



GENETIC DIVERSITY OF RICE IN PAKISTAN

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Region of Basmati Rice In South Asia

Growing Area of Basmati rice



Pakistan & Rice: National Perspective

- 2nd after wheat
- Consumption 16Kg annual per capita
- Cultivation 10% of total cultivated area
- Area 2.963 m.ha
- Production 6.952 million tones in 2008-09.
- Value addition 5.5% in agriculture
- Share in Pakistan GDP 1.6%

Rice Production - Constraints

- **Biotic factors** BBL, Sheath blight
- **Abiotic factors** Drought, Salinity
- **Salt effected soils** 40-70%

Threatened – Genetic Diversity

- **Land races are generally low yielding, but have**
 - high yield stability
 - Resistance against many biotic and abiotic stresses.
- **Locally grown landraces began to disappear**
(available only in gene banks)
- **Wide adaptability of high yielding semi dwarf varieties**

Rice: National Germplasm Explorations

Expeditions Organized for Rice Germplasm Collection in Pakistan

Expd.	Period	Institute/Sponsor	Area	Collections
1	1921-23	Great Britain	Local landraces from all over subcontinent/Kalar tract	555
2	1972-77	USAID/PARC	All over country	900
3	1985	IBPGR	Balochistan	201
4	1987	IBPGR	Sind	196
5	1989	NIAR-Japan/PARC	Except Sindh	58
6	1991	NIAR-Japan/PARC	NWFP	191

Rice: Varieties Development – Time Line (1926)

- Rice Research Institute - Kala Shah kaku (1926).
- Initially purification of local landraces.
- Classification – sixteen commercial groups

Classification of local rice lines into agricultural commercial groups on the basis of morphological traits.

Sr#	Group	Accessions	Sr#	Group	Accessions
1	Bara/Hansraj	9	9	Mushkan	50
2	Basmati	51	10	Palman	17
3	Begmi	9	11	Ratria	22
4	Dhan	27	12	Red Rice	21
5	Jhona Kasarwala	54	13	Santhi	13
6	Jhona	96	14	Sathra	24
7	Jhoni	17	15	Sone	42
8	Kharsu	13	16	Kangra Valley Rice	90
Total =555 accessions					

Rice: Varieties Development – Time Line (1947)

- Development of different varieties by pure line selection
- Basmati-370 – high quality rice (long grain, strong aroma, soft texture)
- Jhona-349 – salt tolerant and short duration.
- Lack of rice germplasm – limitations for the breeders

Varieties developed by pure line selection from sixteen commercial groups

Sr #	Variety	Year	Parentage	Varietal group
1	Basmati 370	1933	Pure line selection	Aromatic
2	Mushkan-7	1933	Pure line selection	Aromatic
3	Mushkan-41	1933	Pure line selection	Aromatic
4	Jhona 349	1933	Pure line selection	Non-aromatic
5	Sathra-278	1934	Pure line selection	Non-aromatic
6	Mahlar-346	1939	Pure line selection	Non-aromatic
7	Palman-246	1939	Pure line selection	Non-aromatic

Rice: Varieties Development – Time Line (1948-04)

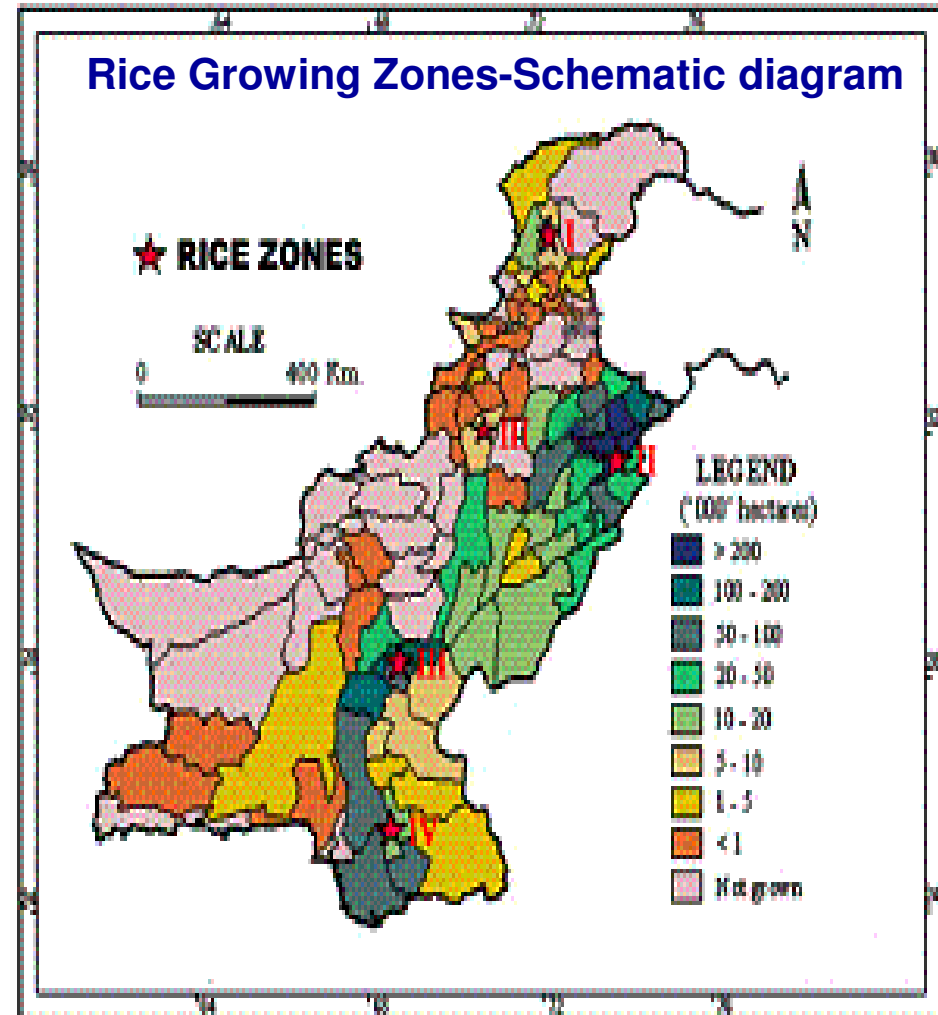
Green revolution in 1960

- Introduction of semi dwarf high yielding varieties from IRRI
- IR-8 – Approved as IRRI-Pak (High yielding, poor cooking qualities)
- Approval of IR-6 for cultivation (1971).
- Hybrid varieties development (crossing indigenous pure lines with others)

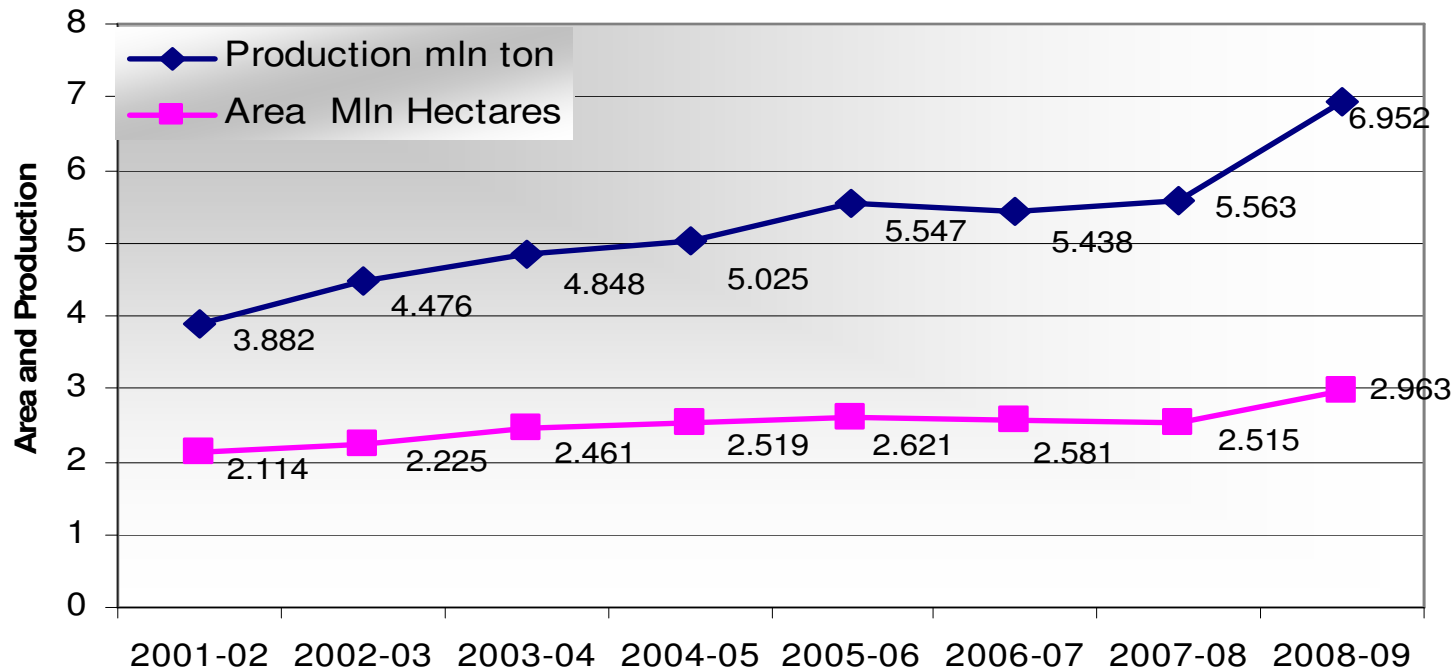
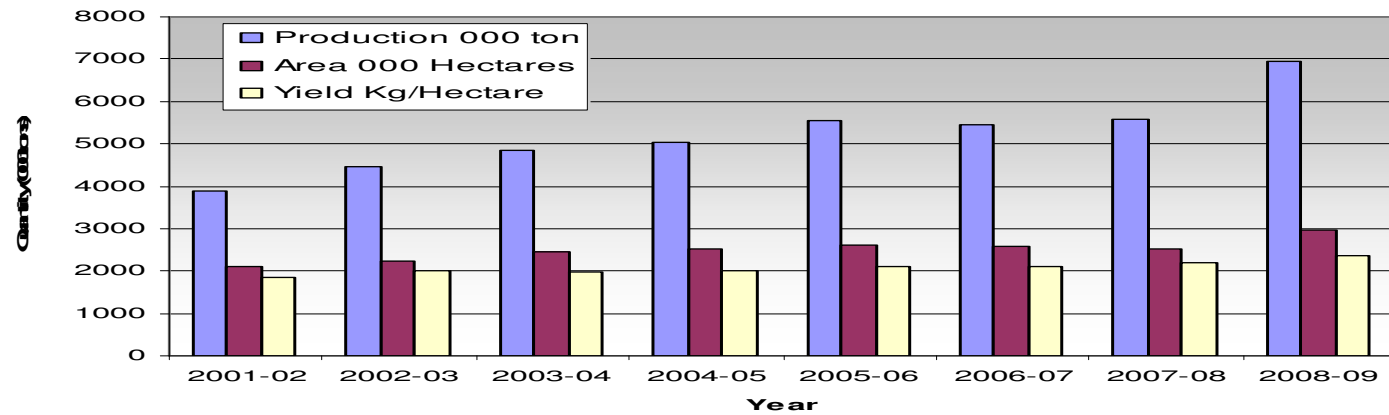
Variety	Year	Parentage
C-622	1964	Basmati 370xMushkan7
Basmati Pak	1968	Pure Line (Kernal Basmati)
IRRI Pak	1969	Introduction from IRRI (Peta x DGWG)
IR-6	1971	Introduction from IRRI (Saim29xDGWG)
Basmati 198	1972	Basmati 370 ³ x TN1
Pak177	1977	Basmati 370xIR760
KS282	1983	Basmati 370xIR95
Basmati 385	1988	Basmati 370 ⁴ x TN1
Super Basmati	1996	Basmati 320x10486
Basmati 2000	2001	Basmati 385x4048-3

Rice Growing Zones In Pakistan

Zone	Characteristics
Zone I	Northern high mountainous areas (Swat and Khaghan) with sub-humid climate, average rainfall of 750-1000mm
Zone II	Lies between Ravi and Chenab, Sub-humid, sub-tropical climate with average rainfall of 400-700mm. Basmati - highly aromatic grain, long and elegantly thin mainly grown in this zone along the Kallar Tract consisting of Sailkot, Sheikhupura, Narowal, Gujranwala, and Hafizabad and Lahore Districts.
Zone III	West bank of Indus river. Larkana, Jacobabad, Nasirabad and Jaffarabad . High temperature and sub-tropical climate with average rainfall of 100mm make it best suited for medium long rice.
Zone IV	Spill flats and basins of Indus delta (Badin and Thatta Districts). Its climate is arid tropical and is suited for coarse varieties.

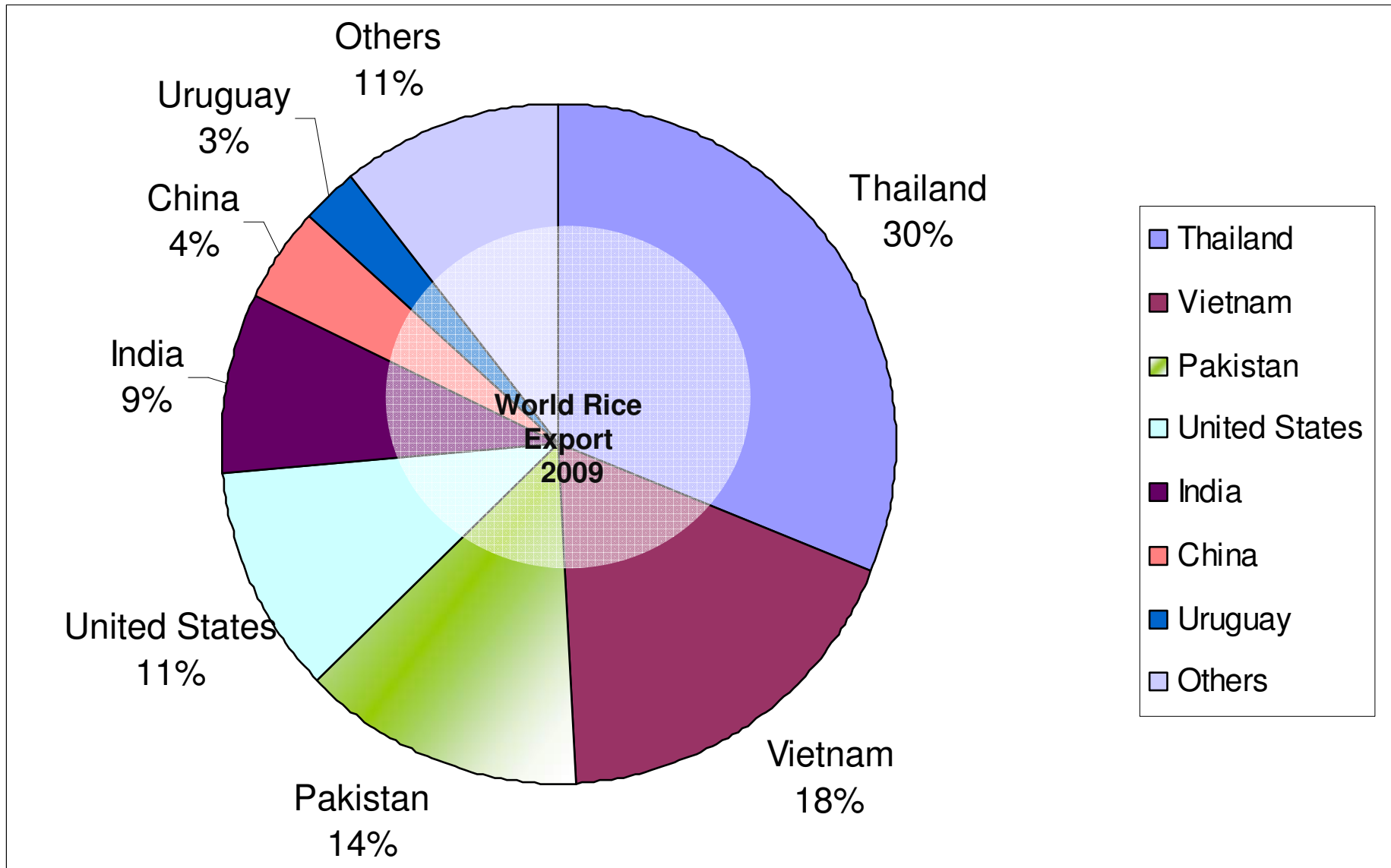


Pakistan Rice-Production and Area



Share in World Rice Export

- Pakistan shares 14% of world trade



World Rice Trade- 2008

- **Total Production** **667.7 m tones**
(paddy)
- **Rice Global Trade** **30.2 m tones (7% of milled rice)**
(milled rice)
- **Basmati Rice trade** **2.45 m tones (8.3% of all rice trade)**
 - India** **1.183 m tones**
 - Pakistan** **1.271 m tones**

Basmati Rice Trade

Basmati Export						
Quantity 1000 tones	2003	2004	2005	2006	2007	2008
India	708.8	771.5	1163.0	1166.6	1045.7	1183.4
Pakistan	716.7	816.3	814.9	839.0	907.9	1271.4
Value million USD						
India	415.8	433.7	628.5	687.3	616.7	1079.1
Pakistan	267.7	308.4	439.2	479.6	556.3	1068.9

Basmati Rice: Source of Revenue

Year 2008

Total: **\$2.044 billion**

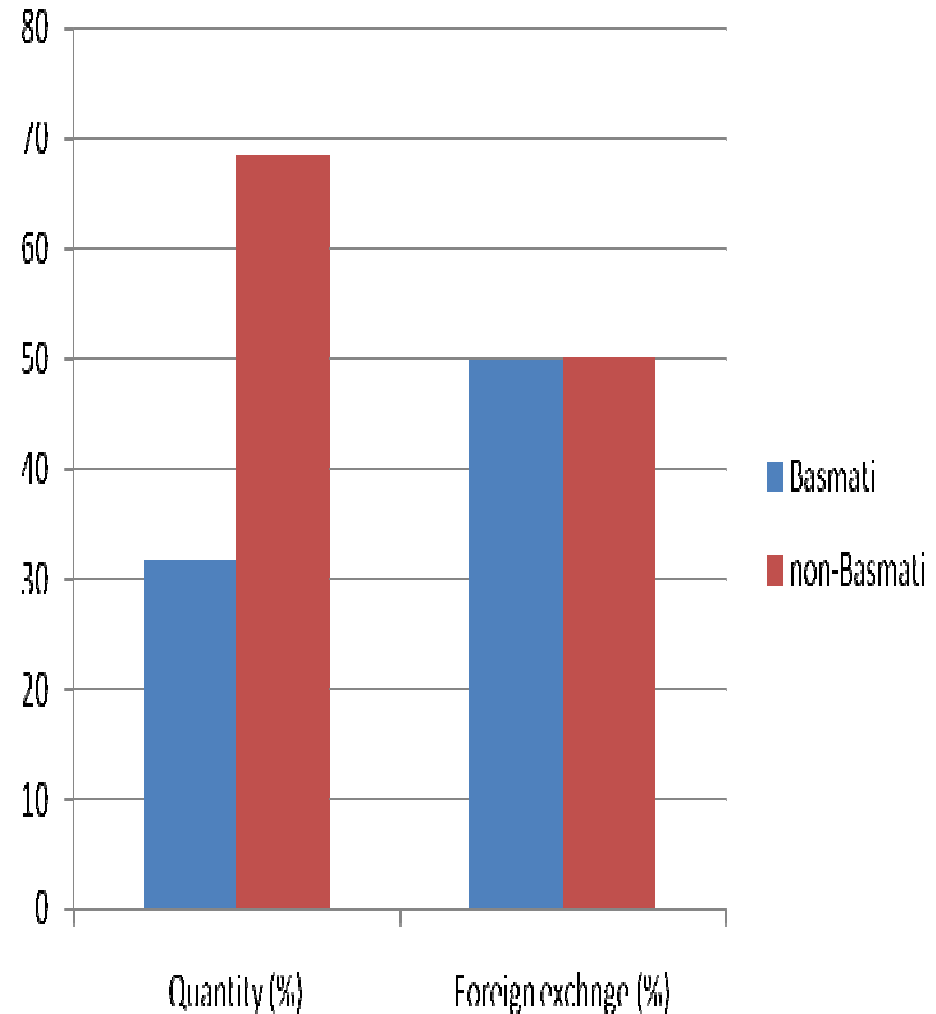
2.930 m tons

Basmati Rice: **0.924 m tons**

(\$1.018 billion)

Non-Basmati: **2.005 m tons**

(\$1.025 billion)



Share of Basmati and non-Basmati rice and the foreign exchange earned by each type

Rice Trade-Pakistan

Private Sector Role

Rice Exporter's Association (REAP)

(www.reap.com.pk)

Formed: 1988 (after denationalization)

Members: 1000(mainly exporters/millers)

Export: 2.5 billion

Pakistan Rice standard (PSI)

Framed: 1992

Abatement price 250 Euro/ton

QRC

Rice Trade- Government Interventions

- **Minimum Export Price (MEP)**
- **Procurement price /indicator price**
MinFA
- **Buy Surplus Rice- TDAP**
- **Rice research**
 - public sector** **6 centers**
 - private sector** **seed/hybrid rice research**
- **Regulations**
various ministries

6 Rice Centers/Institutes in Pakistan



Variety wise certified seed of paddy supplied by public and private sector for 2006 crop

Province/ variety	Seed Availability (Public Sector) tonnes	Seed Availability (Private Sector) tonnes	total	Area Sown (m hect.)	Seed Requirement (tones)	Area covered by certified seed(%)
Punjab	2840	10632	13472	1719	23891	56.4
i) Basmati	1641	6150	7791	1468	17616	44.2
ii) IRRI &others	1199	4482	5681	251	6275	90.5
Sindh “IRRI”	389	1355	1744	598	14950	11.7
NWFP “others”	42	10	52	61	1525	-
Balochistan “IRRI”	N.A	N.A	N.A	194	4850	-
All Pakistan						
i) Basmati	1641	6150	7791	1468	17616	44.2
ii)IRRI+other	1630	5847	7477	1104	27600	33.8
Total	3271	11997	15268	2572	45216	33.8

Source: **FSC&RD and API**

Exports of Pakistani Rice by Region

(2004-05 and 2005-06)

Region	2004-05				2005-06			
	Basmati Rice		Coarse Rice		Basmati Rice		Coarse Rice	
	Quantity (000 tone)	Value (m \$ US)	Quantity (000 tone)	Value (m \$ US)	Quantity (000 tone)	Value (m \$ US)	Quantity (000 tone)	Value (m \$ US)
Asia	651.05	346.25	694.74	184.40	678.14	380.6	910.43	245.06
Oceania	12.32	6.65	0.27	0.08	15.49	9.02	0.99	0.35
Europe	92.82	52.17	49.51	12.16	82.93	50.66	141.50	34.54
Africa	28.58	15.73	1200.57	279.38	34.68	19.33	1696.26	374.20
America	28.48	17.50	30.26	7.11	25.65	18.06	32.38	6.86
CIS	1.62	0.94	39.31	10.16	2.11	1.30	68.18	17.19
Total	814.86	439.24	2014.66	493.31	839.0	479.62	2849.74	678.20

Source: Federal Bureau of statistics, Pakistan

* CIS stands for Central Independent State

Rice: National Germplasm Explorations

1972-77 : 900 accessions were collected mostly from Punjab and Sind by Govt. of Pakistan in Coordination with USAID.

1985 and 1987 – Total of 397 collections were made from Balochistan and Sindh (sponsored IBPGR)
- 201 collections from Balochistan and
- 196 from Sind province.

1989 and 1991 -NIAR-Japan and PARC-Pakistan with funds from IBPGR
Collaborative explorations in northern areas of Pakistan(249 rice accessions)

Rice: Germplasm Preservation

Plant Genetic Resource Programme -92-93

- a project: “**Genetic Resource Preservation and Research Laboratories**” at NARC, Islamabad Pakistan (as a gift from Govt. of Japan)

Gene bank

Plant Genetic Resource Programme was established: having capacity to store 60,000 sample of 500gm each.

Rice Collections

- Maintains and preserve **2092** rice collection with possible duplications – both local (**1661** samples) and exotic origin from 37 countries.
- Accessions representative to all **24** *Oryza* species are preserved – **1897** collections belongs to *O. sativa*



Rice: Germplasm Preservation

Collection of Rice Germplasm at PGRL

Sr #	Species	Accessions	Sr #	Species	Accessions
1	<i>Oryza alta</i>	5	13	<i>Oryza meridionalis</i>	8
2	<i>Oryza australiensis</i>	10	14	<i>Oryza meyeriana</i>	5
3	<i>Oryza barthii</i>	7	15	<i>Oryza minuta</i>	9
4	<i>Oryza brachyantha</i>	8	16	<i>Oryza nivara</i>	9
5	<i>Oryza echingeri</i>	19	17	<i>Oryza officinaRussi</i>	2
6	<i>Oryza glaberrima</i>	1	18	<i>Oryza officinaus</i>	9
7	<i>Oryza glumaepatula</i>	8	19	<i>Oryza phizomiatis</i>	4
8	<i>Oryza grandiglumis</i>	9	20	<i>Oryza punctata</i>	11
9	<i>Oryza granulata</i>	7	21	<i>Oryza ridleyi</i>	10
10	<i>Oryza latifolia</i>	8	22	<i>Oryza ruhpopon</i>	6
11	<i>Oryza longiglumis</i>	6	23	<i>Oryza sativa</i>	1897
12	<i>Oryza longistaminata</i>	5	24	<i>Oryza spontnea</i>	2

Germplasm from various countries preserved in Genebank at PGRL-PARC

Sr#	Origin	Accessions	Sr#	Origin	Accessions	Sr#	Origin	Accessions
1	Pakistan	1661	14	Mali	1	26	Suri Nam	6
2	Australia	16	15	Mayanmar	9	27	Taiwan	3
3	Bangladesh	1	16	Nepal	1	28	Tanzania	1
4	Brazil	15	17	North Korea	103	29	Thailand	13
5	Cameroon	6	18	Papua New Guinea	3	30	Uganda	7
6	Chad	5	19	Philippines	129	31	USA	1
7	China	8	20	Phillipines	2	32	Viet Nam	2
8	Costa Rica	5	21	Senegal	1	33	Zambia	4
9	Egypt	6	22	Sierra Leone	4	34	India	31
10	Ghana	2	23	Sri Lanka	19	35	Indonesia	8
11	Guate Mala	2	24	Kenya	2	36	Japan	3
12	Guinea	4	25	Laos	1	37	Malaysia	5
13	Guyana	1						

Preservation of rice Germplasm of Pakistani origin at various national and international genebanks

Sr #	Institution	Country	Accessions	Source
1	PGRP-NARC ^a	Pakistan	1661	PGRP-NARC (http://www.parc.gov.pk)
2	IRRI ^b	Philippine	7573	(http://beta.irri.org/seeds/)
3	NGRP ^c	USA	857	http://www.ars-grin.gov/cgi-bin/npgs/html/tax_stat.pl?taxno=26077&country=Pakistan&unavail=
4	NIAS ^d	Japan	421	http://www.gene.affrc.go.jp/databases_en.php
5	Global Seed Vault	Norway	567	http://www.nordgen.org/sgsv/index.php?app=data_unit&inc=search_form&unit=sgsv_template&institute_code=PAK001&institute_code=PAK001&full_scientific_name=Oryza+sativa&PHPSESSID=3b1td0arodcnhufcvf6p5mv8h7

a) Plant Genetic Resource Programme, National Agriculture Research Center Pakistan.

b): International Rice Research Institute, Philippines.

c): National Genetic Resources Program, USA.

d): National Institute of Agrobiological Sciences, Japan.

Areas rich in Diversity

- **NWFP – 70%**

(of total cultivated rice comprise traditional varieties)

- **Baluchistan – 43%.**

Surrounded by rice growing countries like China, the Soviet Union, Afghanistan, and Iran – these two provinces possess abundance of diversity.

Rice Characterization: Morphological and Biochemical parameters

Total accessions characterized: 475

Indigenous : 375

Exotic 100

Grain Quality parameters

Sr.	Parameter	Variation
1	Grain Length	6.0~10.66 mm
2	grain width	1.6~3.7mm
3	breadth	1.14~ 2.36mm
4	length to width ratio	2.04~5.24
5	grain weight	0.66~3.02g.
6	Hull/Pericarp Color	minimum in Pakistani rice land races (Yellow, yellowish brownish and purple)

Characterization : Biochemical Parameters

Sr. No	Parameter	Variation
1-	Globulin	no variation Pakistani Landraces
2-	Prolamine	no variation Pakistani Landraces
3-	Albumin	Minor/slight variation
4-	Wx (waxy)-gene product	Present among most of the local rice races
5-	Glutaline	showed significant variation for the character
6-	Esterase 3 isozyme	correlated to rice varietal group Fast band appeared in indica and slow band in japonica.
7-	Amylose Contents	17.7(JP5) to 35.7 (Nali land races)

Progress and status of GM rice development in various institutions of Pakistan

Institute	Problem	gene	stage/level	Reference
CEMB*	Resistance to yellow stem borer and rice leaf folder	<i>Cry1Ac</i> <i>Cry2A</i> <i>Cr1Ac+Cry2A</i> <i>Cry1Ab</i>	Field evaluation Lab. and field evaluation Lab. and field evaluation	Bashir et al., 2005 Bashir et al., 2005 & Riaz et al., 2006 Husnain et al., 2002,
NARC**	Bacterial leaf blight	<i>Xa21</i>	Lab. and green house study	Khan et al., 2007 & Amina et al., 2006,
NIBGE*** CEMB	Drought and salinity	<i>Dreb1A</i> & <i>OsDreb1b</i>	Lab. analysis	Husnain et al., 2004

* National Center of Excellence in Molecular Biology(CEMB), Lahore, Pakistan.

** National Agriculture Research Center, (NARC) Islamabad, Pakistan

*** National Institute for Biotechnology and Genetic Engineering (NIBGE),Faisalabad, Pakistan

References

Bashir et al., 2005, Crop protection,870-879
Riaz et al., 2006, Afri. J. Bot.217-223
Khan et al.,2007,Pak.J.Bot.1285-1292
Amina et al.,2006, Pak.J.Bot.193-203
Husnain et al.,2002 Euphytica 127-128

RICE DNA Purity Tests/Authenticity

- **GM Screening**

No GM rice variety registered and/or developed so far

- **DNA purity testing (Basmati/non Basmati)**

for research and commercial purposes (NIBGE and NIGAB Pakistan)

- **Grain quality testing (ISO certified)**

GQTL working at Islamabad/ Karachi

- **Aflatoxins**

test being conducted at NARC, Pakistan

DNA purity and adulteration test conducted at NIBGE

Year	No. of samples
2004-05	280
2005-06	230
2006-07	762
2007-08	343
2008-09	240

Characterization - Molecular Markers (SSR/RAPD)

- **Evaluation of genetic polymorphism (Rabbani *et al.*, 2008)**
 - among 10 traditional, 28 improved and two Japanese cultivars (Kinmaze' and 'Nipponbare')using RAPDs.
- **Lowest level of diversity was observed among aromatic**
 - Aromatic cultivars – relatively lower in genetic diversity indicates basic similarity among Basmati varieties – due to common ancestors
- **Five varieties have Basmati-370 as one of the parents.**
- Kinmaze' and 'Nipponbare' (Japonicas)– distant relation with Indica cultivars.
- Cultivars – 'Jhona-349', 'Lateefy' and 'Swat-1' distinct from all other non-aromatic cultivars.
- Unique banding patterns – 'Jhona-349', 'Lateefy', not produced in any other cultivar.
- IRRI cultivars – IR-6 & IR-36 shared RAPD profiles with local cultivars. Also having unique fragments.

Ref: Rabbani et al, 2008, Electronic J.Biotech(11)3

Molecular Characterization – SSR

- Investigated SSR based genetic diversity among 16 aromatic, 22 non-aromatic and 2 japonica varieties.
- Traditional varieties – closer to japonica type.
- Aromatic cultivars – dissimilar from non-aromatic.
- Non-aromatic – more diverse from aromatic.
- Cluster analysis grouped most of the basmati cultivars from Punjab - '**Basmati-370**', '**Basmati-Pak**', '**Basmati-385**', '**Basmati-2000**' and '**Super-Basmati**' together, indicating common ancestors.
- **Basmati-370** as one of the parents in their pedigree.
- based of geographic distribution – long slender and medium slender aromatic rice are largely grown in Zone - clustered into group I.
- short to long bold – grown mostly in Sind, southern parts of NWFP and northern cooler areas of Pakistan – clustered into group II.
- **Group I – possesses cultivars with desirable grain characteristics and cooking qualities.**
- Group II – have aroma of varying strength but lack desirable Basmati traits.
- Suggest probability – basmati varieties have evolved by natural mutation in indigenous non-Basmati types.

Ref: Rabbani et al, 2008, Electronic J.Biotech(11)3

Issues of Plant Authenticity

1- Reliability of data of land races

2- Common heritage –GI issues: PGI/PDO

3- Ownership

(Kernal /Super Basmati/1121)

4- Lineage of Basmati (Hybridization/Introgression)

Lineage from pure line to basmati hybrids (70%,50%,10%,5%,or 1%?)

Identity of parents

5- DNA purity test

single test not possible except in GMOs or one variety

6- Product Origin/type

Mandatory?

7- The origin and evolution of fragrance-

Kovach et al.2009. PNAS:(106)14444-14449

Way Forward...

- **Evaluation/Characterization of land races: A joint venture with Europe : a future prospect??**
- **Breeding programme initiated by RRI,KSK with land races of Basmati**
- **Production of hybrid seeds in Basmati**
to compete the spread of Chinese hybrid seed with higher yield
- **Strengthening of infra structure for genomic studies of Basmati rice**
03 National labs have initiated work
- **A strict quality control regime at every level of production**
- **Awareness campaign among various stake holders**

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Plant Genetic Resource Institute

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Sun drying of paddy rice

