an extremely useful tool for the implementation of breeder's rights. This point has particular relevance when the current shift in breeding objectives, from higher yields to sustainable production and tailored varieties for industrial use is taken into account.

RAPD technology is fast, economic and technically undemanding. It can be used as routine work in laboratories where economic constraints are the key factor to be taken into account. Since the amounts of DNA needed for PCR are very small, cultivar identification could be performed starting from a very limited amount of plant tissue, such as single seeds, young seedlings or embryos. If representative of the whole genome, RAPDs can also provide with an accurate representation of the crop genetic diversity.

There is also an important limitation for RAPD analysis with regards to varietal diagnosis: It is absolutely critical to maintain strictly consistent reaction conditions in order to achieve reproducible profiles. In our experience, the protocol herein proposed is extremely dependable, provided that PCR parameters are kept constant. In practice, however, it is not possible to predict which changes could possibly undergo within a research laboratory. In the present case, for instance, this procedure was developed at Dr. Baum's laboratory, and will be carried out in Buenos Aires. Therefore, efforts aimed at the standardization of this methodology are currently underway at the Instituto Nacional de Semillas (INASE SAGyP). Since only seven markers are necessary for complete characterization of any Argentinean oat variety, future work aimed at designing SCAR markers is being planned. Development of specific markers will allow to achieve independence from reaction environment, and might prove useful for inter-laboratory exchange.

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POSTER

ALUMINUM TOXICITY IN OAT GERMPLASM, SCREENING IN HYDROPONIC SOLUTIONS

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ABSTRACT

Twenty-one oat (*Avena sativa L.*) genotypes from the UFRGS breeding program, were evaluated for their reaction to aluminum toxic levels in nutrient solutions. The aluminum levels tested were 5, 10, 15, 20 ppm and root regrowth was evaluated after 48 hours in presence of Al. Phenotypic variability was observed at 20 ppm level and two groups one of tolerant and other of sensitive genotypes were discriminated for future genetic studies. Furthermore, the results of this study suggest that the hydroponic method is reliable for screening germplasm to aluminum toxicity and may be used in breeding programs .

INTRODUCTION

The oat area and production for industrial uses, have increased significantly in the southern of Brazil. New genotypes have been obtained for modern agriculture development. Acid soils with excess of aluminum (Al^{3+}) are common in Brazil and are one of the main factors of plant toxicity of several species (Rincón & Gonzales, 1992). Some aluminum toxicity effects, include interference with cell root division and DNA replication in the mitotic cycle, decrease of root respiration, interference with uptake , transport and use of nutrients and water (Foy & Fleming, 1978).

Several studies were conducted for understanding the mechanisms of aluminum stress and its genetic basis in wheat, barley, rice, corn and soybean. In oat, variability for aluminum toxicity has been observed (Bilski & Foy, 1987; Floss,1992). However, the genetic mechanisms for the tolerance in oat has not been studied.

Plant aluminum sensitivity can be detected by several methods. An easy, effective and reliable method is using hydroponic nutrient solutions. Measuring of the root regrowth after submitting to Al stress solution makes possible to separate tolerant and sensitive genotypes (Camargo & Oliveira, 1981; Dornelles, 1994). The objectives of this study were: to identify an adequate level of Al for selection of tolerants oat genotypes and to characterize oat elite germplasm for genetic studies.

MATERIALS AND METHODS

Experiments were developed in Tissues culture laboratory of the Department of Plantas de Lavoura (Universidade Federal do Rio Grande do Sul - UFRGS) in 1994,1995 and 1996. The germplasm had included elite genotypes from the UFRGS oat breeding program and was tested in two groups: group I (in 1994) and group II (in 1995). Seeds of each genotype were, disinfected with 10% sodium hypochlorite solution for 15 minutes and repeatedly washed in distilled water, after placed on petri dishes with filter paper, the plates were placed in refrigerator at 5 ^{0}C for five days and transferred to a growth chamber at 25 °C for two days. The nutrient solution was: made of: 4mM Ca $(NO_3)_2$; 2mM Mg SO_4; 4mM KNO_3; 0,435mM $(NH_4)_2SO_4$; 0,5 mM KH_2PO_4; 2uM $MnSO_4$; 0,3uM $CuSO_4$; 0,8 uM $ZnSO_4$; 30uM NaCl; 10 uM FeEDTA; 0,10uM $NaMoSO_4$; 10uM H_3BO_3.

The composition of the treatment solution was one tenth of the nutrient solution without addition of phosphorus to avoid precipitation of Al and aluminum added as $Al_2(SO_4)_3.18H_2O$. Genotypes of Group I were tested with 5, 10 ,15 and 20 ppm of Al and of Group II with 5, 10 and 20 ppm. The components of solutions were dissolved in distilled water and placed into 8,3 liters plastics recipients. The pH was adjusted to 4,0 with 0,1 M HCl and daily checked. The evaluation was made measuring the regrowth of principal root of each genotype.

The genotypes into each aluminum level were arranged in a completely randomized design. The 1994 experiments contained three replicates and 1995 ones, four replicates. Six seedlings were grown per Al x genotype combination in each replicate.

RESULTS AND DISCUSSION

Aluminum toxicity, as observed in this study, induced different effects in the root regrowth of oat genotypes tested after 48 hours, at the four levels of Al^{3+} in the nutritive solution. The results obtained showed phenotypic variability among elite genotypes selected in 1994 and 1995 (Table 1). The differences observed in each genotype and level Al^{3+} concentration were statistically significant and the most variation was among genotypes within each aluminum level. The ratio of tolerant/sensitive genotypes at 15 ppm was 10:6 and at 20 ppm 5:16. The higher severity of aluminum on the root regrowth size was observed at 20 ppm and this level was chosen for screening germplasm tolerant to aluminum toxicity. Other studies in oat have shown that there is Al toxicity between 7 to 30 ppm (McLean & Gilbert, 1927; Bilski & Foy, 1987). The results from the 1996 experiment confirmed the performance of the elite oat genotypes obtained in the previous experiments in similar conditions (Table 2).

The present study has shown that exist phenotypic variability for Al^{3+} reaction among oat elite genotypes growing in the southern of Brazil. The level of 20 ppm is adequate for screening the oat germplasm using hydroponic nutrient solutions. This variability will be used for genetic studies and as a future source of tolerant germplasm.

Table 1. Root regrowth of 21 oat genotypes treated with four aluminum levels in nutrient solutions. UFRGS / 1994-1995

GENOTYPE	TREATMENTS (ppm)											
UFRGS		5			10			15			20	
10	a	20.2	ABC	a	18.4	A	b	14.7	A	b	11.3	A
898065	a	20.5	AB	b	17.0	ABC	c	13.3	ABC	d	8.3	CDE
17	a	18.8	ABCD	b	14.9	BCDE	b	14.2	AB	c	11.0	AB
912098	a	21.9	A	b	14.3	CDEF	bc	12.6	ABCD	c	9.9	ABC
4	a	17.7	BCDE	a	17.6	AB	b	13.4	ABC	c	7.1	DEFG
884077	a	17.8	BCDE	ab	15.4	ABCD	b	12.9	ABCD	c	9.7	ABCD
15	a	19.2	ABC	b	16.2	ABCD	c	11.6	BCDE	d	8.6	BCDE
901707	a	17.6	BCDE	a	16.4	ABCD	b	11.6	BCDE	c	8.5	BCDE
884021	a	17.7	BCDE	a	15.6	ABCD	b	7.7	H	c	5.1	GH
14	a	15.4	DEFG	b	11.6	FG	bc	10.4	DEFG	c	7.8	CDEF
911740	a	16.7	CDEF	b	13.9	CDEF	c	10.6	CDEFG		3.5	HI
881971	a	13.8	FG	a	12.2	EFG	b	8.6	FGH	c	5.7	FGHI
884020	a	14.8	EFG	b	11.9	EFG	b	9.2	EFGH		3.4	HI
90787	a	14.8	FG	b	9.3	GH	bc	8.2	GH	c	6.9	EFG
16	a	11.9	G	b	8.5	H	c	4.8	I	c	3.7	HI
911715	a	13.2	FG	b	7.9	H	c	3.7	I	c	1.8	I
93605*	a	15.2	AB	ab	13.8	A		-		b	12.2	A
93506*	a	16.0	A	b	12.2	AB		-		b	10.6	A
930584*	a	14.5	AB	b	11.7	AB		-		b	10.1	A
93600-4*	a	13.5	AB	b	10.4	B		-		c	5.4	B
93598-6*	a	12.0	B	b	6.5	C		-		c	3.2	C

Means followed by the same letter in columns (capital letters) and in the same row (small letters), do not differ by Duncan's significant difference test (P= 0.05),for the group I (1994 and group II 1995). *Genotypes tested in 1995

Table 2. Root regrowth of genotypes selected to genetic aluminum toxicity studies. UFRGS-1996

GENOTYPE	TREATMENTS (ppm)								
UFRGS		5			10			20	
93605	a	14.2	A	a	11.8	A	a	11.1	A
10	a	15.5	A	a	13.7	A	a	10.0	A
17	a	14.3	A	a	13.0	A	a	11.5	A
93506	a	13.7	A	a	10.1	B	a	9.3	A
912098	a	14.1	A	a	12.5	A	a	9.5	A
93600-4	a	11.6	AB	ab	8.8	BC	b	5.2	C
16	a	9.4	AB	a	6.5	C	a	5.0	C
93598-6	a	13.5	AB	b	6.1	C	b	4.6	C
911715	a	13.1	AB	a	9.0	B	a	6.8	BC

Means followed by the same letter in columns (capital letters) and in the same row (small letters), do not differ by Duncan's significant difference test (P= 0.05)

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POSTER

EARLY FORAGE YIELD EVALUATION IN OAT (*Avena Sativa* L.) GENOTYPES UNDER TWO ENVIRONMENTAL SITUATION OF HUMID ARGENTINEAN PAMPA

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ABSTRACT

Improvement of forage yield in oat (*Avena sativa* L.) depends on thorough understanding of the influences of genotype, environment and the genotype x environment interaction (G X E). The objective of the present study was to evaluate the early forage yield of oat genotypes taking into account the probably presence of genotype x environments interactions (G X E). Twelve genotypes were grown in different environments during three years (1993-94-95) at the locations of La Dulce and La Plata, Buenos Aires Province, Argentina. The forage yield (dry matter yield Kg/ha) was determined at 60, 100 days after emergence. A highly significant environment SS was observed (41.15 % of the total SS $p<.001$). The genotype SS also recorded a highly significant variation (2.32 % of Total SS $p<0.01$). The AMMI analyses showed a highly significant G X E (36.36 % $p<0.001$). The biomass production rate-trial location relation was an important contribution to the significant of GXE interaction. This knowledge will be very important to establish the grazing techniques according to forage offer that the commercial genotypes and advanced lines have presented.

INTRODUCTION

Oat (*Avena sativa* L.) has become a very important forage cereal in Argentina. Seventy percent of its production is used for this purpose. In recent years the planted area has grown (nearly two million ha) simultaneously with increment in the number of commercial cultivars. This large planted area has different edaphic and climatic conditions. The environmental diversity acts as a limiting factor of both the relative performance of commercial cultivars and the selection process. The commercial cultivars differ in its agronomics trait such as: cycle, grown rate and habit, regrown capacity and levels of resistance to biotics and environmentals factors. The objective of the present study was to evaluate the early forage yield of oat genotypes taking into account the probably presence of genotype x environments interactions (GXE).

MATERIAL AND METHODS

Trials were carried out during 1993, 1994 and 1995 at La Dulce (38 45' S, 58 30'W) and La Plata (34 55' S, 57 57'W), which are within 520 km each other. The following cultivars were studied: Boyera F.A., Tambera F. A., Buck 152, Buck Epecuen, Cristal INTA, Millauquén INTA and Bonaerense Payé. Line 1, line 13, line 14, and line 35 were evaluated, they belong to Criadero A-1349 (INASE) Cátedra de Cerealicultura, Departamento de Producción Vegetal, Facultad de Ciencias Agrarias y Forestales (UNLP). La Plata. Argentina.

Two clippings of material were performed ($1 m^2$/plot). We determined dry matter yield (kg/ha) at first clipping (60 days after emergence), dry matter yield at second clipping (approximately 100 days after emergence). A randomized plot design with four replicates and a plot size of 7.7 m^2 (seven 5.0 m rows spaced 20 cm apart) was used.

AMMI analysis

$$Y_{ijk} = \mu + \alpha_g + \beta_e + \Sigma_n \lambda_n \gamma_{gn} \delta_{en} + \rho_{ge} + \varepsilon_{ger}$$

Where: Additive parameters: μ is the grand mean; α_g is the genotype mean deviation; β_e is the environment mean deviation;

Multiplicative parameters: λ_n eigenvalue of the principal component analysis (PCA) axis, n; γ_{gn} and δ_{en} are the genotype and environment PCA scores for the PCA axis n; N is the number of PCA axes retained, ρ_{ge} residual of AMMI; ε_{ger} error term. It is a mixed model, with genotypes as fixed factor and environment and replicates as aleatory ones.

The interaction SS was divided into N axes of principal components. Its degrees of freedom were calculated by the methodology of Gollob (1968):

D.F = G + E - 1- 2n where: G is the number of genotypes; n is the number of retained axes; E is the number of environments. Results obtained by principal components analysis were detailed in a biplot (Kempton, 1984). AMMI analysis was carried out using SAS software (SAS Institute, 1988).

RESULTS AND DISCUSSION

Results were detailed in Table 1. A highly significant environment SS was observed (41.15 % of the total SS $p<.001$). The genotype SS also recorded a highly significant variation (2.32 % of Total SS $p<0.01$). The AMMI analyses showed a highly significant G X E (36.36 % $p<0.001$).

The AMMI showed a first PCA axis which accounted for 57.99% of the variation of the interaction SS ($p<0.001$). The second and third PCA axis explained 29.03% and 6.27 % additional of the interaction SS ($p<0.001$). The residual left by AMMI was nonsignificant. The AMMI model as a whole accounts for 85.39% of the total SS (environment + genotypes + GXE interaction), with 79 degrees of freedom (11 for environment, 11 for genotypes and 57 for GXE interaction).

Table 1: Additive main effects and multiplicative interaction (AMMI) analysis of forage yield during the period 1993-1995. Three PCA axes was included.

Source	D.F	S.S(¥)		%S.S
Total	575	13347.77		
Genotype	11	1051.80	* §	7.88 a
Environment	11	5492.75	*** #	41.15 a
Blq/Site	36	309.67	** ¶	2.32 a
GXE	121	4854.30	*** ¶	36.36 a
PCA 1	21	2815.01	*** ¶	57.99 b
PCA 2	19	1409.20	*** ¶	29.03 b
PCA 3	17	304.36	*** ¶	6.27 b
Resd	64	325.70	n.s ¶	6.71 b
Error	396	1639.24		12.28 a

¥ : S.S : Sume of Square: Actual values = reported values x 10^4.
*,**,*** : significant at the 0.05, 0.01 and 0.001 probability level, respectively. n.s: nonsignificant.
§: Tested against GXE Mean Square (MS) #: Tested against Block/Env. M.S.
¶: Tested against Error M.S.
%S.S: percent of S.S: a: respecting of Total S.S. b: respecting of GXE S.S.

Figure 1 presents a biplot of AMMI results. The abscissa shows the main effects (genotypes and environments means) and the ordinate shows the first PCA axis. Three groups of genotypes were visualized. The greenbug tolerant commercial cultivars and advanced lines conformed a group with forage yield similar o above to the grand mean. This germplasm has shown low or intermediate PCA 1 axis values that reflect a high or intermediate stability. There was a close association between this group and the first clipping environments, reflecting the "precocity" and high biomass production rate of these genotypes. These two features could be related both *Schizaphis graminum* resistance gene incorporated into this germplasm and the selection process employed (controlled and field conditions).

At the second clipping the late and non tolerant genotypes (Millauquen INTA, Cristal INTA and Bonaerense Payé) have showed a superior forage yield. There was a close relation between this genotypes and the second clipping environments. The biomass production rate-trial location relation was an important contribution to the significant of GXE interaction. This knowledge will be very important to establish the grazing techniques according to forage offer that the commercial genotypes and advanced lines have presented.

POSTER

DOUBLE PURPOSE WINTER CEREALS

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ABSTRACT

With the objective of studying the behavior of some winter cereals, focusing cattle breeding and agricultural production, a three year trial was done at the Fundação Agrária de Pesquisa Agropecuária - FAPA. Ten winter cereal genotypes had been studied in three different production systems (without cut, one cut and two cuts). The results showed that some cereals like white and black oats, rye (BR-2) and triticale (IAPAR-23) presented a better grain production, when they were cut once or twice. On the other hand, the wheat cultivar BR-35, the malting barley cultivar BR-2 and the forage barley cultivar Carazinho presented a grain yield reduction when they were cut. In addition, it was noticed a good effect in all oat genotypes for grain quality (thousand kernel weight) when they were cut.

INTRODUCTION

The Cooperativa Agrária Mista Entre Rios, located at Guarapuava, State of Paraná, South Brazil is an organization settled in 1951, in order to shelter German Immigrants after the Second World War. These immigrants, and their descendants, have been highly skilled for agricultural activities. Nevertheless, due to the great weather variability during the winter growing season, crop frustrations have occurred. Beyond this fact, after the summer crop harvest, soil surface remains uncovered, resulting soil erosion. On the other hand, when the growing season is very favorable for the vegetative development, lodging may occur. In the oat crop, an significant grain yield reduction and low quality kernel have been caused by lodging. The objectives of this study are: ① offer to the farmers an alternative way of farming, which can contribute to a more sTable cash income through cattle breeding. ② improve cover crops to protect soils against water erosion ③ increase grain yield and kernel quality through the reduction of lodging. In order to reach these objectives, winter cereals crops were studied for forage production, growth after cutting capability and grain yield production (double purpose).

MATERIAL AND METHODS

During three consecutively years, a trial was repeated with different winter cereals in Entre Rios, Guarapuava, in the State of Paraná, South Brazil. Those trials were done at FAPA. Soil was plowed, followed by a cultivator. An 5-25-25 fertilizer was broadcasted before planting in the whole area. The experiments were sown with an experimental nursery planter HEGE, in the following planting days: 04/26/1994; 04/25/1995 and 04/19/1996 for the systems with two cuts and 06/10/1994; 06/08/1995 and 06/10/1996 for the system without cut. The amount of seed used for the systems with cuts were: oat, rye and barley 400 seeds and wheat and triticale 500 seeds per square meter. The amount of seed used for the systems without cut were: oat and rye 280 seeds, wheat and triticale 400 seeds and barley 250 seeds per square meter. A split plot design was used, with three replicates, where cut system (without, one or two cuts) was installed in the main plot and genotypes in the sub-plot. Plots were six rows five meters long 0.17 meters apart. In order to estimate the biomass and grain yield, four central rows were evaluated. An average of 22.5 kg ha^{-1} of nitrogen was broadcasted during the first two years and 40.0 kg ha^{-1} of nitrogen during the last year. This side dressing was realized 21 days after the emergency of the seedlings and after each cut. The cut height was defined when the earliest genotype was in its booting stage which correspond 5-7 cm from the soil.

RESULTS AND DISCUSSION

Analysis of the dry matter has revealed not only differences among the winter cereals, but also differences among the oat cultivars. It was also realized that cereals respond differently after a cut. The white oats UPF 15, FAPA-1 and the triticale IAPAR 23 increased dry matter production in the second cut. On the contrary, other genotypes, decreased dry matter in the second cut. The differences in the cut answers were provoked by the capability that each genotype has in react after the cut. It was observed that the oat cultivars UPF-15 and FAPA-1 showed a highly growth capacity, along with good tiller emission. On the other hand, it was noticed that rye, wheat, barley and black oat showed a small growth capacity, with a poor tiller emission. Grain yield results are presented in Table 1. There were differences among the production systems, within the materials. There were also differences among the cereals and /or cultivar within the production system. Some cereals were more grain productive in the no cut system (wheat and barley). Others were more grain productive with one cut (triticale, rye, white oat, with the UFRGS-16 exception. The increase of grain yield in some genotypes, at this systems of cutting, should be mostly due to the decrease in lodging, caused by the shorten of plant height and biomass reduction. The capability of tillering after cut, may also contribute to the grain yield increase. Otherwise, the grain yield reduction observed in the other genotypes is caused by the high rate of tiller mortality. There were differences for test weight among the production systems and among the winter cereals and oat cultivars (Table 2). With the exception of wheat BR 35 and triticale IAPAR 23, all other genotypes had an improvement in the test weight after been cut. This improvement is probably due to the fact of the reduction in lodging, resulting heavier grains. To sum up, there are evidences that systems which include cutting of some winter cereals, mainly oat, through grazing or cutting, contribute to increase grain yield and kernel quality.

Table 1. Grain yield in the different systems, in three years of evaluation. FAPA, Entre Rios, Guarapuava, PR, Brazil, 1997.

Genotype	Grain yield (kg/ha)						
	without cut average		one cut average		two cuts average		average
TCL - IAPAR 23	B †	3601 a	A	4050 a	C	1632 b	3095 a
AB - CTC 87b185-B	NS	2927 b		3000 bc		3044 a	2990 a
AB - FAPA 1	B	2704 bc	A	3130 b	AB	2872 a	2902 ab
AB - UPF 15	AB	2883 bc	A	3147 b	B	2646 a	2892 ab
AB - UFRGS 16	B	2304 c	AB	2598 bcd	A	2928 a	2610 bc
TR - BR 35	A	3716 a	B	2017 d	C	1447 b	2393 cd
CE - BR 1	A	2388 bc	A	2453 cd	B	1714 b	2185 de
CEV - BR 2	A	2572 bc	B	2088 d	C	1509 b	2056 e
CEV - Carazinho	A	1603 d	B	906 e	B	674 c	1061 f
AP - GAROA	B	361 e	AB	582 e	A	789 c	578 g
Average	A	2506	A	2397	B	1925	2276
CV (%)		17,9					

† Means followed by the same letter are not significantly different at the 0.05 probability level (Tukey test).TCL = triticale, AB = white oat, CE = rye, TR = wheat, CEV = barley and AP = black oat

Table 2. Test weight in the different systems, in three years of evaluation. FAPA, Entre Rios, Guarapuava, PR, Brazil, 1997.

Genotype	Test Weight (kg/hl)						
	without cut average		one cut average		two cuts average		average
TR - BR 35	A†	77,0	A	74,9	B	71,6	74,5
TCL - IAPAR 23	NS	68,1		69,2		67,6	68,3
AB - UPF 15	B	46,3	A	54,8	B	44,4	48,5
AB - FAPA 1	B	45,3	A	50,8	B	46,2	47,4
AB - CTC 87b185-B	B	45,3	A	49,3	B	43,9	46,2
AB - UFRGS 16	B	43,1	A	47,6	A	46,5	45,8
AP - GAROA	B	34,4	A	38,9	B	36,5	36,6
Average	B	51,4	A	55,1	B	50,9	52,5
CV (%)		6.0					

† Means followed by the same letter are not significantly different at the 0.05 probability level (Tukey test).TCL = triticale, AB = white oat, CE = rye, TR = wheat, CEV = barley and AP = black oat

POSTER

MINERAL PROPORTION IN PRODUCTS ELABORATED USING FLOUR AND OATMEAL MIXTURES WITH CAKE, COOKIE, AND PASTA.

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ABSTRACT

The products were developed at the Center of Research in Alimentation (CEPA) at the University of Passo Fundo (UPF), at different proportions of flour and oatmeal. The analytic determinations took place under spectrophotometry of atomic absorption upon final solutions of samples obtained by the method of dry mode and by ashes' recovering, through a Perkin Elmer's spectrophotometer. The experimental delineation used was entirely casualized with three repetitions. The results of the analysis were submitted to analysis of variation and comparison of averages using the Tukey's test at 5%. The minerals magnesium, iron, manganese, copper, and zinc showed expressive differences among treatments on pasta and cookie. The minerals manganese and zinc showed expressive differences among treatments on cake. These differences are explained due to the fact that the oatmeal is industrialized with the whole flake.

INTRODUCTION

The oat represents one of the most important cultures of Rio Grande do Sul, used as food, as raw material for the industry or as a form of diversification in the agriculture.

The oat is one of the most nutritive cereals offered by nature to the human alimentation, because it shows a balance of aminoacids nutritionally superior to other cereals, as well a greater proportion of proteins. The oat is rich in dietetic fibers, resulting in excelent physiologic effects.

Mineral substances are components of vegetal and animal tissues which turn into ashes when these tissues are incinerated. These mineral substances perform important rolls in their ionic form in body fluids, as well as part of essential compositions. The milling technology of cereals removes the germ and the outer layers, where most of the minerals are located, while the flour mineral content is relatively low, the remainder of the minerals is promptly available, since some minerals of integral flour are firmly complexed by the concentrations of phytate and fibers.

This research sought to investigate the effect of the substitution of part of flour for oatmeal in cookies, cakes, and pasta, regarding the mineral proportion.

MATERIAL AND METHODS

The products were developed at the experimental bakery of the Center of Research in Alimentation (Centro de Pesquisa em Alimentação - CEPA) at the University of Passo Fundo (Universidade de Passo Fundo - UPF), at different proportions of flour and oatmeal. The research tried to investigate what would be the effect of substituting flour for oatmeal. In the treatments with cake and pasta the levels were: T1=0%; T2=10%; T3=20%; T4=30%; and T5=40%. Regarding the treatments with cookie the levels were: T1=0%; T2=25%; T3=50%; and T4=75%. The analytic determinations took place under spectrophotometry of atomic absorption upon final solutions of samples obtained by the method of dry mode and by ashes recovering using hydrochloric acid, at the CEPA's laboratory of physics and chemistry and at the soils' laboratory of the UPF's College of Agronomy, through a Perkin Elmer's spectrophotometer model 3110, using hollow cathode lamps of only one element. The minerals sodium and potassium were analyzed using a Corning-EEL's photometer. The experimental delineation used was entirely casualized with three repetitions. The results of the analysis were submitted to the analysis of variation and to the comparison of averages using the Tukey's test at 5%.

RESULTS AND DISCUSSION

Table 1 - Mineral proportion in cakes elaborated with different proportions of flour and oatmeal. CEPA/UPF, Passo Fundo, RS, 1996

Treatment	Ca ppm	Mg ppm	Fe ppm	Cu ppm	Mn ppm	Zn ppm
T1 = 0 %	63.96ns	25.05ns	2.34ns	0.08ns	0.36d	0.78b
T2 = 10 %	60.11	28.82	2.56	0.21	0.52cd	0.85ab
T3 = 20 %	61.21	33.66	2.57	0.14	0.68bc	0.90ab
T4 = 30 %	61.43	38.17	3.08	0.26	1.08ab	0.95a
T5 = 40 %	59.67	38.99	2.77	0.23	1.21a	0.91ab
X	61.28	33.29	2.66	0.17	0.715	0.88
C.V. (%)	**11.74**	**13.17**	**12.41**	**27.49**	**8.38**	**4.19**

Averages followed by the same letter don't differ statistically by the Tukey's test (P>0.05); ns: not significative.

Table 2 - Mineral proportion in pasta elaborated with different proportions of flour and oatmeal. CEPA/UPF, Passo Fundo, RS, 1996.

Treatment	Ca ppm	Mg ppm	Fe ppm	Cu ppm	Mn ppm	Zn ppm
T1 = 0 %	34.65ns	32.72c	3.72ab	0.39b	0.59d	1.10c
T2 = 10 %	34.26	40.20bc	2.75c	0.42ab	1.00c	1.24b
T3 = 20 %	44.16	43.61bc	3.24bc	0.40ab	1.26b	1.23b
T4 = 30 %	44.33	59.67abc	3.48ab	0.55a	1.48b	1.39[a]
T5 = 40 %	42.51	71.77a	4.18a	0.53ab	1.91a	1.44[a]
X	40.98	49.60	3.47	0.46	1.25	1.28
C.V. (%)	**16.07**	**10.01**	**4.63**	**7.45**	**4.37**	**1.96**

Averages followed by the same letter don't differ statistically by the Tukey's test (P>0.05); ns: not significative.

Table 3 - Mineral proportion in cookies elaborated with different proportions of flour and oatmeal. CEPA/UPF, Passo Fundo, RS, 1996.

Treatment	Ca ppm	Mg ppm	Fe ppm	Cu ppm	Mn ppm	Zn ppm	Na %	K %
T1 = 0 %	31.86c	16.12c	1.40b	0.10c	0.30d	0.71b	0.42ns	0.14c
T2 = 10 %	35.35b	19.65bc	1.18b	0.10c	0.52c	0.75b	0.44	0.16bc
T3 = 20 %	37.57b	23.86b	1.32b	0.18b	0.68b	0.71b	0.44	0.19ab
T4 = 30 %	41.64a	44.91a	2.04a	0.30a	1.36a	1.23a	0.44	0.23a
X	36.61	26.14	1.48	0.17	0.71	0.85	0.43	0.18
C.V. (%)	**3.91**	**9.93**	**12.90**	**13.15**	**7.66**	**18.17**	**6.56**	**13.27**

Averages followed by the same letter don't differ statistically by the Tukey's test (P>0.05); ns: not significative.

Regarding the obtained results, the minerals magnesium, iron, manganese, copper, and zinc showed expressive differences among treatments on pasta. The minerals manganese and zinc showed expressive differences among treatments on cake. Cookie presented significative differences regarding the minerals calcium, magnesium, iron, copper, manganese, zinc, and potassium. These differences are explained due to the fact that the oatmeal is industrialized with the whole flake.

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