ANNUAL REPORT 2016-17

Dr. Muhammad Akhter

Director

RICE RESEARCH INSTITUTE,

Kala Shah Kaku, 17 Km G. T. Road, Lahore

Ph. (Office): +92 42 37951826, Fax #: +92 42 37951827
Email: director_rice@yahoo.com
facebook.com/rriksk twitter.com/RRIKSK
http://www.aari.punjab.gov.pk/institutes-sections/rice-research-institute

Compiled & Composed by:

Dr. Arshed Makhdoom Sabir
Assistant Entomologist
Rice Research Institute, Kala Shah Kaku

CONTENTS

A. RICE RESEARCH INSTITUTE, KALA SHAH KAKU

Work on varietal development/ improvement in rice started in 1926 with the establishment of Rice Farm at Kala Shah Kaku in the famous rice bowl called "Kalar tract" of the Punjab. Rice Farm was elevated to the level of Rice Research Station in 1965 and later upgraded to the status of full-fledged Rice Research Institute during 1970 with eight research disciplines i.e., Plant Breeding and Genetics, Agronomy, Soil Chemistry, Entomology, Plant Pathology, Rice Technology, Agricultural Engineering and Economics & Statistics.

The report covers research work done at multidisciplinary Rice Research Institute, Kala Shah Kaku (RRI, KSK) that is engaged in research on different aspects of rice crop during 2016-17.

Objectives

The objectives of research at Rice Research Institute, Kala Shah Kaku are as under:

- Development of high yielding, early maturing, medium and fine grain varieties of rice that are resistant to insect pests and diseases.
- Devise optimum agronomic practices for rice crop suited for different rice growing regions in the Punjab.
- Determine macro/ micro nutrient requirements of rice varieties under different soil conditions.
- Determine the physico-chemical properties of rice grain.
- Better grain quality (AGL > 8 mm, CGL > 15.5 mm).
- Screen out the salinity, drought and submergence tolerance.
- Devising integrated pest and disease management strategies.
- Production of pre basic seed for public and private sector.
- Rice hybrids with >15 % higher yield potential than commercial varieties.
- Impart trainings to extension workers/ agri. departments for transfer of rice production technology and to the growers and train rice procurement staff of different agencies in identification of paddy and rice of different varieties.

Location and Area

Rice Research Institute, Kala Shah Kaku is situated at 17 kilometers to the North of the Lahore on Great Trunk Road at 30 °N Latitude and 74 °E Longitude (Fig. 1).

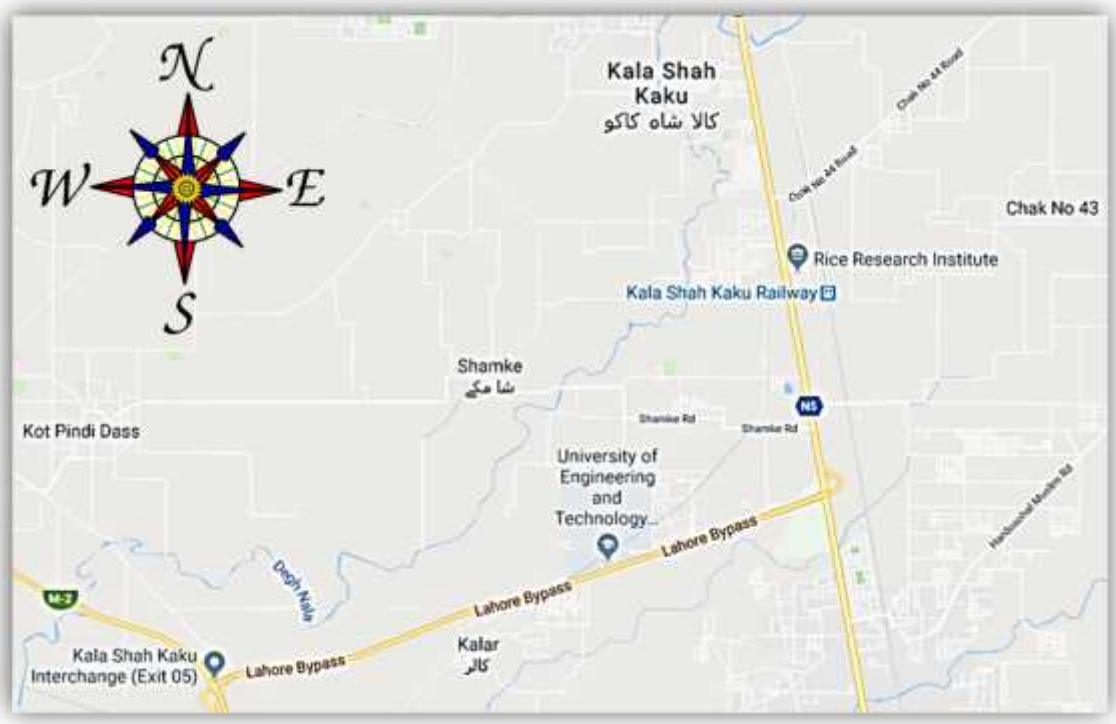

Fig. 1: Location map of the institute

It is located in the "Kalar" tract known for producing Basmati rice, which accounts for big share of the total foreign exchange earnings of Pakistan from rice export. The total area of the Institute is 506 acres, with following bifurcations:

Area under experiments	103 acres
Area under tenants cultivation	332 acres
Area under roads, buildings and workshops	71 acres
Total	**506 acres**

The soil of the Institute farm is calcareous with impervious sub-soil. It is plastic in wet state but stony hard when dry. The pH of the soil varies from 7.5 to 9 and water level is at the depth of about 25 feet.

Area, Production and Yield of Rice in the Punjab

The area, production and yield of rice in the Punjab during the year under report and the previous two years (Table 1) depicted that the area and production decreased in 2016-17 by 2.5% and 0.8%, respectively, as compare to 2015-16. On the other hand, total rice yield per unit area increased by 2.9% and 1.7% during the year under report as compared to years 2014-15 and 2015-16.

Table 1: Area, Production and Yield of Rice in the Punjab from 2014-15 to 2016-17

YEARS	VARIETY	AREA ('000' ha)	PRODUCTION ('000' tons)	YIELD (Kg/ ha)
2014-15	Basmati	1320.1	2337.21	1771
	IRRI	196.7	503.33	2559
	Others	360.9	807.46	2237
	Total	1877.7	3648	1942
2015-16	Basmati	1254.1	2279	1817
	IRRI	183.3	461	2513
	Others	342.8	762	2223
	Total	1780.2	3502	1967
2016-17	Basmati	1352.84	2524.39	1866
	IRRI	145.28	391.79	2697
	Others	238.36	558.82	2345
	Total	1736.48	3475	2001

Source: Crop Reporting Service, Punjab

Prices of Paddy and Cleaned Rice

The market prices of paddy and cleaned rice during the years 2015-16 and 2016-17 (Table 2) reflected that the price of paddy of coarse rice increased from 750 to 1030 (27%) in 2016-17 as compared to previous years. Similarly cleaned coarse rice price increased from 1300 to 1500 (13%) in 2016-17, whereas, price of paddy and cleaned basmati rice was increased 31% and 8.8%, respectively, as compared to previous years.

Table 2: Comparison of market prices of coarse and Basmati rice

Variety	Price in rupees per 40 Kg			
	Paddy		Cleaned rice	
	2015-16	2016-17	2015-16	2016-17
Coarse	750	1030	1300	1500
Basmati	1100	1600	3100	3400

I. BREEDING

Objectives

- Development of high yielding, early maturing, Basmati and coarse rice varieties carrying biotic (BLB) and abiotic (salinity and submergence) resistant genes with good cooking quality suitable for irrigated and direct seeded (DSR) rice.
- Pre-Basic seed production of approved cultivated rice varieties.

1. Maintenance of Germplasm

Rice germplasm comprising of 1704 lines / varieties originating from local and exotic sources were divided into two sets i.e. Set-I (852 lines/varieties) and Set-II (852 lines/varieties) for planting on alternate years to maintain their seed. During the year under report, Set-I was planted in the field with single row of 25 plants of each entry. Recommended crop management practices were adopted. Data on different agronomic characteristics were recorded. Some entries were used for making fresh crosses. At maturity, the seed of all the lines/varieties was collected, dried, cleaned and stored properly. Traits variability range observed in the Set-I of the germplasm is as under (Table 1):

Table 1: Traits diversity present in the germplasm

Plant Trait	Minimum	Maximum
Plant height (cm)	61	171
No. of tillers / plant	6	31
Flowering days	41	110
Maturity days	72	140
1000 Grain weight (g)	20	29.5
Panicle length (cm)	15	33
Grain length (mm)	5.5	9.7
Gelatinization temperature (^{o}C)	40	100
Amylose content (%)	6	30
Alkali Spread Value (range:0-7)	0	7

2. Study of Filial Generations

To evaluate and select desirable recombinants, early (F_1 – F_3) and advance (F_4 – F_7) generations were evaluated in the field.

i. Early Generations (F_1 – F_3)

a) F_1 Generation

In all, 210 F_1 crosses were studied. Pre-soaked seed was placed in plastic jars at room temperature for germination. Seven days old seedlings were sown on raised nursery beds. Thirty days old nursery was transplanted in the field with double spacing. Undesirable and selfed crosses were rejected. At maturity, the seed of 159 crosses was collected for further evaluation in F_2 generation. Some desirable crosses were also used in making back, double and three way crosses.

b) F_2 Generation

F_2 populations of 359 crosses were transplanted in the field with 25cm x 25cm spacing. Each population was comprised of 2000 plants. Recommended crop management practices were adopted. Maximum segregation was observed in the population. Based on target breeding objectives, 1152 single panicle selections from 359 crosses were made on for further evaluation in subsequent generations.

c) F_3 Generation

Thirty seven days old nursery of 1574 single panicles was transplanted in single row progeny lines with 25 cm plant spacing. Recommended crop management practices were adopted for healthy crop stand. Field observations were recorded for desirable traits. At maturity, 515 single plant selections were made for further studies in subsequent filial generation.

ii. Advance Generations (F_4 – F_7)

Four hundred and thirty-one (431) progeny blocks comprising of five meter long three rows of F_4 generations were transplanted in the field. At maturity,

single plants of 95 lines and 27 uniform lines for quality testing were selected on the basis of field performance.

In F_5 generation, 90 progeny blocks were transplanted in the field and at maturity single plants of 44 lines and 22 uniform lines were identified and selected for quality testing.

Similarly, 44 progeny blocks of F_6 generation were studied. Single plants of 14 progeny lines and 10 uniform lines were selected on field performance basis. Twenty one (21) progeny blocks of F_7 generations were evaluated for desirable traits and 10 best performing uniform lines were selected for further studies.

Sixty nines (69) uniform lines comprising of four coarse and 64 fine grain lines of advance generations were subjected to quality testing to identify the lines having desirable cooking quality. In fine grain group, fifty four (54) lines were categorized as aromatic while the rest were non-aromatic. The cooking quality of 31 lines of aromatic and four lines of non-aromatic group was found excellent.

3. Crossing Block

In order to induce genetic variability in desirable recombinants, nursery of 300 elite parental lines/ varieties from different sources were transplanted on three different dates with 10 days interval to synchronize the flowering time for making target fresh crosses between the parental lines. Recommended crop management practices were adopted for healthy crop stand. Data regarding 50% flowering were recorded. Representative plants of target female lines were tagged and potted one day before emasculation. The panicles with 50-60% emergence were emasculated with 500 mmHg vacuum emasculator in afternoon. Next day, emasculated panicles were pollinated with target male parents. Pollinated pot plants were placed in net house and properly managed till maturity. At maturity, 210 successful crosses were harvested for their evaluation in filial generations (Table 2). The seed of all parental lines was also collected, dried, cleaned, labeled and stored properly for the next season.

Table 2: Number of Successful Fresh Crosses with various Target Breeding Objective

Breeding objective	No. of crosses	Breeding objective	No. of crosses
High yielding	55	Grain quality	20
Salt tolerance	05	BLB resistance	40
Genetic diversity	20	Aerobic	02
Drought tolerance	10	Blast resistance	03
Early maturity & Short stature	20	Planthopper resistance	02
Plant type	10	Aroma	08
Flood tolerance	10	Back cross	05

Fig. 2: Raising of nursery seedlings

Fig. 3: Transplanted crop

Fig. 4: Flowering in crossing block

4. Evaluation of Advanced Lines

One hundred and seventy (170) advanced lines of medium and fine grain along with five checks i.e., Super Basmati, Basmati 515, PS 2, KS 282, and KSK 133 were evaluated for various agronomic traits in non-replicated observational plots. The plot size of each entry was 5.5 m2. Recommended agronomic practices including need based plant protection measures were adopted for healthy crop stand. Data regarding plant height, number of productive tillers per plant, days to 50% flowering, maturity days and paddy yield were recorded. Data for cooking quality parameters i.e., average grain length, average grain width, average grain thickness, cooked grain length, broken percentage, elongation ratio and visual observation were recorded. On the basis of field performance, 86 lines were selected. In cooking quality test, forty six (46) lines were marked as best performers. Paddy yield ranging from 2.53 to 5.69 t/ha was recorded for advance lines. Eleven Basmati lines (Table 3) performed better than the three Basmati check varieties Super Basmati (3.12 t/ha), Bas 515 (4.93 t/ha) and PS2 (3.85 t/ha). However, PK 10938-3-1-1 out yielded all the lines and ranked as top performer with excellent cooking quality (Fig. 5a).

Table 3: Data regarding different Plant Traits of five Promising Lines

Sr. #	Designation	Plant Height (cm)	Tillers/ plant	Maturity days	Paddy Yield (t/ ha)	Cooking
1.	PK 10938-3-1-1	138	14	105	5.69	Excellent
2.	PK 10845-6-2-2	138	11	114	5.36	Very Good
3.	PK 10969-39-1	100	9	106	5.19	Fair
4.	PK 10824-9-1-3	144	10	132	5.12	Excellent
5.	PK 10835-9-1-1	149	12	117	5.02	Excellent
6.	PS 2 (Check-I)	123	16	120	3.85	Excellent
7.	Basmati 515 (Check-II)	143	15	121	4.93	Very Good
8.	Super Basmati (Check-III)	128	17	121	3.16	Very Good

(a) (b)

Fig 5: Cooking of OP lines: (a) PK10938-3-1-1 and (b) PK 10845-6-2-2

5. Coarse Grain Yield Trials

i. Trial - A

This experiment was conducted to evaluate high yielding, early maturing, insect-pests and disease resistant medium grain lines. Thirteen lines were evaluated against check variety KSK 434 for their yield performance in replicated trials. The experiment was laid out in RCBD with three replications having 2.0 m x 5.0 m plot size. Fertilizer @170-100-62 NPK kg/ ha was applied and recommended plant protection measures were adopted. Data on 50% flowering, maturity days, plant height, number of tillers per plant and yield was recorded.

The results (Table 4) depicted that KSK 499 having yield 6.51 t/ ha having medium height and maturity is the top performer in this set of varieties. KSK 501 has excellent cooking with yield of 5.72 t/ ha.

Table 4: Characteristics of Coarse Grain Rice Lines Tested in Yield Trial- A

S. #	Strain/ variety	Plant height (cm)	Maturity days	Paddy Yield (t/ha)	Cooking
1.	KSK 499	101	99	6.51	Good
2.	KSK 500	109	112	5.89	Good
3.	KSK 501	105	108	5.72	Excellent
4.	KSK 502	106	107	5.56	Good
5.	KSK 503	110	103	5.47	Good
6.	KSK 434 (Check)	109	104	5.37	Good
7.	KSK 507	82	101	4.91	Good
8.	KSK 509	105	102	4.31	Good
9.	KSK 510	106	103	3.94	Good
10.	KSK 505	113	99	3.90	Poor
				LSD 0.498	

ii. Trial - B

This experiment was conducted to evaluate high yielding, early maturing, insect-pests and disease resistant medium grain lines. Nine lines were evaluated against check variety KSK 434 for their yield performance. The experiment was laid out in RCBD with three replications having 2.0 m x 5.0 m plot size. Fertilizer @170-100-62 NPK kg/ha was applied and recommended plant protection measures were adopted. Data on 50% flowering, maturity days, plant height, number of tillers per plant and yield were recorded.

The results (Table 5) indicated that the KSK 493 (6.84 t/ha) and KSK 496 (6.74 t/ha) having short height and early maturity are good performer in this set of varieties. KSK 490 has excellent cooking with yield 6.15 t/ha, 92 maturity days and 110 cm height.

Table 5: Characteristics of Coarse Grain Rice Lines Tested in Yield Trial- B

S. #	Strain / variety	Plant height (cm)	Maturity days	Paddy Yield (t/ha)	Cooking
1.	KSK 493	85	94	6.84	Good
2.	KSK 496	92	94	6.74	Good
3.	KSK 492	90	94	6.55	Good
4.	KSK 489	110	92	6.37	Good
5.	KSK 490	103	94	6.15	Excellent
6.	KSK 434 (Check)	110	105	5.89	Good
7.	KSK 491	97	94	5.48	Good
8.	KSK 497	93	97	5.47	Good
9.	KSK 498	115	93	5.41	Poor
10.	KSK 494	92	97	4.99	Good

LSD 0.477

iii. Trial - C

This experiment was conducted to evaluate high yielding, early maturing, insect-pests and disease resistant medium grain lines. Nine Lines were evaluated for their yield performance and grain quality in replicated trials against check variety KSK 434.

The experiment was laid out in RCB Design with three replications having 2.0 m x 5.0 m plot size. Fertilizer @170-100-62 NPK kg/ha applied and recommended plant protection measures adopted. Data on 50% flowering, maturity days, plant height, number of tillers per plant and yield was recorded. The salient results are presented in the Table 6.

Table 6: Characteristics of Coarse Grain Rice Lines Tested in Yield Trial- C

S. #	Strain / variety	Plant Height (cm)	Maturity Days	Paddy Yield (t/ha)	Cooking
1.	KSK 487	120	112	6.85	Excellent
2.	PK 9259-4-1-1-1	125	103	6.82	Excellent
3.	KSK 486	118	110	6.69	Excellent
4.	KSK 484	101	112	6.62	Good
5.	KSK 488	122	110	6.11	Excellent
6.	KSK 434 (Check)	112	105	5.72	Good
7.	KSK 483	116	102	5.50	Good
8.	PK 9379-45-1-4-1-1	113	96	5.49	Good
9.	KSK 482	118	89	5.37	Good
10	KSK 485	120	111	5.27	Fair

LSD 0.489

The results (Table 6) observed that three rice lines KSK 487, PK 9259-4-1-1-1 and KSK 486 gave paddy yield 6.85, 6.82 and 6.69 t/ha, respectively, with excellent in cooking quality with medium height and maturities. Excellent cooking quality was recorded for KSK 488 with yield (6.11 t/ha) and maturity days (112).

6. Fine Grain Yield Trial

i. Trial - A1

Sixteen fine grain lines were tested against standard check varieties viz., Basmati 515, Super Basmati and PS 2. Thirty days old nursery of the lines including check varieties was transplanted in Randomized Complete Block Design with three replications with standard agronomic practices. The data regarding plant height, productive tillers per plant, maturity days, paddy yield and cooking quality were recorded. The yield data were subjected to statistical analysis. The characteristics of the lines tested in fine grain yield Trial-A are given in Table 7.

Table 7: Characteristics of Fine Grain Rice Lines Tested in Yield Trial- A1

Sr. #	Designation	Plant height (cm)	Tillers/ plant	Maturity Days	Paddy Yield (t/ha)	Cooking
1	PK 10344-12-1-1	144	9	101	5.89	Good
2	PK 10495-7-3-1	130	10	102	5.66	Fair
3	PK 10473-3-1-1	140	12	98	5.22	Excellent
4	PK 10383-5-1-1	164	14	114	5.03	Excellent
5	PK 10355-13-2-1	142	17	105	4.96	Good
6	PK 10355-13-1-1	147	15	113	4.95	Good
7	PK 10356-10-1-1	139	12	107	4.88	Good
8	PS 2 (Check-I)	133	20	115	4.35	Excellent
9	PK 10395-1-1-1	169	12	99	4.27	Excellent
10	PK 10683-12-1	136	19	113	4.25	Excellent
11	PK 10820-8-1	156	14	115	4.22	Excellent
12	PK 10350-7-2-1	146	9	110	4.01	Excellent
13	Basmati 515 (Check-II)	154	15	115	3.93	Excellent
14	PK 10348-7-1-3	156	18	105	3.61	Excellent
15	PK BB 15-11	152	19	100	3.30	Excellent
16	Super Basmati (Check-III)	138	20	115	3.15	Excellent
					LSD 0.91	

The results (Table 7) indicated that paddy yield data ranged from 3.15 to 5.89 t/ha. Seven rice lines yielded (4.88-5.89 t/ha) better than the check variety PS 2 (4.35 t/ha). The yield of other check variety Basmati 515 and Super Basmati was recorded as 3.93 t/ha and 3.15 t/ha, respectively. PK 10344-12-1-1 produced maximum yield (5.89 t/ha) among the tested lines followed by PK 10495-7-3-1 (5.66 t/ha), PK 10473-3-1-1 (5.22 t/ha), PK 10383-5-1-1 (5.03 t/ha), PK 10355-13-2-1 (4.96 t/ha), PK 10355-13-1-1 (4.95 t/ha) and PK 10356-10-1-1 (4.88 t/ha). The cooking quality of 10 lines was categorized as 'excellent' while the rest were in 'good' category (Fig. 6a).

(a) (b)

Fig 6: Cooking Quality of A1 Trial: (a) PK 10473-3-1-1 and (b) PS 2

ii. Trial - A2

Twelve (12) fine grain lines were evaluated in Randomized Complete Block Design with three replications against standard check varieties viz., PS-2, Basmati 515, and Super Basmati. Standard agronomic practices including plant protection measures were adopted. The data regarding plant height, maturity days, productive tillers per plant, paddy yield and cooking quality were recorded. The yield data ware statistically analyzed (Table 8).

Table 8: Characteristics of Fine Grain Rice Lines Tested in Yield Trial-A2

Sr. #	Designation	Plant height (cm)	Tillers/ plant	Maturity Days	Paddy Yield (t/ha)	Cooking
1	PK 9832-4-1	139	11	100	6.29	Excellent
2	PK 9847-10-1	140	13	103	6.27	Excellent
3	PK BB 15-8	129	16	91	5.06	Fair
4	PK 10395-8-1-1	148	11	113	4.92	Good
5	PK 9986-6-2-1-1-1	148	14	100	4.89	Fair
6	PK 10045-7-3-2-2-1	146	12	100	4.86	Good
7	PK 10198-19-1-1-1	135	15	90	4.85	Fair
8	PK 10436-2-1-1	136	16	110	4.81	Excellent
9	PK 9963-4-1-2-1-1	141	15	91	4.78	Fair
10	Basmati 515 (Check-II)	153	12	114	4.68	Excellent
11	PS 2 (Check-I)	128	24	115	4.63	Excellent
12	PK 10419-2-1-1	143	14	116	4.48	Excellent
13	Super Basmati (Check-III)	126	16	115	4.47	Excellent
14	PK 10434-6-2-1	131	13	110	4.44	Excellent
15	PK 10437-14-2-1	139	13	119	3.53	Excellent
					LSD=0.87	

(a) (b)

Fig 7: Cooking of yield Trial A-2: (a) PK 9847-10-1 and (b) PK 10436-2-1-1

i. Trial - B

Twelve fine grain lines were tested in Randomized Complete Block Design with three replications against check varieties viz., PS 2, Super Basmati and Basmati 515. Thirty days old nursery of the test lines was transplanted in 5.5m^2 plot. Standard agronomic practices and plant protection measures were adopted. Data regarding plant height, productive tillers per plant, maturity days, paddy yield and cooking quality were recorded. The yield data were subjected to statistical analysis. The characteristics of the lines tested in fine grain yield Trial-B are described in Table 9.

Table 9: Characteristics of Lines Tested in Fine Grain Yield Trial- B

Sr.#	Designation	Plant height (cm)	Tillers/ plant	Maturity Days	Paddy Yield (t/ha)	Cooking
1	PK 10306-15-5	117	21	107	6.31	Excellent
2	PK 10324-1-1	113	20	110	6.19	Excellent
3	PK 9444-8-1-2	139	23	105	6.02	Excellent
4	PK 9924-5-1-1	125	22	115	5.57	Good
5	PK 9563-3-2-2-1	127	15	103	5.16	Good
6	PK 10029-13-2-1	142	25	110	5.01	Excellent
7	PK PB-8	130	33	116	4.66	Excellent
8	Basmati 515 (Check-II)	140	21	116	4.06	Excellent
9	PK 9966-10-1	118	24	116	4.03	Excellent
10	PK 9533-9-6-1-1	113	21	116	3.86	Excellent
11	PK 10161-1-5-1	121	46	116	3.66	Excellent
12	PS 2 (Check-I)	127	30	115	3.55	Excellent
13	PK 10101	138	23	117	3.45	Excellent
14	PK 10198-7-2	124	33	117	3.41	Excellent
15	Super Basmati (Check-III)	127	19	117	3.12	Excellent

The yield data indicated that 7 lines viz. PK10306-15-5 (6.31 t/ha), PK10324-1-1 (6.19 t/ha), PK9444-8-1-2 (6.02 t/ha), PK9924-5-1-1 (5.57t/ha) PK9563-3-2-2-1 (5.16 t/ha), PK10029-13-2-1 (5.01 t/ha) and PK PB-8 (4.66 t/ha) gave better yield than the check varieties, Basmati 515 (4.06 t/ha) PS-2 (3.55 t/ha) and Super Basmati (3.12 t/ha). The cooking quality was recorded as ‘good’ for

two genotypes and “excellent” for 13 genotypes including PK PB- 8 and PK 9966-10-1 (Fig. 8a,b).

(a) (b)

Fig 8: Cooking picture of yield Trial B: (a) PK PB- 8 and (b) PK 9966-10-1

ii. Trial - C

Twelve fine grain lines were tested in Randomized Complete Block Design with three replications against check varieties viz., PS-2, Super Basmati and Basmati 515. Thirty days old nursery of the test lines along with check varieties was transplanted in 5.5m^2 plot. Standard agronomic practices and plant protection measures were adopted. Data regarding plant height, productive tillers per plant, maturity days, paddy yield and cooking quality were recorded. The yield data was subjected to statistical analysis. The characteristics of the lines tested in fine grain yield trial- C are described in Table 10. The results indicated that the yield data of seven lines i.e., PK9699-6-2-1 (6.50 t/ha), PK9748-16-2-1 (6.39 t/ha), PK10967-37-1 (6.26 t/ha), PKBB 15-1 (6.09 t/ha), PK10967-36-1 (5.17 t/ha), PK10963-3-1 (4.95 t/ha) and PK9435-4-1-1 (4.94 t/ha) yielded better than the check varieties Super Basmati (3.62 t/ha), PS2 (3.66 t/ha) and Basmati 515 (4.82 t/ha). Eleven lines

exhibited excellent cooking, while four lines showed Good cooking quality (Fig. 9).

Table 10: Characteristics of Fine Grain Rice Lines Tested in Yield Trial– C

Sr. #	Designation	Plant height (cm)	Tillers / plant	Mat. Days	Paddy Yield (t/ha)	Cooking
1	PK 9699-6-2-1	142	17	104	6.50	Excellent
2	PK 9748-16-2-1	137	10	105	6.39	Good
3	PK 10967-37-1	140	15	114	6.26	Excellent
4	PK BB 15-1	130	12	98	6.09	Good
5	PK 10967-36-1	132	17	108	5.17	Excellent
6	PK 10963-3-1	131	18	102	4.95	Excellent
7	PK 9435-4-1-1	132	13	113	4.94	Excellent
8	Basmati 515 (Check- II)	131	22	115	4.82	Excellent
9	PK 10967-30-1	117	17	106	4.78	Excellent
10	PK BB 15-11	124	18	118	3.93	Good
11	PK 10969-39-1	131	24	120	3.84	Excellent
12	PK BB 15-6	130	16	118	3.75	Good
13	PS 2 (Check- I)	134	21	115	3.66	Excellent
14	Super Basmati (Check- III)	139	28	118	3.62	Excellent
15	PK 10749-18-1-1	143	19	115	3.45	Excellent
					LSD 0.72	

(a) (b)

Fig 9: Cooking of yield Trial C: (a) PK 10967-30-1 and (b) PK 10969-39-1

7. National Uniform Rice Yield Trial

Nine fine grain lines were tested in Randomized Complete Block Design with three replications on seven different agro- climatic locations. Thirty days old nursery of the lines was transplanted in 10.0m^2 plot size.

All the genotypes showed significant variations in terms of paddy yield over a number of environments (Table 11). Candidate variety RRI3 showed maximum average paddy yield (4166 kg/ha), followed by check variety PS 2 (4054 kg/ha), PK PB8 (3962 kg/ha), NS5 (3838 kg/ha) and PK BB15-1 (3812 kg/ha). Minimum paddy yield was observed in case of candidate variety PK 9194-54-1-1-2-2. RRS (Thatta) location showed the maximum paddy yield in terms of average paddy yield of all the studied entries, whereas the minimum was observed in case of ARI (Swat), KPK location.

Table 11: Paddy Yield (Kg/ha) of Candidate Rice Varieties (Fine) Evaluated in NUYT- 2016 at different Locations

Name of Candidate lines	ARI, Swat KPK	RRI, Dokri Sindh	RRI (KSK) PARC	RRI KSK	NIAB FSD	RRS, Thattha	NIA, Tando -jam	Ave. (kg/ha)
RRI 3	2628	4833	4749	4820	3462	5210	3461	4166
PS 2 (check)	1692	5000	4948	4393	3353	4973	4020	4054
PK PB-8	1890	4717	4142	5040	3447	4873	3628	3962
NS-5	2578	4100	3808	5168	3009	4803	3397	3838
PK BB15-1	2365	4333	3832	5872	2035	5123	3122	3812
NIAB- 100	1332	3717	2187	3561	3238	5520	3198	3250
Basmati 515(check)	0	4000	3340	4574	2713	5147	2586	3727
PK BB15-6	0	3600	2581	3512	3629	5660	2064	3508
PK 9194-54-1-1-2-2	0	3333	1714	4357	3329	4659	2851	3374
Average	1387	4181	3478	4589	3135	5108	3147	3575
LSD (0.05)	320	3	253	59	145	234	309	189

8. Seed Multiplication of Rice Lines

Eleven fine grain lines were planted for seed multiplication. Thirty days old nursery of the lines was transplanted in the field and proper agronomic practices were adopted for good crop stand. Rouging was done to ensure the seed purity. At maturity, the seed was harvested, dries, cleaned, labeled and stored properly. The results regarding yield production (Table 12) of each

entry indicated that the maximum seed (44 Kg) of PK8892-4-2-1-1 was produced followed by PK8431 (40 Kg), RRI 3 (39 Kg) and PK 8892-4-1-3-1 (38 Kg).

Table 12: List of lines/ varieties for seed multiplication

S. #	Variety/ Line Code	Designation	Seed Produced (kg)
1.	MR-13	PK 8892-4-2-1-1	44
2.	MR-11	PK 8431 (Chenab Basmati)	40
3.	MR-16	RRI 3	39
4.	MR-14	PK 8892-4-1-3-1	38
5.	MR-21	PK 10355	33
6.	MR-12	PK 8685 (Punjab Basmati)	28
7.	MR-17	PK BB15-1	26
8.	MR-20	PK 10683	25
9.	MR-18	PK BB15-6	21
10.	MR-15	PK 9194	20
11.	MR-10	RRI 7 (Kissan Basmati)	18

9. Development of Bacterial Leaf Blight (BLB) Resistant Basmati Lines/ Varieties

The objective of this experiment was to evaluate breeding material to develop BLB resistant lines/ varieties. For this purpose, thirty days old seedlings of BLB material were transplanted in the field as per details given in the table. Standard agronomic practices were adopted. Data on yield and BLB disease incidence under natural conditions was recorded. The target gene selection was done using linked DNA marker for BLB resistant genes in filial generations F_2 - F_4 (Table 13).

Table 13: Details of BLB material studied during 2016

Generation / lines	Plot size	Crosses/ lines studied	Crosses / lines selected
F_1	Single row comprising of 5 plants of a cross	45 crosses studied	The seeds of all crosses was harvested at maturity.
F_2	Upto 2000 plants for each population	54 crosses studied	Single panicles were selected carrying single or combination of BLB resistant genes i.e., *Xa4, xa5, Xa7, xa13, Xa21*

Generation/ lines	Plot size	Crosses/ lines studied	Crosses/ lines selected
F_3	Two rows comprising of 25 plants with spacing of 22.5cm	44 crosses studied	Out of 147 entries, 59 single panicles of desirable recombinants carrying BLB resistant genes were selected.
F_4		03 crosses studied	15 single panicles were selected.

i. Evaluation of Uniform Lines at BLB Hotspot Sites

The objective of this trial was to test the performance of advance uniform lines and reaction against BLB disease at three hotspots locations i.e.; KSK, Hafizabad and Gujranwala. Thirty days old seedlings of advance uniform lines and NILs (IRBB lines) were transplanted during 2nd week of July in Randomized Complete Block Design with three replications. Standard agronomic practices adopted. The data on yield and BLB disease incidence under natural conditions recorded as Table 14.

Table 14: Paddy Yield (Kg/ ha) Performance and Cooking Quality of BLB Uniform Lines at three hot spots

Rank #	Designation	KSK	HFZ	GRW	Average	Cooking	Genes status
1	PK BB 15-2	4260	4656	4455	4457	Excellent	*xa5, Xa7*
2	PK BB 15-5	4380	-	4400	4390	Good	*xa5, Xa7*
3	Basmati-515 (check)	4250	-	-	4250	Excellent	-
4	PK BB 15-3	3600	4344	4640	4195	Good	*Xa4, Xa7, xa13*
5	PS2 (check)	4020	-	-	4020	Excellent	-
6	PK BB 15-6	3740	-	4105	3923	Excellent	*Xa4*
7	PK BB 15-1	4680	4072	2767	3840	Excellent	*xa5, Xa7*
8	PK BB 15-8	4200	3360	3240	3600	Excellent	*xa5, Xa7*
9	PK BB 15-7	3200	3360	2760	3107	Excellent	*Xa7*
10	PK BB 15-9	3020	3200	3060	3093	Fair	*Xa7*
11	PK BB 15-4	3340	2576	3240	3052	Good	*xa5, Xa7*
12	PK BB 15-10	3220	2416	2600	2745	Good	*xa5, Xa7*

The results (Table 14) indicated that the maximum yield of PK BB 15-1, PK BB 15-2 and PK BB 15-3 were observed at KSK, Hafizabad and Gujranwala locations, respectively. However, PK BB 15-2 was more consistent and top performer on average basis of all three locations. During the current year, no BLB disease attack was observed at hotspot locations.

10. Pre Basic Seed Production

Pre-Basic seed of approved rice varieties was produced for the purpose of further multiplication of the Basic and Certified seed. A part of the pre-basic seed was used for multiplication at the Rice Research Institute, Kala Shah Kaku for production of basic seed. Pre-basic seed was also supplied to the Punjab Seed Corporation for multiplication on its own farms. Some quantity of seed was also supplied to the private seed companies for further multiplication. The quantity of pre-basic seed were produced during 2016-17 described in Table 15.

Table 15: Detail of Pre-Basic Seed Production

S. #	Variety	Quantity (kg)	Total
1.	Super Basmati	273	Basmati 1747 kg
2.	Basmati 515	367	
3.	Punjab Basmati	240	
4.	Chenab Basmati	684	
5.	Kissan Basmati	183	
6.	IR 6	363	Coarse 1788 kg
7.	KS 282	172	
8.	KSK 133	553	
9.	KSK 434	700	
10	PS 2	272	Non Aromatic Fine 715 kg
11	PK 386	443	

II. BREEDING FOR HYBRID RICE

Objective:

❖ To exploit heterosis for yield and income enhancement of rice farmers.

1. Source Nursery

Ninety-two (92) genotypes/ lines of source nursery transplanted in the field in single row plots of 2.5 m length on three different dates i.e., 25.06.2016, 10.07.2016& 25.07.2016 by adopting recommended crop management practices. Data on different agronomic characters also recorded.

Desirable lines were utilized for making 52 fresh test crosses to identify maintainers and restorers. Out of these, 43 successful test crosses were harvested. At maturity, seed of single representative plant from each entry of the source nursery collected for next season. The harvested material was threshed, dried and stored properly.

Fig. 1: Emasculation and Pollination activities for desired cross combinations

2. Maintenance and evaluation of CMS lines

Twenty-five cytoplasmic male sterile (CMS) lines and their respective maintainer lines transplanted in the field in single row plots of 2.0 m length. Recommended crop management practices adopted. The data on all agronomic traits recorded. At flowering stage all CMS lines were crossed with their respective maintainers to produce the nucleus seed of CMS lines (Table 1). At maturity the seed of 'A' and 'B' lines were collected (Fig. 2).

The results reflected that out of twelve promising CMS lines, two belong to Basmati, one in Fine and nine in Course back ground. Plant height ranged from 68 cm in KSK 4365 A, IR 68897 A to 120 cm in KSK 99404 A. Maximum number of tillers (23) were observed in IR 62829 A followed by 22 in KSK 99404 A. Minimum number of days (79) taken for maturity were observed in IR 62829 A. Basmati CMS line KSK 99404 A used maximum days (105) for maturity. Highest out crossing rate (46 %) was observed in IR 68897 A. IR 58025 A, IR 62829 A, IR 73328 A, IR 75156 A and Basmati CMS line KSK 99404 A showed more than 30 % out crossing rate and may be considered as the most promising CMS lines for future breeding program.

Table 1: Characteristics of promising CMS lines

S. #	Designation	Type	Plant height (cm)	No. of Tillers/ plant	Maturity days	Out crossing rate (%)
1.	KSK99404A	Basmati	120	22	105	32
2.	KSK4365A	Basmati	69	15	85	25
3.	IR58025A	Fine	77	20	93	30
4.	IR62829A	Coarse	78	23	79	38
5.	IR68897A	Coarse	68	16	85	46
6.	IR69616A	Coarse	76	19	95	29
7.	IR73322A	Coarse	78	16	92	29
8.	IR73328A	Coarse	82	14	89	31
9.	IR75596A	Coarse	75	16	85	30
10.	IR79156A	Coarse	78	12	90	36
11.	KSK1501A	Coarse	100	12	96	30
12.	KSK1502A	Coarse	82	18	98	27

Fig. 2. Seed production of CMS lines with maintenance

3. **Test Cross Nursery**

The nursery of eighty nine (89) test crosses along with their respective pollen parents was sown. Single row of ten plants per entry transplanted in the field. Recommended agronomic practices and crop protection measures adopted for healthy growth.

Pollen studies carried out for their fertility/ sterility of testcross F_1 plants. For the purpose, 15- 20 spikelets from the just emerged panicles of three randomly selected plants collected in a vial containing 70% ethanol. All the anthers from at least six spikelets taken out with the help of a forceps and placed on a glass slide with a drop of 1% Iodine Potassium Iodide (IKI) stain. The anthers gently crushed by using a needle to release the pollen grains and observed under the microscope. The entire slide scanned and pollen sterility counted in three random fields. At maturity, spikelet fertility also recorded to confirm the microscopic studies.

Out of eighty-nine (89) fresh testcrosses evaluated in the field eighteen (18) maintainers and fifteen (15) restorers identified. All the maintainers having desirable traits back crossed for the transfer of cytoplasmic male sterility system into these elite lines for developing new CMS lines. Data regarding

maturity days, plant height, productive tillers per plant, filled grains per panicle and spikelet fertility of expected test hybrids also recorded.

(a) (b) (c)

Fig 3. Microscopic studies of pollen grains (a) for fertility (b) and sterility status (c)

4. Backcross Nursery

Thirty nine (39) backcrosses were sown in the backcross nursery. Single row of ten plants per entry transplanted in the field following recommended agronomic practices and crop protection measures for healthy growth.

The microscopic pollen study carried out and following backcrosses made for the development of new CMS lines of desirable traits. The out crossing rate (OCR) remained up to 30% (Table 2).

Table 2: List of different crosses in backcross nursery

Sr. #	BC No.	No of Crosses	Category	OCR %
1	BC6	2	Basmati	28
2	BC5	2	Basmati	28
3	BC4	1	Basmati	30
4	BC3	7	Basmati/ Coarse	-
5	BC2	16	Basmati/ Coarse	-
6	BC1	11	Basmati/ Coarse	-

5. Development of new Parental lines

Eight hundred and ninety (890) lines from AxR crosses of F_2 to F_6 filial generations were transplanted in the field. Recommended agronomic

practices and plant protection measures were adopted. At maturity, three hundred and thirty three (333 single panicles were selected on field performance basis for further studies in the subsequent filial generations. Seventy five (75) uniform lines and eighty (80) single plants were also harvested.

Table 3: List of selected material from different hybrid rice generations

Generations	Selected Entries
F_2 (A x R)	40
F_3 (A x R)	417
F_4 (A x R)	214
F_5 (A x R)	61
F_6 (A x R)	3
Single Plants	105
HRDC (AxR)	50
Total Entries	890

Fig 4. Selections from different hybrid Generations (F_2-F_6)

6. Seed Production of Local hybrids

For seed production of two local rice hybrid KSK 111H (Basmati rice) and KSK 118H (coarse rice), differential seeding of parental line (R Line) done for the flowering synchronization and to prolong the pollen availability. The row ratio of Restorer and CMS lines was 2:6. At flowering stage, supplementary pollination done by shaking the R lines with the help of a rope to ensure the proper pollen shedding for good seed setting. At maturity, 5kg seed of KSK111H and 13kg seed of KSK118H harvested for the evaluation of these hybrids in preliminary yield trials.

(a) (b)

Fig 5. (a) Hybrid Seed Multiplication and (b) hybrid Seed Production

7. Seed multiplication of CMS lines

The cytoplasmic male sterile (CMS) lines, IR58025A and IR75596A seeded on 24.05.2016. The seeding of maintainer (B) line, IR58025B and IR75596B done on 26.05.2016 and 29.05.2016 to prolong the pollen availability period. The CMS lines along with their respective maintainer lines transplanted in the field accordingly with plant spacing of 20cm x 20cm and adopted recommended agronomic and plant protection measures. Flag leaf clipping of A lines done at booting stage to maximize the availability of pollen grains by avoiding the hindrance of long & broad flag leaves. At flowering, supplementary pollination by shaking maintainer lines with the help of a rope carried out to ensure the proper pollination for having good seed setting of CMS line. At maturity, 6 kg seed of the CMS line IR58025A and 3 kg seed of IR75596A harvested.

(a) (b)

Fig. 6: Flag Leaf clipping (a) Supplementary Pollination for seed multiplication and seed production (b)

8. Development of Parental Lines Resistant to BLB, Submergence and Salinity using MAS approach

Identified R and B lines selected for the development of new rice hybrids. The selected R and B lines crossed with resistant sources for BLB, Submergence and Salinity to transfer resistant genes in parental lines for the development of hybrids. Forty-two crosses attempted and thirty (30) successful crosses including eight for submergence, seven for BLB and 15 for salinity tolerance harvested for further evaluation.

9. Evaluation of new rice hybrids:

The nursery of 14 test hybrids and two check varieties sown on 10.06.2016. Thirty-five days old seedlings transplanted in the field in Randomized Complete Block Design with three replications. Fertilizers @ 100-50-0 NPK Kg/ha applied to each plot of each entry (5m x 1.8m with a hill spacing of 22.5 cm x 22.5 cm) and followed recommended agronomic practices for good crop stand with chemical protection against diseases and insect pests. The data regarding plant height, heading days, productive tillers per plant, panicle length, filled grains per panicle, spikelet fertility, maturity days, disease reaction and paddy yield recorded with cooking quality tests (Table 4).

Table 4: Yield and Quality of New Test Hybrids 2016

S. #	Hybrid	Yield (t/ha)	Type	Cooking
1.	KSK 111H	4.5	Basmati	Good
2.	KSK 132H	4.1	Basmati	Very Good
3.	KSK 126H	4.0	Basmati	Very Good
4.	KSK 128H	3.8	Basmati	Excellent
5.	KSK 131H	3.0	Basmati	Good
6.	Basmati 385 (Check)	3.4	Basmati	Good
7.	KSK 130H	5.4	Coarse	Good
8.	KSK 124H	4.6	Coarse	Good
9	KSK 118H	4.4	Coarse	Good
10	KSK 134H	4.3	Coarse	Fair
11	KSK 125H	4.1	Coarse	Good
12	KSK 127H	3.6	Coarse	Very Good
13	KSK 133H	3.0	Coarse	Good
14	KSK 129H	3.0	Coarse	Fair
15	KSK 123H	3.0	Coarse	Fair
16	Mumtaz 1471(check)	4.6	Coarse	Good

Fourteen test hybrids along with two checks evaluated for yield, quality and agronomic traits. Maximum yield 4.6 t/ha observed in Mumtaz 1471 (check) and 4.5t/ha in KSK111H. The yield of different hybrids ranged from 3.0-4.6 t/ha but excellent cooking quality observed in KSK128H.

Fig 7. Cooking quality of different test hybrids

10. Adaptability Trials on Rice Hybrids (NHRYT) 2016

To test the adaptability of imported rice hybrids at Rice Research Institute, Kala Shah Kaku seed of seventy (70) test hybrids supplied by Coordinator, Rice Programme, National Agriculture Research Center, Islamabad. The experiment laid out in Randomized Complete Block Design with three replications. The plot size of each variety kept 1.35 x 5.63 meter with 22.5 x

22.5 cm plant spacing. Data on maturity days, plant height, number of tillers/ plant, panicle length and grain yield recorded (Table 5).

Table 5: Adaptability Trials of Rice Hybrids 2016

S. #	Entry No.	Plant Height (cm)	No. of tillers	Maturity days	Tons/ ha
1	1	120	8	93	5.87
2	3	126	9	91	5.13
3	4	115	10	92	5.00
4	10	124	8	92	4.85
5	2	108	10	86	4.82
6	63	122	11	96	4.79
7	18	123	9	87	4.75
8	8	121	15	93	4.70
9	5	120	12	91	4.70
10	9	120	10	91	4.68
11	65	125	9	93	4.52
12	22	111	11	90	4.49
13	59	123	10	92	4.48
14	17	121	12	91	4.44
15	Mumtaz 1471 (Check)	110	12	92	4.44

Seventy two test hybrids were evaluated in the national adaptability yield trial 2016 for the agronomic traits and yield potential. The Maximum yield of 5.8t/ha was obtained in entry no.1 in comparison to entry no. 15 (check) with lowest yield of 4.4t/ha. More than 30% heterosis was observed in entry # 1.

III. AGRONOMY

Objective:

- Enhancement of rice production through resource saving, eco-friendly technologies and striving for farming excellence on sustainable basis
- Finding out optimum transplanting time and production technology of advance basmati and coarse grain lines.
- Development, standardization and popularization of resource conservation technologies for sustainable productivity.
- Screening of pre and post-emergence herbicides for effective weed control in transplanted and direct seeded rice.
- Integrated weed management in rice.
- Dissemination of modern rice production technology through demonstration, electronic and print media, and publications.
- Training to the master trainers and rice growers.

1. Effect of transplanting dates on the yield of fine grain rice lines/ varieties

To find out the optimum period of transplanting of fine grain lines/ varieties for obtaining maximum paddy yield and quality rice, an experiment was laid out using RCBD (factorial) design with three replicates. Thirty days old seedlings of each line/ variety were transplanted in the field on four different dates viz., 01-06-2016, 23-6-2016, 15-7-2016, 09-8-2016 by adopting the standard agronomic practices.

From the results (Table 1) it is revealed that two lines RRI 3 and PK 9194 performed best when transplanted on 23.06.2016 and least on transplanting date (09.08.2016). However, the highest average yield (6.30 t/ha) for all lines/ varieties was attained when transplanted on 23.06.2016.

Table 1: Effect of transplanting dates on paddy yield (t/ha) of fine grain rice lines

Varieties/ Lines	D1 (01.06.16)	D2 (23.06.16)	D3 (15.07.16)	D4 09.08.16)	Average
Basmati 515	4.67 ghij	6.42abcd	6.75 ab	4.92 j	5.69 b
RRI 3	5.42 ef	7.00 a	5.33efgh	4.33 ij	5.52 bc
PK 9194	5.25efgh	7.00 a	4.58 hij	4.48 hij	5.32 bc
PK BB15-1	5.50 ef	5.42 efg	4.83 fghi	4.71 fghi	5.11 c
PK BB15-6	5.83cde	6.00bcde	5.25 cfgh	5.50 ef	5.65 b
PK PB-8	4.42 ij	5.33ef	6.50 abc	6.00bcde	5.56 b
PK 10683	5.33efgh	5.67 de	5.50efgh	5.92 cde	5.60 b
PS 2	6.33abcd	6.92 a	5.67 de	5.50 ef	6.10 a
Average	5.38 b	6.30 a	5.28b	5.23 b	

2. Provincial coordinated yield trial for newly evolved fine grain rice varieties/ lines

The objective of this study to test the performance of newly evolved fine grain rice lines/ varieties under different ecological zones. The trial was laid out in RCBD (factorial) design with three repeats. The transplanting of lines/ varieties (Basmati 515, RRI 3, PK 9194, PK BB-15-1, PK BB-15-6, PK PB-8) was done in June and July according to the optimum time of transplanting of fine and coarse varieties. The newly evolved lines were transplanted on four different locations viz., Gujranwala, Faisalabad, Kala Shah Kaku and Farooq Abad by adopting standard crop management practices. The data regarding paddy yield and yield components was recorded.

Overall, PK PB-8 performed best (4.07 t/ha) at all ecological zones, whereas, bottle rank was occupied by Basmati 515 (check). All the lines out yielded than check on all four locations. Similarly, from the average of all locations it is revealed that all the lines/ varieties performed best at Farooqabad and least at Gujranwala.

Table 2: Yield (t/ha) of fine grain lines/varieties grown under different ecological zones

Lines/ Varieties	Gujranwala	Faisalabad	KSK	Farooqabad	Average
Basmati 515	3.44	2.62 c	3.44 b	4.02 ab	3.38
RRI 3	3.50	3.80 b	3.87 ab	3.85 ab	3.76
PK 9194	3.19	4.08 b	3.07 c	3.46 b	3.45
PK BB-15-1	3.02	3.88 b	3.80 b	3.54ab	3.56
PK BB-15-6	3.24	3.77 b	4.37 a	4.13 ab	3.88
PK PB-8	3.28	4.71 a	3.99 a	4.29 a	4.07
Average	3.28	3.81	3.76	3.88	
LSD	N.S	0.51	0.50	0.76	

3. Effect of transplanting dates on the yield of coarse grain rice lines/ varieties

Effect of transplanting dates was studied to find out the optimum period of transplanting of coarse grain rice lines/ varieties for getting maximum paddy yield. Eight lines were transplanted on 5th May, 27th May, 18th June and 10th July 2016. Data regarding paddy yield (t/ ha) are presented in the Table 3.

Table 3: Effect of transplanting dates on the yield (t/ha) of coarse grain rice lines/ varieties

Varieties/ Lines	D1 05.05.16	D2 27.05.16	D3 18.06.16	D4 10.07.16	Varieties Average
KSK 133	7.67	7.92	6.25	6.04	6.97
KSK 434	7.50	8.08	7.08	6.08	7.19
KSK 476	6.04	6.13	5.83	5.50	5.88
KSK 480	7.46	8.13	7.25	6.17	7.25
KSK 481	3.58	3.75	4.08	4.92	4.08
PK 7688-1-1-2-2	4.75	4.92	3.67	3.42	4.19
PK 9388-45-1-4-1-1	5.33	4.58	3.00	3.75	4.17
Dates average	6.05	6.22	5.31	5.13	

The data depicted that out of the seven lines, KSK 480 gave more yield in D2, D3, and D4 as compared to both check varieties (KSK 133, KSK 434). This line performed better (8.13 t/ha) when transplanted on 27th May. Before and after that considerable yield reduction occurred. It was also observed that all the coarse lines performed better when transplanted on 27th May and gradual reduction in yield was observed at all other dates of transplanting except PK

9388-45-1-4-1-1, which gave highest yield when transplanted on May 5, 2016. Overall, maximum average yield out of all transplanting dates was recorded in case of 27th May and highest paddy yield 8.08 and 8.13 t/ha was recorded in case of KSK 434 and KSK 480, respectively (Table 3).

4. Provincial coordinated yield trial for newly evolved coarse grain rice lines/ varieties

An experiment was conducted to test the performance of newly evolved coarse grain rice lines/ varieties under different ecological zones. Seven lines were transplanted on four location (Gujranwala, Faisalabad, Kala Shah Kaku and Farooqabad). The data (Table 4) illustrates that out of the seven lines/ varieties. KSK 481 produced maximum yield at Farooqabad (5.96 t/ha) followed by Faisalabad (5.84 t/ha) as compared to check variety, KSK 434 (5.65 t/ha).

Moreover, it observed that all the lines performed best at Farooqabad location and least at Gujranwala location. Overall, the new coarse promising line KSK 481 (4.92 t/ha) was out yielded than check variety KSK 434 (4.85 t/ha).

Table 4: Yield (t/ha) of coarse grain lines/varieties grown under different ecological zones

Lines/ Varieties	Gujranwala	Faisalabad	KSK	Farooqabad	Average
KSK 434 (check)	3.85	5.08	4.83	5.65	4.85
KSK 449	3.87	4.95	4.48	5.32	4.66
KSK 476	3.28	4.89	4.11	5.84	4.53
KSK 480	4.47	5.10	4.19	5.63	4.84
KSK 481	3.59	5.84	4.31	5.96	4.92
PK-7888-1-1-2-2	4.05	4.78	4.41	5.88	4.78
9347	4.39	4.26	4.62	5.31	4.645
Average	3.93	4.99	4.42	5.66	

5. Efficacy of post-emergence herbicides to control *Leptochloa chinensis* at different leaf stages

The objective of the study was to find out the most appropriate herbicide and leaf stage to control the noxious weeds, *Leptochloa chinensis* of aerobic rice systems. Ethoxysulfuron + fenoxaprop-p-ethyl+Isodoxafin (new chemical) @ 250 and 500 ml/acre and fenoxaprop-p-ethyl (Puma Super) performed better to control the weeds at all leave stages. All other herbicides showed higher efficacy against this weed at initial stage of weed growth (3- 5 leave stages) and their efficacy was reduced to control this weeds when their application was delayed mean at higher leave stages such as 6-16 and 10-26 leave stages.

Fig. 3: ***Leptochloa chinensis* weed of aeroic and anaerobic rice**

Table 5: Plant survival and biomass of weed plant sprayed by different herbicides at different leave stages

Herbicides	Plant survived/pot at varying LV stages			Biomass (g/pot) at varying LV stages		
Leave stages	**3-8**	**6-16**	**10-26**	**3-8**	**6-16**	**10-26**
Ethoxysulfuron + Fenoxaprop-p-ethyl+Isodoxafin @ 250 ml/acre	0	0	0	0	0	0
Ethoxysulfuron + Fenoxaprop-p-ethyl +Isodoxafin @ 500 ml/acre	0	0	0	0	0	0
Fenoxaprop-p-ethyl (Puma Super) @ 500 ml/acre	0	0	0	0	0	0

Herbicides	Plant survived/pot at varying LV stages			Biomass (g/pot) at varying LV stages		
Leave stages	**3-8**	**6-16**	**10-26**	**3-8**	**6-16**	**10-26**
Bispyribac sodium + bensulfuron + fenoxaprop 400 + 100ml adjuvant/acre	5	6	10	0.37	3.75	5.56
Bispyribac sodium + bensulfuron + clodinofap 400 + 100ml adjuvant/acre	3	4	8	0.48	3.95	4.20
Bispyribac sodium + Bensulfuron (jugni) 100g + 100ml adjuvant g/acre	6	8	19	0.41	1.61	8.62
Ethoxysulfuron + triafamone @ 200 g/acre	5	9	12	0.45	0.68	9.16
Control	16	16	15	0.63	5.37	10.95

Table 6: Percent weed control and percent biomass reduction of weed plant sprayed by different herbicides at varying leave stages

Herbicides	Plant survived/pot at varying LV stages			Biomass (g/pot) at varying LV stages		
Leave stages	**3-8**	**6-16**	**10-26**	**3-8**	**6-16**	**10-26**
Ethoxysulfuron + Fenoxaprop-p-ethyl @ 250 ml/acre	100	100	100	100	100	100
Ethoxysulfuron + Fenoxaprop-p-ethyl @ 500 ml/acre	100	100	100	100	100	100
Fenoxaprop-p-ethyl (Puma Super) @ 500 ml/acre	100	100	100	100	100	100
Bispyribac sodium + bensulfuron + fenoxaprop 400 + 100ml adjuvant/acre	69	63	33	42	30	49
Bispyribac sodium + bensulfuron + clodinofap 400 + 100ml adjuvant/acre	81	75	47	24	26	62
Bispyribac sodium + Bensulfuron (jugni) 100g + 100ml adjuvant g/acre	63	50	27	35	70	21
Ethoxysulfuron + triafamone @ 200 g/acre	69	44	20	29	87	16
Control	0	0	0	0	0	0

6. Effective weed control in dry-seeded rice through chemical approaches

The experiment was conducted to explore the best weedicide for effective control of weeds especially for three noxious weeds i.e., *Leptochloa chinensis* (Kallar Grass), *Eragrostis japonica* (Bansi grass) and *Dactyloctenium aegyptium* (Madhana Grass) in dry-seeded rice, DSR (Fig. 4).

The results (Table 8) revealed that among all the treatments, the excellent weed control (91%) was achieved in the plots where pendimethalin was applied as pre-emergence followed by bispyribac sodium + bensulfuron followed by phenoxaprop-p-ethyl with highest yield (4.5 t/ha). The lowest weed control was observed in plots treated with Pendimethalin alone (44%) and Pendimethalin followed by ethoxysulfuron (59%). Similar trend for weed control and paddy yield recorded at Adaptive Research Farm, Sheikhupura (Table 8).

Fig. 4: **Pics of *Leptochloa chinensis* (Kallar Grass), *Eragrostis japonica* (Bansi grass) and *Dactyloctenium aegyptium* (Madhana Grass)**

Fig. 5: **DSR drill sowing, weed identification, herbicide application and DSR rice crop after weed control**

Table 7: **Weed count and biomass as effected by varying herbicide application as a sole and combinations**

Treatment	Grasses		Sedges		BLW	
	Density	Weight (g)	Density	Weight (g)	Density	Weight (g)
Pendimethalin fb bispyribac sodium + bensulfuron fb fenoxaprop-p-ethyl	5.00	20.33	3.00	17.67	1.33	2.33
Pendimethalin fb bispyribac sodium fb fenoxaprop-p-ethyl	7.33	25.33	5.33	28.33	0,00	0.00
Pendimethalin fb ethoxysulfuron fb fenoxaprop-p-ethyl	9.00	48.00	5.67	24.33	0.00	0.00
Pendimethalin fb bispyribac sodium + bensulfuron	6.67	50.00	8.67	26.67	0.33	0.67

Treatment	Grasses		Sedges		BLW	
	Density	Weight (g)	Density	Weight (g)	Density	Weight (g)
Pendimethalin fb fenoxaprop-p-ethyl	8.00	50.33	10.33	84.67	0.00	0.00
Pendimethalin fb bispyribac sodium	11.33	69.00	6.67	37.33	2.67	2.00
Pendimethalin fb ethoxysulfuron	12.67	42.00	23.67	180	1.33	4.67
Pendimethalin	17.33	107.33	20.33	130.33	13.00	26.00
Control	79.67	364.33	10	66	6.67	13.67
LSD	18.7	86.3	9.3	63.0	NS	NS

Table 8: Total weed count, biomass, % weed control and grain yield of rice as affected by varying herbicide application as a sole and combinations

Treatments	Weeds/ m^2		Weed Control (%)	Yield (t/ ha)	
	Total No	Dry weight (g)		RRI, KSK	ARF, Shakargarh
Pendimethalin fb bispyribac sodium + bensulfuron fb fenoxaprop-p-ethyl	9	40.3	91	4.45	3.21
Pendimethalin fb bispyribac sodium fb fenoxaprop-p-ethyl	12	55.7	87	4.3	3.08
Pendimethalin fb ethoxysulfuron fb fenoxaprop-p-ethyl	16	73.3	83	4.25	2.97
Pendimethalin fb bispyribac sodium + bensulfuron	16	73.3	83	4.32	2.81
Pendimethalin fb fenoxaprop-p-ethyl	17	135.3	81	3.89	2.69
Pendimethalin fb bispyribac sodium	19	108	79	3.36	2.46
Pendimethalin fb ethoxysulfuron	37	228	59	2.76	2.42
Pendimethalin	52	267.7	44	1.44	2.35
Control	91	436	0	0.1	1.44
LSD	22	104.7		1.84	0.1

7. Screening of Pre-Emergence Herbicides to Control Weeds in Transplanted Rice

To find out the most effective pre-emergence herbicides for control of weeds in transplanted rice, experiment laid out in randomized complete block design with three replications. Thirty-five days old seedlings of variety Super Basmati were planted on 21-07-2016. Pre-emergence herbicides viz: Council Active (triafamone 10%+ ethoxy sulfurone methyl 20%) and Kelion (orthosulfamuron) as a standard were applied with shaker bottle after four days of transplanting. Water was remained standing in the field for five days after herbicide application then flushed out from the field. After two-weeks of herbicide application, data of weeds/ m^2 recorded. Data regarding date of 100% flowering, plant height, productive tillers/plant, grains per panicle,1000 grain weight and paddy yield were recorded. The data regarding number of weeds/ m^2, percent (%) weed control and paddy yield (t/ha) are presented in Table 9. Among all the treatments (Table 10), the maximum weed control (84.6%) was achieved in the plots where triafamone + ethoxysulfurone methyl was applied with highest paddy yield (3.74 t/ha) followed by orthosulfamuron with weed control of 63.3% and paddy yield (3.47 t/ha). However, lowest weed control and paddy yield (1.96 t/ha) was observed in the plots where no herbicide was applied.

Fig. 5: Herbicide application and crop 30 days after herbicide application

Table 9: Weed count after varying herbicide application as a pre-emergence

Treatments	No. of Grasses	No. of Sedges	No. of Broad Leave Weeds
Triafamone + Ethoxy sulfurone methyl	3.33	2.00	0.00
Orthosulfamuron	7.67	5.33	0.00
Control	11.0	13.3	3.33

Table 10: Effect of herbicide application as a pre-emergence on Weed survival, %weed control and paddy yield (t/ha)

Treatments	No. of weeds/m^2	Percent (%) Control	Paddy yield (t/ha)
Triafamone + Ethoxy sulfurone methyl	5.3 c	84.6 a	3.74a
Orthosulfamuron	13.0 b	63.3 b	3.48b
Control	27.7 a	-	1.96c

8. Bio-Fortification of Rice Varieties with Zinc and Iron

The study designed in split plot design to assess the response of promising coarse and fine grain rice varieties to foliar application of micronutrients, zinc and iron for bio fortification of rice grains aimed to improving nutritional value of rice grain.

Table 11: Fe and Zn contents (ppm) in polished rice grains of different coarse rice varieties

Rice varieties	No foliar applied		Foliar applied		% Increase	
	Fe	Zn	Fe	Zn	Fe	Zn
KS 282	12.0	19.1	19.9	26.8	7.9	7.7
KSK 133	21.8	17.5	31	17.7	9.2	0.2
KSK 434	23.3	18.6	29.5	23.2	6.2	4.6

A considerable increase in the zinc contents of grains recorded in KS 282 and KSK 434, the former being at the top in response (Table 11). As far as Fe is concern, a maximum percent increase in the Fe contents of grains was

recorded in KS 282 (7.9%) and KSK 133 (9.2%). The maximum yield 5.55 and 5.45 t/ha was obtained when foliar application of 0.1% zinc (Zn) solution and 0.2 % iron (Fe) solution was applied at milking and dough stages in KSK 434 and KS 282, respectively.

Similarly, foliar application of Fe and zinc in the form of zinc sulphate improved zinc contents of grains and the Super basmati gave the highest response (Table 11).

Table 11: Fe and Zn contents (ppm) in polished rice grains of different basmati rice varieties

Rice varieties	No foliar applied		Foliar applied		% Increase	
	Fe	Zn	Fe	Zn	Fe	Zn
PK 386	21.0	13.6	31.5	16.9	10.5	3.3
Basmati 515	16.3	13.3	20.8	15.9	4.5	2.6
Super Basmati	22.0	14.0	36.8	18.6	14.8	4.6

9. Effect of Tillage Systems on Rice Crop Growth and Productivity in Rice-Wheat Cropping System

To find out an appropriate tillage-residue (TR) system for productivity enhancement of rice-wheat cropping system through resource conservation, an experiment laid in RCBD with split plot arrangement (Fig. 6). This trial conducted to select appropriate residue management options to improve soil health and save the environment (Table 12).

The results (Table 13) reflected that the highest wheat yield (3.72 t/ha) was achieved with DSR–ZT (partial retention) while the highest paddy yield (3.59 t/ha) was recorded with TR–ZT (partial retention) however it remained at par with DSR–ZT (partial retention) and TR – CT (partial burning). Whereas the total system productivity reached its peak in the plots where rice was direct seeded (partial retention) and wheat was planted in ZT with partial retention.

Table 12: Different tillage systems in Kharif and Rabi crops

Treatments	Kharif	Rabi
TR – CT (partial burning)	TR (partial burning)	CT-wheat (partial burning)
TR – CT (incorporation)	TR (incorporation)	CT-wheat (incorporation)
DSR – ZT (partial retention)	DSR-CT (partial retention)	ZT-wheat (full retention)
TR – ZT (partial retention)	TR (partial retention)	ZT-wheat (full retention)
DSR(ZT) - ZT (full retention)	DSR-ZT (full retention)	ZT-wheat (full retention)

CT: Conventional tillage, ZT: Zero tillage, DSR: Direct seeded rice, TR: Transplanted rice

Table 13: Grain yield of wheat and rice crops under different tillage systems

Treatments	Wheat Yield (t/ha)	Paddy yield (t/ha)	Average (t/ha)
TR – CT (partial burning)	3.35 bc	3.48 ab	3.42
TR – CT (incorporation)	3.01 c	2.89 cde	2.95
DSR – ZT (partial retention)	3.72 a	3.40 ab	3.56
TR – ZT (partial retention)	3.42 ab	3.59 ab	3.51
DSR(ZT) - ZT (full retention)	3.66 ab	3.02 bc	3.34
LSD	0.344	0.35	

Wheat crop in rice residue

Rice crop in wheat residue

Fig. 5: Emergence of wheat crop drilled in rice residue and rice crop drilled in wheat residue

10. Enhancing rice yield with foliar application of macronutrients (phosphorous and potassium)

The experiment aimed at to decrease the P & K fixation in soil and to reduce the fertilizer cost along with harvesting better yield in rice (Table 14). The results (Table 15) revealed that the highest grain yield recorded in the plots where along with recommended dose of NP, 75% of K applied as basal dose along with its two foliar applications. However, application of P as foliar spray could not result any increase in the yield.

Table 14: Doses of soil and foliar application of macronutrients (phosphorous and potassium)

Treatment Description	Soil Application			Foliar Application @ 2%
	N kg/ha	P_2O_5 kg/ha	K2O kg/ha	Stage of P & K Spray
Control	0	0	0	0
Recommended Dose of NPK	133	85	62	0
Recommended Dose of NK + 75% P (Soil application) + Two sprays of P @ 2 %	133	64	62	1st spray of P at tillering & 2nd at panicle initiation
Recommended Dose of NK + 50% P (Soil application) + Three sprays of P @ 2 %	133	43	62	1st spray of P at tillering, 2nd before panicle initiation & 3rd after panicle initiation
Recommended Dose of NP + 75% K (Soil application) + Two sprays of K @ 2 %	133	85	47	1st spray of K at tillering & 2nd at panicle initiation
Recommended Dose of NP + 50% K (Soil application) + Three sprays of K (@ 2 %	133	85	31	1st spray of K at tillering, 2nd before panicle initiation & 3rd after panicle initiation

Table 14: Paddy grain yield (t/ha) as effected by soil and foliar applied macronutrients (phosphorous and potassium)

Treatment	Paddy Yield (t/ha)
RD NPK	4.8 ab
RD NK + 75 % P (Soil Application) + 2 Spray of P	4.5 ab
RD NK + 50 % P (Soil Application) + 3 Spray of P	4.1 bc
RD NP + 75 % K (Soil Application) + 2 Spray of K	5.2 a
RD NP + 50 % K (Soil Application) + 3 Spray of K	4.2 bc
Control	3.3 c
LSD	0.959

RD = Recommended Dose

IV. ENTOMOLOGY

Objective:

- To study lines/ varietal response against different insect pests.
- To evaluate the effectiveness of pesticides against different rice pests and impact assessment of insecticides on beneficial fauna.
- To develop integrated pest management strategies to suppress the population of notorious insect pests.

1. Screening of breeding material for resistance against rice leaffolder (*Cnaphalocrocis medinalis*) under field conditions

Thirty-eight fine and eighteen coarse grain rice lines/ varieties of local origin were tested and analyzed for their respective response against leaffolder (Fig. 1) by using Standard Evaluation System (SES) for Rice, 2013 developed by the IRRI, Philippine.

The least percent infestation of leaffolder (15.92) observed in coarse line RC-5 (Table 1) followed by fine line PK PB-8 (19.74) as depicted in Table 2.

(a)

(b)

Fig. 1: Rice leaffolder larvae (a) feed inside the longitudinal leaf fold (b) made by his salivary secretions

Table 1: Percentage infestation record of rice leaffolder on coarse lines/ varieties.

S.#	Line/ variety	Percent infestation	SES Score	*Response
1.	RC-5	15.92	3	MR
2.	ZCHI F	17.34	3	MR
3.	RC-7	18.78	3	MR
4.	PK 9259-4-1-1	19.75	3	MR
5.	KSK 485	19.76	3	MR
6.	KSK 133	21.16	5	MS
7.	RC-8	21.30	5	MS
8.	KSK 482	21.49	5	MS
9.	KSK 488	21.96	5	MS
10.	KSK 476	22.51	5	MS
11.	KSK 487	24.15	5	MS
12.	KSK 484	24.76	5	MS
13.	KSK 486	25.27	5	MS
14.	RC-6	25.47	5	MS
15.	KSK 283	26.01	5	MS
16.	KSK 434	27.21	5	MS
17.	IR 73014-59	30.39	5	MS
18.	PK 9832-45-1-4-1-1	32.53	5	MS

* MR – Moderately resistant; MS – Moderately susceptible

Table 2: Percentage infestation record of rice leaffolder on fine lines/ varieties

S.#	Line/ variety	Percent infestation	SES Score	*Response
1.	PK PB-8	19.74	3	MR
2.	PK 10820-8-1	19.94	3	MR
3.	PK 10344-12-1-1	17.86	3	MR
4.	PK 10395-8-1-1	19.14	3	MR
5.	OL 160	19.34	3	MR
6.	Shaheen Basmati	18.40	3	MR
7.	PK 9531-6-3-1-1	30.93	5	MS
8.	PK 9301-5-2-1-2	24.34	5	MS
9.	PK 9435-4-1-1	21.65	5	MS
10.	PK10198-7-2	20.66	5	MS
11.	PK 9533-9-6-1-1	27.20	5	MS
12.	PK 9966-10-1	33.54	5	MS
13.	PK 10161-1-5-1	38.81	5	MS
14.	PK 9699-6-2-1	23.72	5	MS
15.	RRI 7	30.12	5	MS
16.	PK 9748-16-2-1	21.66	5	MS
17.	PK 10683-12-1	28.96	5	MS
18.	PK 10348-7-1-3	27.13	5	MS
19.	PK 10350-7-2-1	25.66	5	MS

S.#	Line/ variety	Percent infestation	SES Score	*Response
20.	PK 10355-13-2-1	28.63	5	MS
21.	PK 10356-10-1-1	27.23	5	MS
22.	PK 10473-3-1-1	21.11	5	MS
23.	PK 10495-7-3-1	21.55	5	MS
24.	PK 10383-5-1-1	31.98	5	MS
25.	PK 10395-1-1-1	22.39	5	MS
26.	PK 10419-2-1-1	20.91	5	MS
27.	PK 10434-6-2-1	34.44	5	MS
28.	PK 10436-2-1-1	21.53	5	MS
29.	OL 159	27.49	5	MS
30.	PK BB 15-01	23.08	5	MS
31.	PK BB 15-06	31.11	5	MS
32.	PK BB 15-08	28.90	5	MS
33.	Super Basmati	23.40	5	MS
34.	Basmati 515	25.13	5	MS
35.	PS 2	20.33	5	MS
36.	PK 9699-6-2-1	38.81	7	S
37.	PK 9194-54-1-1-2-2	40.16	7	S
38.	PK 10355-13-1-1	36.86	7	S

* MR – Moderately resistant; MS – Moderately susceptible; S - Susceptible

Keeping in view, the response of lines/ varieties against rice leaffolder (Fig. 2) six fine grain lines (PK PB-8, PK 10820-8-1, PK 10344-12-1-1, PK 10395-8-1-1, OL160 and Shaheen Basmati) and five coarse grain lines (RC-5, ZCHI F, RC-7, PK 9259-4-1-1 and KSK 485) behaved as moderately resistant.

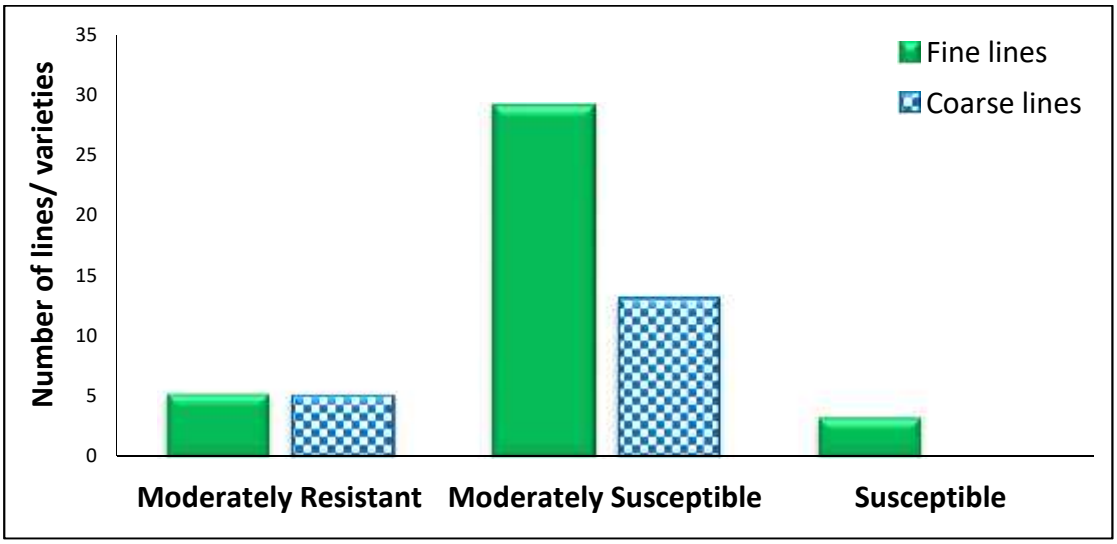

Fig. 2: Response of rice lines/ varieties against leaffolder

2. Screening of pesticides for the effective control of different rice insect pests under field conditions

To observe the efficacy of different pesticides (Table 3) for the effective control of rice insect pests along with standard treatments tested for their effectiveness against target pests on Basmati 515 using standard agronomic practices under field conditions in RCBD, replicated thrice. Two candidate insecticides tested against leaffolder, seven against stem borers and one against planthopper (Table 3) and all applied at their respective economic threshold level- ETL viz., 3 larvae or folded leaves/ plant in September, 5% deadheart by stem borers and 20-25 nymphs or adults of planthoppers/ plant.

Table 3: Insecticides used against rice insect pests

Sr. #	Insecticides	Common Name	Dose/ acre	Category
A.	**LEAFFOLDER**			
1.	Tri super 40EC, JBL	triazophos	600ml	Candidate
	Trizone 40EC, SUNCROP	triazophos	600ml	Standard
2.	Belt 480SC, BAYER	flubendiamide	20ml	Candidate
	Virtako 405WG, SYNGENTA	thiamethoxam+ chlorantraniliprole	40g	Standard
B.	**STEM BORER**			
1.	Tri super 40EC, JBL	triazophos	600ml	Candidate
	Trizone 40EC, SUNCROP	triazophos	600ml	Standard
2.	Regent 80WG, BAYER	fipronil	30gm	Candidate
	Coragen 20SC, DUPOMT	chlorantraniliprole	50ml	Standard
3.	Tara Gold 5G, TARA	monomehypo	7Kg	Candidate
	Hoopoe 4G, FMC	cartap hydrochloride	9Kg	Standard
4.	Star 4G, SUNCROP	cartap hydrochloride	9Kg	Candidate
	Padan 4G, FMC	cartap hydrochloride	9Kg	Standard
5.	Ford 5G, SUNCROP	monomehypo	7Kg	Candidate
	Brifur 3G, KANZO	carbofuran	8Kg	Standard
6.	Oncol 3G, OAT PAK	benfuracarb	8Kg	Candidate
	Padan 4G, FMC	cartap hydrochloride	9Kg	Standard
7.	Pravo 10SC, R.B. AVARI	fipronil+lambda cyhalothrin	300ml	Candidate
	Karate 2.5EC, SYNGENTA	lambda cyhalothrin	160ml	Standard

C.	PLANTHOPPER			
1.	Plenum 30WG, SYNGENTA	pymetrozine	120g	Candidate
	Regent 80 WG, BAYER	fipronil	30gm	Standard

The effectiveness of pesticides (Fig. 3) showed that maximum and minimum percent mortality of leaffolder observed in Belt (93.94) and Tri-super (91.66) respectively. Minimum and maximum survival percentage of beneficial fauna (Table 4) per 5 plants observed in Trizone (50.05) and Belt (65.75), respectively as compared to untreated check (113.03).

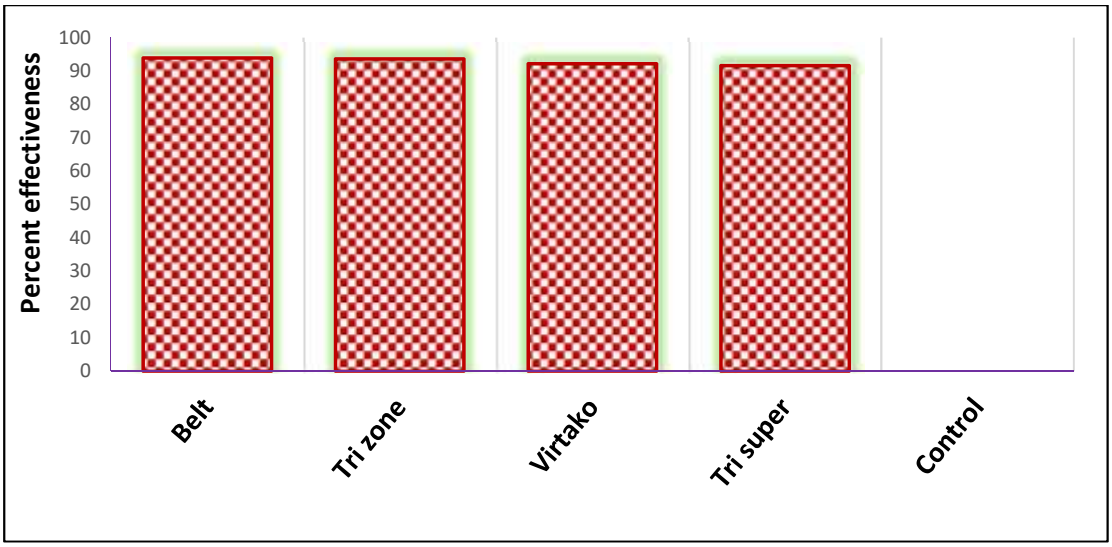

Fig. 3: Post- treatment percent effectiveness of insecticides against rice leaffolder with respect to control

Table 4: Impact assessment of insecticides used against leaffolder on beneficial fauna

S.#	Treatment	Common Name	Beneficial fauna/ 5 plants	
			Pre-treatment (Number)	Post- treatment survival percentage
1.	Trizone 40EC	triazophos	4.93	50.05
2.	Tri super 40EC	triazophos	4.60	50.22
3.	Virtako 405WG	thiamethoxam+ chlorantraniliprole	4.47	52.11
4.	Belt 480SC	flubendiamide	4.33	65.75
5.	Control	-	4.53	113.03

The results (Fig. 5) further elucidated the minimum and maximum percent deadhearts by stem borers (Fig. 4) in case of Oncol (0.10) and Regent (0.50), respectively. However, minimum and maximum survival percentage of beneficial fauna per 5 plants (Table 5) was observed in Karate (43.33) and Padan (62.96), respectively as compared to untreated check (105.41).

Fig. 4: Deadheart

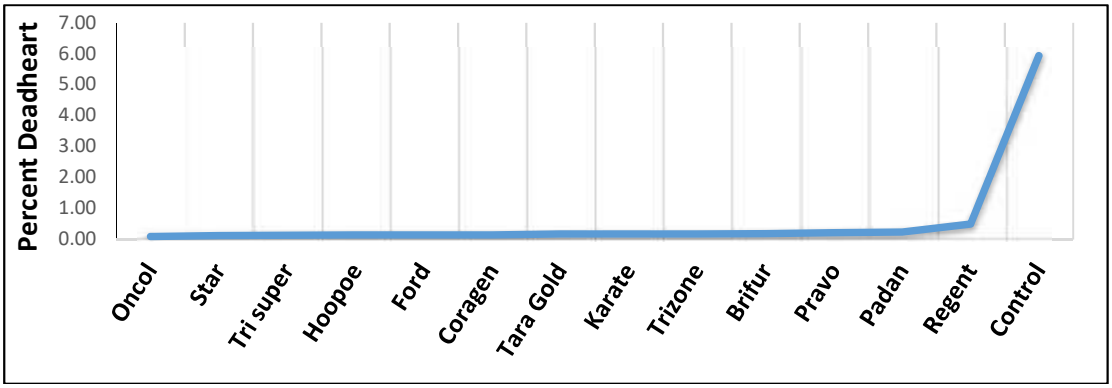

Fig. 5: Post- treatment percent deadhearts in case of stem borers

Table 5: Impact assessment of insecticides used against stem borers on beneficial fauna

S.#	Treatments	Common Name	Beneficial fauna/ 5 plants	
			Pre-treatment (Number)	Post- treatment survival percentage
1.	Karate 2.5EC	lambda cyhalothrin	2.13	43.33
2.	Pravo 10SC	fipronil+lambda cyhalothrin	2.27	46.34
3.	Coragen 20SC	chlorantraniliprole	2.33	46.87
4.	Regent 80WG	fipronil	1.8	49.97
5.	Trizone 40EC	triazophos	1.73	50.00
6.	Tri super 40EC		2.6	51.11
7.	Tara Gold 5G	monomehypo	1.87	51.26
8.	Ford 5G		0.85	52.38
9.	Oncol 3G	benfuracarb	1.53	52.38
10.	Brifur 3G	carbofuran	1.93	52.78
11.	Hoopoe 4G	cartap hydrochloride	2.67	53.61
12.	Star 4G		2.25	55.95
13.	Padan 4G		1.53	62.96
14.	Control	-	2.09	105.41

Similarly, the results (Fig. 7) showed that maximum percent mortality of planthoppers (Fig. 6) observed both in plenum and in Regent (99.13). However, minimum and maximum survival percentage of beneficial fauna per 5 plants (Table 6) was observed in Regent (52.58) and Plenum (57.52), respectively as compared to untreated check (136.83).

Fig. 6: Whitebacked planthopper

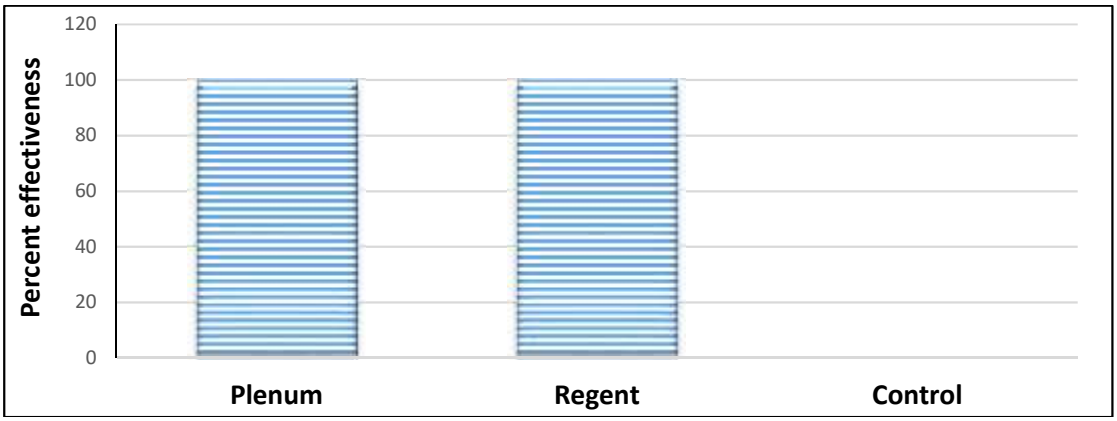

Fig. 7: Post- treatment percent effectiveness of insecticides against planthoppers with respect to control

Table 6: Impact assessment of insecticides used against planthoppers on beneficial fauna

S. #	Treatments	Common Name	Pre- treatment (Number)	
			Pre- treatment (Number)	Post- treatment survival percentage
1.	Regent 80WDG	fipronil	2.60	52.58
2.	Plenum 30WG	pymetrozine	3.00	57.52
3.	Control	-	7.60	136.83

V. PLANT PATHOLOGY

Objective:

- Screening of rice germplasm against different diseases.
- Evaluation of different chemicals/ fungicides against the diseases.

1. Screening of Rice Lines/ varieties against Bacterial Leaf Blight (*Xanthomonas oryzae* pv. *oryzae*)

The objective of this trial was to find out resistant sources in available genetic material of rice. For this purpose, fifty-five (55) rice lines/varieties (both coarse and fine) were evaluated. Inoculation of the plants was done with *X. oryzae* pv. *oryzae* at booting stage. Data on percent leaf area infected (Fig. 1) was recorded 14 and 21 days after inoculations following the Standard Evaluation System for Rice-IRRI.

Fig. 1: Bacterial leaf blight

Among the 55 lines/varieties, 29 were moderately resistant and 17 were moderately susceptible. Moderately resistant lines that were found resistant against the disease can be used in the breeding program for the development of resistant varieties (Table. 1).

Table 1: Response of 55 lines/varieties against BLB infection

Quality	No of lines	Name of variety/line
Resistant	0	-
Moderately Resistant	29	KSK 484, KSK 485, KSK 486, KSK 487, KSK 488, KSK 434, RC 5, RC 8, PK 9531-6-3-1-1, PK 9699-6-2-1, PK 9435-4-1-1, PK 10198-7-2, PK 9533-9-6-1-1, PK 9966-10-1, PK 10161-1-5-1, PK BB-8, PK 10683-12-1, PK 10344-12-1-1, PK 10348-7-1-3, PK 10355-13-2-1, PK 10473-3-1-1, PK 10395-1-1-1, PK 10395-8-1-1, PK 10434-6-2-1, PK BB 15-06, OL160, Super Basmati, Basmati 515, PS 2
Moderately Susceptible	17	KSK 476, PK 9259-4-1-1, KSK 133, RC-7, PK 9301-5-2-1-2, PK 9699-6-2-1, RRI 7, PK 9748-16-2-1, PK 9194-54-1-1-2-2, PK 10820-8-1, PK 10350-7-2-1, PK 10356-10-1-1, PK 10419-2-1-1, PK 10436-2-1-1, OL 159, PK BB-15-08, PK BB 15-01,
Susceptible	09	KSK 482, KSK 483, PK 9832-45-1-4-1-1, RC 6, ZCHIF, PK 10355-13-1-1, PK 10495-7-3-1, PK 10383-5-1-1, IR 73014-59

2. Screening of Rice Lines/ Varieties against Blast (*Pyricularia oryzae*)

The trial was conducted with the objective that screening of rice lines/ varieties against rice blast (*P. oryzae*) to develop new durable resistant varieties through breeding programme (Fig. 2). The nursery sown on raised dry bed in last week of August. Inoculation with *P. oryzae* done three weeks after sowing. Varieties were evaluated following the Standard Evaluation System for Rice.

Fig. 2: Blast symptoms on leaves

Table 2: Response of 55 lines/varieties against BLB infection

Quality	No. of lines	Name of variety/line
Resistant	0	-
Moderately Resistant	1	KSK 476
Moderately Susceptible	24	Basmati 515, Super Basmati, PK BB 15-08, PK BB 15-06, OL 159, PK 10436-2-1-1, PK 10395-8-1-1, PK 10356-10-1-1, PK 10350-7-2-1, PK 9194-54-1-1-2-2, PK 9533-9-6-1-1, RC-8, RC-7, RC-6, PK 9832-45-1-4-1-1, PK 9259-4-1-1, KSK-488, KSK-487, KSK-486, KSK-485, KSK-484, KSK-483, KSK-482
Susceptible	30	IR 73014-59, KSK 133, KSK 434, RC- 5, ZCHIF, PK 9531-6-3-1-1, PK 9301-5-2-1-2, PK 9699-6-2-1, PK 9435-4-1-1, PK 9966-10-1, PK 10161-1-5-1, PK PB-8, RRI-7, PK9748-16-2-1, PK 10683-12-1, PK10820-8-1, PK 10344-12-1-1, PK10348-7-1-3, PK 10355-13-1-1, PK10355-13-2-1, PS 2, PK BB 15-01, OL 160, PK 10434-6-2-1, PK 10419-2-1-1, PK10395-1-1-1, PK10383-5-1-1, PK 10495-7-3-1, PK 10473-3-1-1

The evaluation of the rice lines/ varieties data was recorded (Table. 2) and observed one variety as moderately resistant **(**KSK 476).

3. Efficacy of Different Fungicides for the Control of Blast (*Pyricularia oryzae*) of Rice

In addition to resistant varieties, another promising method of disease control is the judicious use of fungicides. For this purpose, a field experiment was conducted with randomized complete block design (RCBD). Most susceptible rice variety Basmati C-622 was sown. The crop was inoculated with *P. oryzae.* Seven fungicides viz., Amistar Top 325 SC (Azoxystrobin + Difenoconazole), Nativo 75 WG (Trifloxystrobin+Tebuconazole), Dora 10 WG (Difenoconazole), Dorazole 50 EC (Difenoconazole+Propiconazole), Score 250 EC (Difenoconazole), Kocide 3000 52.4 WG (Copper hydroxide) and simple sterilized water were sprayed at late booting stage and 4-5 days after panicle emergence. Blast incidence and paddy yield data was recorded following the IRRI scale.

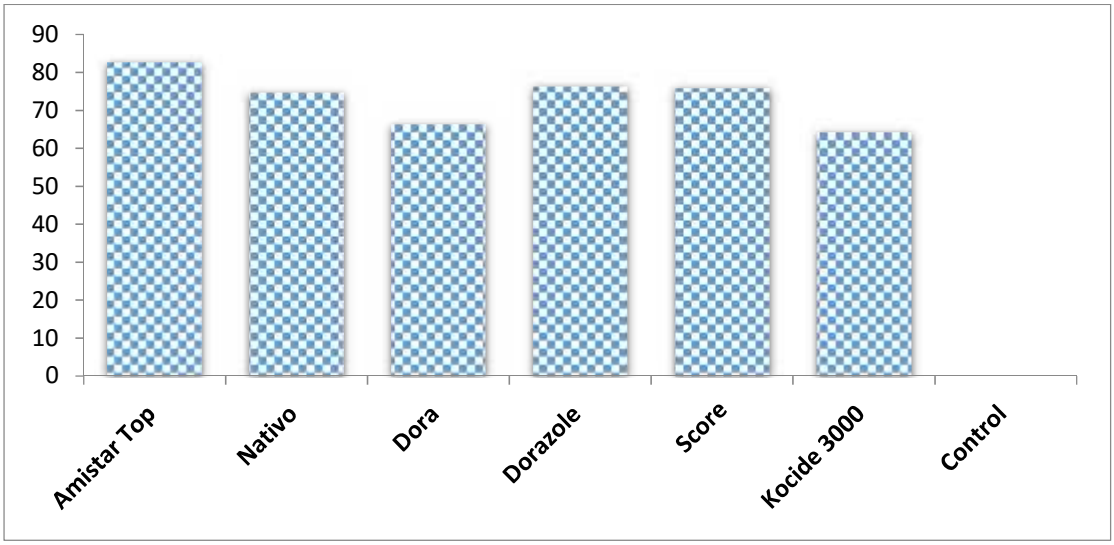

Fig. 3: Control (%) of different fungicides against Blast

Results showed that Amistar Top (83%) gave good control of blast disease, followed by Dorazole (76%), Score (76%) and Nativo (75%) as compared to control (Fig. 3).

4. Effect of Different Chemicals on Bacterial Leaf Blight (*Xanthomonas oryzae* pv. *oryzae*) of Rice

For the evaluation of available chemicals/fungicides, viz., Nativo 75WG (Trifloxystrobin+Tebuconazole), Score 250EC (Difenoconazole), Copper oxychloride, Dorazole 50EC (Difenoconazole+Propiconazole), Switch-DF 80WG (Sulfur), and Kocide 3000 52.4WG (Copper hydroxide) against bacterial leaf blight disease were applied. Susceptible variety Basmati-2000 was sown. The crop was inoculated with *X. oryzae* pv *oryzae*. Seven treatments including six (06) test chemicals/fungicides and one (01) simple sterilized water were sprayed at booting stage and repeated after 7 days. Data regarding BLB incidence was recorded 2-3 weeks after second spray following the scale devised by IRRI.

The trial results (Fig. 4) showed that Nativo was most effective among all the treatments with 88% control from disease and 5.4 tons/ha yield. After Nativo, Score and Copper oxychloride gave better results showing 86% protection and 4.25 tons/ha yield and 84% protection and 4.5 tons/ha yield, respectively. Highest disease incidence was recorded in control (sterilized water) with lowest yield of 2.3 tons/ha.

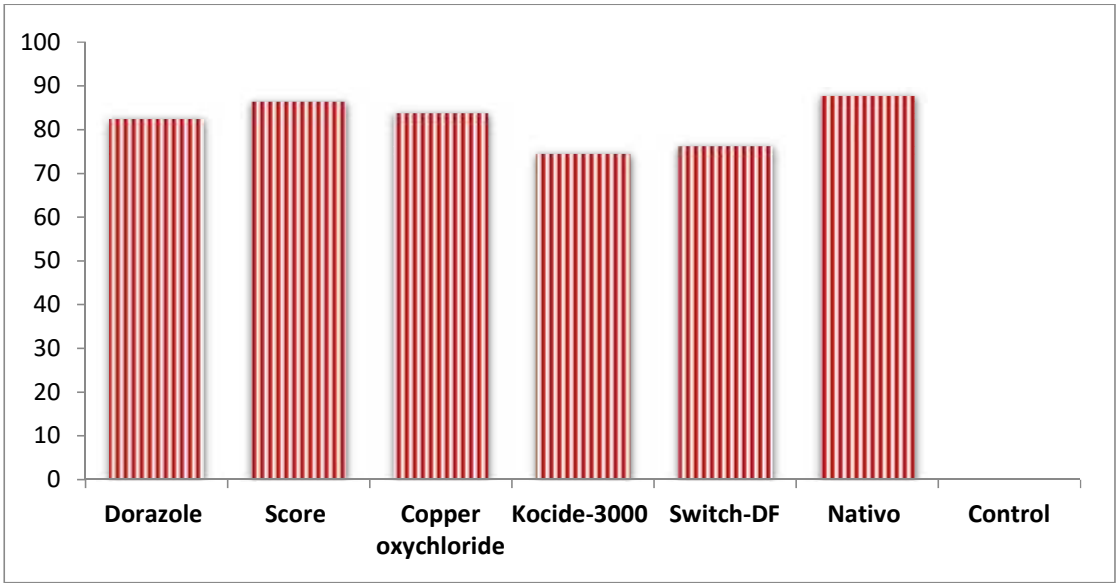

Fig. 4: Control (%) of different fungicides against Bacterial Leaf Blight (BLB)

5. Efficacy of Different Spray Fungicides for the Control of Brown Leaf Spot (*Drechslera oryzae*) of Rice

Six (06) fungicides viz., Amistar Top 325 SC (Azoxystrobin + Difenoconazole), Kumulus DF 80 WG (Sulfur), Nativo 75 WG (Trifloxystrobin + Tebuconazole), Switch-DF 80 WG (Sulfur), Kocide-3000 54.2 WG (Copper hydroxide) and Score 250 EC (Difenoconazole) were evaluated against the disease (Fig. 5) with control (sterilized water) in RCBD layout replicated thrice. Super Basmati was sown as susceptible variety in the experiment. The crop was inoculated with the inoculum of *D. oryzae*. The test fungicides were sprayed at booting stage and repeated after 10 days. Data regarding BLS disease incidence was recorded by following the scale devised (IRRI).

Fig. 5: Brown leaf spot

Switch-DF gave the highest protection from disease (84%) with yield of 4.8 tons/ha, followed by Amistar Top (76% protection and 4 tons/ha yield) and Kumulus-DF (75% and 3.75 tons/ha). All the treatments were compared with

control (sterilized water) which gave highest disease incidence and lowest yield (Fig. 6).

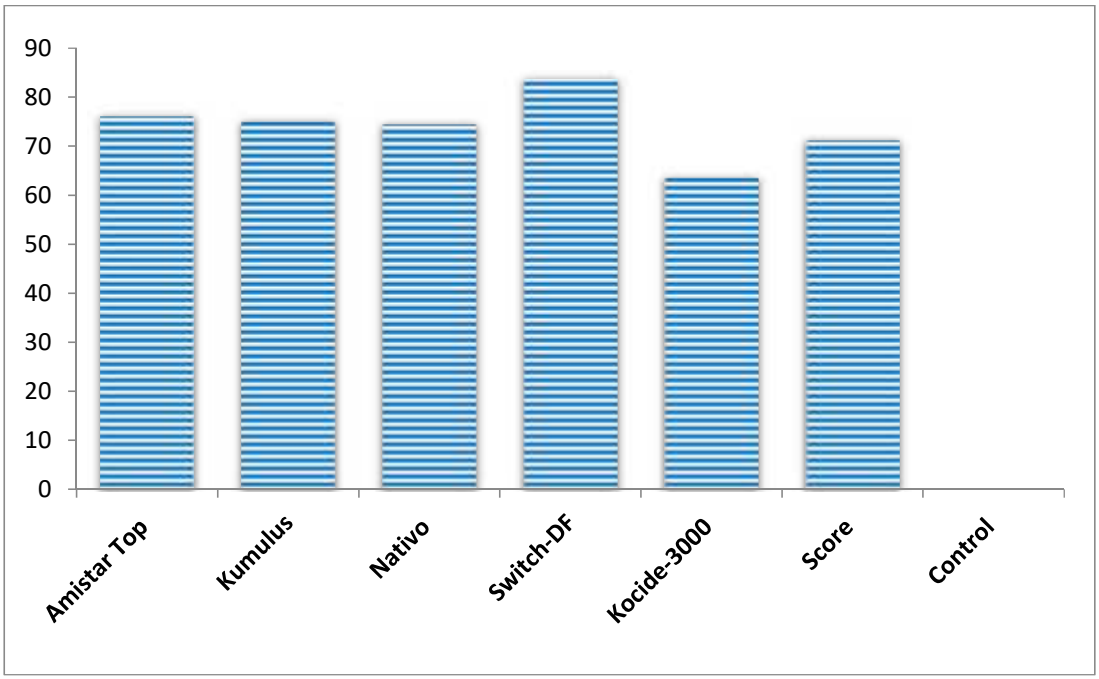

Fig. 6: Control (%) of different fungicides against Brown Leaf Spot (BLS)

VI. AGRICULTURAL ENGINEERING

Objectives:

- To maximize crop and water productivity through improved water saving techniques and management interventions

1. Varietal performance of different rice cultivars in terms of yield and yield components as affected by water irrigation regimes

To evaluate the four different rice varieties against three different Irrigation Regimes (IR), experiment designed to check their varietal performance in terms of yield and yield components. To observe the effect of three different levels of Alternate Wetting and Drying (AWD) on yield and yield components; four varieties (Punjab Basmati, Chenab Basmati, Kissan Basmati and Basmati 515) tested using their standard agronomic practices under field conditions in split plot (RCBD) in four replications. Standard method for AWD adopted throughout the rice season. Water Level (WL) inside the Perforated Tube (AWD tube) checked on daily basis with the help of a measuring tape. Irrigation applied when the WL dropped inside the AWD tube upto 15 cm (safe AWD), 20 cm and 25 down from the field surface. Depth of water applied in each irrigation was same (5cm above field surface).

The average yield against three different irrigation regimes (Fig. 1) showed the yield response of all four varieties against three different irrigation regimes of AWD. Chenab Basmati performed well than all other three varieties when the WL in AWD tubes was at 15 and at 20 cm below surface. Yield of Chenab basmati recorded higher (5.63 t/ha and 3.88 t/ha) at 15 and 20 cm WL respectively (Fig. 1). Punjab Basmati obtained the higher yield (3.63 t/ha) at 25 cm. Poor yield performance was observed for Kissan Basmati not only at 20 and 25 cm level but even at safe AWD (Table 1). At 20 cm and 25 cm WL although the yield is less than the safe AWD but there is no significant difference was recorded in yield of Punjab Basmati, Chenab Basmati and Basmati 515 (Table 1).

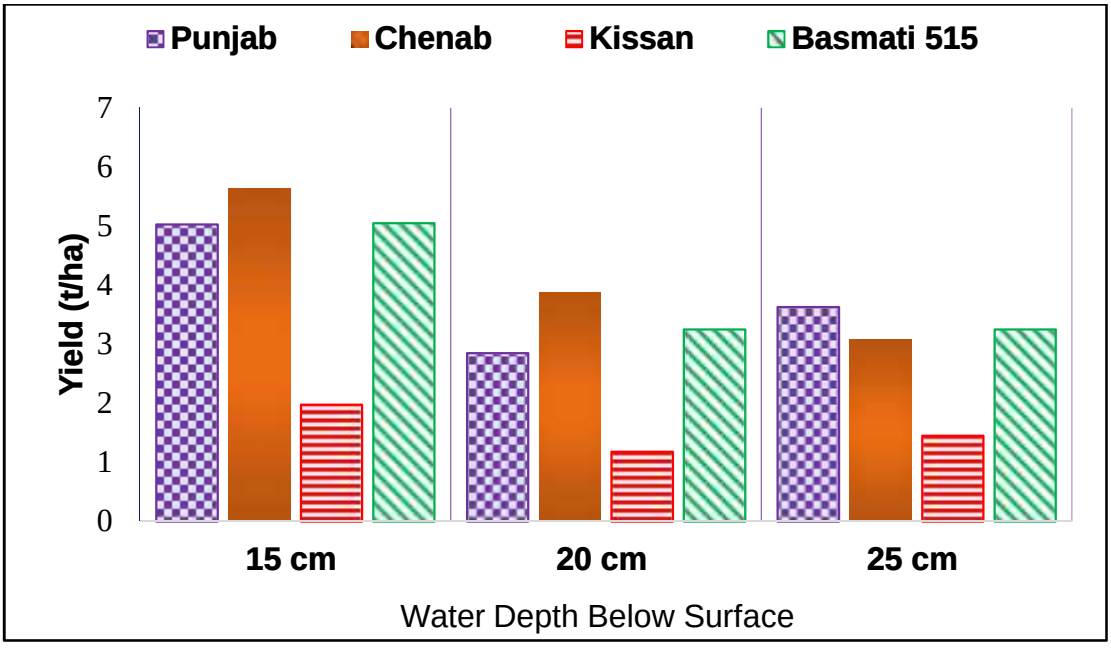

Fig. 1: Average yield against three different Irrigation Regimes

Results indicated that all varieties except Kissan Basmati, have resistance up to some extent against water stress and can survive in aerobic field condition so it can be concluded that these three varieties are suitable for dry seeding.

Table 1: Pairwise comparisons test of yield and yield components for irrigation regime*variety

Water Level in AWD tube or IR	Variety	Filled Grains/ Panicle	1000 Grain weight (g)	Yield (t/ha)
15 cm	Chenab Basmati	124.75 ab	24.0 a	5.63 a
15 cm	Basmati 515	122.50 ab	22.0 ab	5.05 a
15 cm	Punjab Basmati	134.25 a	22.0 ab	5.03 a
20 cm	Chenab Basmati	107.25 bc	23.3 a	3.88 b
25 cm	Punjab Basmati	99.25 bc	19.0 b	3.63 bc
20 cm	Basmati 515	100.25 bc	21.8 ab	3.25 bc
25 cm	Basmati 515	108.25 bc	19.5 b	3.25 bc
25 cm	Chenab Basmati	109.00 abc	20.0 b	3.08 bc
20 cm	Punjab Basmati	94.25 c	22.0 ab	2.85 c
15 cm	Kissan Basmati	65.00 d	20.0 b	1.98 d
25 cm	Kissan Basmati	49.75 d	21.8 ab	1.45 d
20 cm	Kissan Basmati	51.75 d	24.5 a	1.18 d
LSD		25.793	3.098	0.817

VI. RICE TECHNOLOGY

Objectives

- Determination of Quality features of Rice varieties using different parameters.
- Evaluation of cooking quality of Rice grains.
- Quantification of Rice aroma compounds by SPME-GC.
- Advisory service to Farmers, stakeholders and millers for Variety identification.

1. Studied on Physiochemical Characteristics of Rice Generations

In this experiment, more than 100 rice generation lines were tested for grain dimensions, cooking quality and elongation ratio against standard check varieties of KS 282, Basmati 515 and PS 2.

The results (Table 1) depicted that maximum grain length of 9.06 mm was observed in generation line OB-26 followed by line 70021 with 9.00 mm grain length. Maximum cooked grain length (CGL) of 18.3 mm was observed in line 70021 followed by line OB-19 with 16.8 mm CGL. Maximum elongation ratio of 2.227 was recorded for lines 40401 followed by lines OB-20, 50035 and OB-21 with 2.186 and 2.133 elongation ratios, respectively. Bursting upon cooking percentage of all observation lines ranged from 0.0 % to 80.0 %. Maximum bursting of was recorded in line 40170 (80.0%) followed by line 40172 (75.0%). Other lines which showed poor cooking in terms of higher percentage of bursting include line 70013 (20.0%) and lines OB-12 (17.0%), OB-18 (15.0%), and 40178 (13.0%) and overall, lines 70021 and OB-20 performed exceptionally well along with OB-19 and OB-26.

Table 1: Physical & Chemical Characteristics of Rice Generations

Sr. #	Line #	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thickness	CGL (mm)	Bursting (%)	E/R
1	40002	7.30	1.48	1.32	11.8	5.0	1.616
2	40032	7.34	1.28	1.22	14.0	68.0	1.907
3	40033	7.64	1.44	1.28	13.8	50.0	1.806
4	40037	8.76	1.56	1.34	16.2	2.0	1.849
5	40045	8.30	1.38	1.26	16.7	1.0	2.012
6	40070	7.32	1.36	1.22	13.7	9.0	1.872
7	40126	8.24	1.48	1.32	15.4	2.0	1.869
8	40128	8.34	1.40	1.30	15.5	1.0	1.859
9	40132	7.44	1.38	1.28	13.4	70.0	1.801
10	40170	7.48	1.44	1.30	12.2	80.0	1.631
11	40172	7.24	1.30	1.24	11.0	75.0	1.519
12	40182	7.00	1.34	1.30	13.4	8.0	1.914
13	40183	7.26	1.40	1.32	14.0	6.0	1.928
14	40187	7.14	1.42	1.28	13.0	13.0	1.821
15	40195	7.04	1.36	1.30	12.0	10.0	1.705
16	40218	8.00	1.38	1.30	12.8	6.0	1.600
17	40227	8.36	1.42	1.34	15.0	0.0	1.794
18	40235	7.50	1.48	1.28	12.5	11.0	1.667
19	40345	7.08	1.46	1.32	13.1	1.0	1.850
20	40349	8.28	1.36	1.24	14.2	2.0	1.715
21	40382	7.20	1.38	1.22	12.5	8.0	1.736
22	40387	8.14	1.38	1.34	15.3	2.0	1.880
23	*40388*	8.16	1.42	1.32	14.3	6.0	1.752
24	40397	7.32	1.54	1.28	16.3	0.0	2.227
25	40401	7.92	1.42	1.32	12.6	0.0	1.591
26	40403	7.20	1.46	1.38	13.6	4.0	1.889
27	40404	6.92	1.58	1.38	12.0	10.0	1.734
28	50011	7.64	1.32	1.22	13.3	4.0	1.741
29	50013	7.60	1.30	1.20	13.7	1.0	1.803
30	50021	8.30	1.44	1.32	16.0	2.0	1.928
31	50024	8.26	1.48	1.36	15.4	1.0	1.864
32	50026	7.42	1.46	1.34	14.0	11.0	1.887
33	50027	7.52	1.48	1.36	15.0	0.0	1.995
34	50035	7.50	1.44	1.34	16.0	2.0	2.133
35	50057	8.16	1.46	1.36	14.1	4.0	1.728
36	50060	7.82	1.42	1.30	14.9	8.0	1.905
37	50064	7.26	1.32	1.22	12.7	5.0	1.749
38	50065	8.30	1.44	1.30	14.6	6.0	1.759
39	50066	8.12	1.46	1.40	15.2	7.0	1.872
40	50070	8.44	1.48	1.40	16.7	5.0	1.979
41	50071	7.36	1.28	1.20	14.3	9.0	1.943

Sr. #	Line #	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thickness	CGL (mm)	Bursting (%)	E/R
42	50072	7.52	1.30	1.22	15.5	5.0	2.061
43	50073	8.62	1.42	1.32	15.7	0.0	1.821
44	50076	7.56	1.38	1.28	13.8	1.0	1.825
45	50077	8.00	1.48	1.40	14.3	2.0	1.788
46	50078	7.16	1.32	1.26	12.8	1.0	1.788
47	50084	7.52	1.48	1.38	14.2	2.0	1.888
48	50088	7.58	1.48	1.38	14.6	2.0	1.926
49	50090	7.62	1.48	1.38	14.3	6.0	1.877
50	60009	8.34	1.36	1.26	16.6	2.0	1.990
51	60011	7.58	1.34	1.24	13.8	5.0	1.821
52	60012	8.54	1.36	1.26	16.2	3.0	1.897
53	60013	8.44	1.36	1.22	15.4	10.0	1.825
54	60027	8.68	1.36	1.26	14.6	1.0	1.682
55	60029	8.78	1.44	1.36	14.7	7.0	1.674
56	60031	8.42	1.40	1.22	15.4	0.0	1.829
57	60032	8.50	1.42	1.30	14.4	4.0	1.694
58	60033	7.74	1.54	1.32	13.6	0.0	1.757
59	60042	8.52	1.48	1.28	15.2	2.0	1.784
60	70004	7.62	1.54	1.40	14.0	4.0	1.837
61	*70008*	7.92	1.38	1.28	14.0	0.0	1.768
62	70005	8.36	1.48	1.34	12.2	7.0	1.459
63	70012	8.00	1.44	1.32	13.3	2.0	1.663
64	70013	7.84	1.44	1.34	14.0	10.0	1.786
71	70014	8.20	1.38	1.28	14.2	3.0	1.732
72	70016	8.78	1.48	1.34	14.6	8.0	1.663
73	70019	8.16	1.4	1.30	13.8	20.0	1.691
74	70020	8.74	1.46	1.34	15.7	2.0	1.796
75	70021	9.00	1.46	1.30	18.3	3.0	2.033
76	OB-1	8.48	1.52	1.24	16.0	0.0	1.887
77	OB-2	8.66	1.44	1.26	15.2	3.0	1.755
78	OB-3	7.74	1.5	1.22	11.6	0.0	1.499
79	OB-4	7.86	1.42	1.22	12.5	0.0	1.590
80	OB-5	6.46	1.64	1.36	12.0	2.0	1.858
81	OB-6	7.44	1.48	1.32	12.7	4.0	1.707
82	OB-7	7.90	1.48	1.30	12.9	3.0	1.633
83	OB-8	6.96	1.42	1.32	13.4	12.0	1.925
84	OB-9	8.04	1.50	1.30	14.2	4.0	1.766
85	OB-10	8.10	1.46	1.26	13.1	3.0	1.617
86	OB-11	8.08	1.38	1.26	14.2	5.0	1.757
87	OB-12	7.72	1.44	1.30	12.2	17.0	1.580
88	OB-13	8.02	1.38	1.30	12.5	4.0	1.559
89	OB-14	8.02	1.46	1.06	14.2	5.0	1.771

Sr. #	Line #	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thickness	CGL (mm)	Bursting (%)	E/R
90	OB-15	8.08	1.40	1.24	13.7	4.0	1.696
91	OB-16	8.12	1.34	1.24	14.7	8.0	1.810
92	OB-17	7.34	1.68	1.40	11.0	2.0	1.499
93	OB-18	8.08	1.38	1.28	15.4	15.0	1.906
94	OB-19	8.50	1.54	1.26	16.8	7.0	1.976
95	OB-20	7.64	1.42	1.28	16.7	0.0	2.186
96	OB-21	7.50	1.42	1.16	16.0	0.0	2.133
97	OB-22	8.76	1.38	1.30	15.5	1.0	1.769
98	OB-23	7.18	1.32	1.22	13.8	3.0	1.922
99	OB-24	7.60	1.44	1.28	14.3	2.0	1.882
100	OB-25	8.60	1.46	1.28	14.6	0.0	1.698
101	OB-26	9.06	1.52	1.36	14.8	2.0	1.634
102	Bas 515 (Check)	7.70	1.48	1.38	15.2	2.0	1.974
103	PS 2 (Check)	8.30	1.54	1.45	17.2	2.0	2.072
104	KS 282 (Check)	7.10	1.80	1.64	12.3	0.0	1.732
105	KSK 133 (Check)	7.10	1.74	1.62	12.2	1.0	1.718

2. Studied on Physiochemical Characteristics of Rice Observational Lines and Observational Plots

In this experiment, 92 lines of observation plots (OP) were tested for grain dimensions, cooking quality and elongation ratio against standard check varieties of KSK 133, PS 2 and Basmati 515.

The results (Table 2) show that maximum grain length (AGL) 9.92 mm was observed in line PK 10684-6-1-1 followed by PK 10498-8-1-2-4 with 9.46 mm grain length.

Maximum cooked grain length (CGL) of 19.0 mm was observed in line PK 10684-6-1-1 followed by lines PK 10479-11-1-1-1 with 18.0 mm. Maximum elongation ratio of 2.164 was traced in line OP 65 followed by PK 10677-4-3-1 with elongation ratio 2.109. Bursting upon cooking was ranged from 0.0 % to 22.0 % which was highest for OP 08. In all, observational plot OP-09, OP-14 and OP-65 performed excellent in comparison with standard check varieties.

Table 2: Physicochemical characteristics of OP- I Lines

Sr. #	OP #	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thick-ness	CGL (mm)	Br (%)	E/R
1	PK10963-3-1	8.82	1.60	1.38	14.8	8.0	1.678
2	PK10967-30-1	8.10	1.56	1.41	16.1	7.0	1.987
3	PK10967-36-1	8.74	1.72	1.42	17.5	9.0	2.002
4	PK10967-37-1	8.00	1.64	1.50	14.8	13.0	1.850
5	PK10969-39-1	6.80	2.02	1.54	11.9	8.0	1.750
6	PK10749-18-1-1	8.88	1.50	1.36	16.1	7.0	1.813
7	PK10677-3-1-1	8.00	1.62	1.40	14.4	4.0	1.800
8	PK10677-4-3-1	8.06	1.52	1.36	17.0	22.0	2.109
9	PK10678-2-1-1	9.30	1.58	1.44	18.0	1.0	1.935
10	PK10680-3-3-2	9.24	1.58	1.32	16.5	4.0	1.786
11	PK10680-5-1-1	9.16	1.68	1.48	15.8	2.0	1.725
12	PK10684-2-1-2	8.58	1.58	1.28	13.6	15.0	1.585
13	PK10684-2-4-1	8.80	1.50	1.22	15.0	6.0	1.705
14	PK10684-6-1-1	9.92	1.58	1.32	19.0	4.0	1.915
15	PK10675-1-2-2	8.30	1.56	1.38	15.5	6.0	1.867
16	PK10681-1-3-2	9.18	1.38	1.20	15.0	5.0	1.634
17	PK10681-4-1-1	9.24	1.48	1.22	16.0	7.0	1.732
18	PK10813-12-3-2	7.92	1.64	1.44	14.2	25.0	1.793
19	PK10816-5-3-1	8.48	1.72	1.46	14.6	3.0	1.722
20	PK10816-19-1-1	8.18	1.64	1.44	14.3	9.0	1.748
21	PK10824-9-1-1	8.92	1.82	1.36	15.3	2.0	1.715
22	PK10824-9-1-2	8.82	1.68	1.40	14.6	1.0	1.655
23	PK10824-9-1-3	8.94	1.72	1.36	14.5	0.0	1.622
24	PK10824-9-1-5	8.82	1.80	1.36	14.4	3.0	1.633
25	PK10825-4-1-1	7.50	1.70	1.52	11.5	7.0	1.533
26	PK10825-5-1-4	8.58	1.48	1.34	13.8	2.0	1.608
27	PK10825-13-1-1	8.62	1.64	1.42	15.2	1.0	1.763
28	PK10828-11-1-1	8.20	1.60	1.51	15.7	3.0	1.914
29	PK10828-11-1-2	8.84	1.66	1.34	15.9	2.0	1.799
30	PK10834-7-1-2	8.24	1.62	1.28	15.1	3.0	1.833
31	PK10834-15-3-2	9.14	1.62	1.32	15.4	6.0	1.685
32	PK10834-15-3-3	8.24	1.59	1.42	16.2	8.0	1.966
33	PK10835-8-2-2	8.01	1.54	1.40	15.4	1.0	1.922
34	PK10835-9-1-1	8.92	1.66	1.30	16.0	0.0	1.794
35	PK10836-2-1-1	8.72	1.66	1.38	15.3	2.0	1.755
36	PK10843-1-1-1	8.56	1.50	1.32	15.1	3.0	1.764
37	PK10843-1-3-1	8.15	1.62	1.52	16.2	1.0	1.987
38	PK10843-7-1-1	8.26	1.58	1.32	13.1	5.0	1.585
39	PK10843-7-2-2	8.24	1.58	1.38	14.1	2.0	1.711
40	PK10845-4-2-1	7.80	1.64	1.46	13.0	9.0	1.666
41	PK10845-4-2-3	8.24	1.52	1.36	12.2	4.0	1.481
42	PK10845-6-2-2	7.64	1.54	1.42	11.0	0.0	1.440

Sr. #	OP #	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thick-ness	CGL (mm)	Br (%)	E/R
43	PK10850-1-2-2	8.92	1.56	1.38	12.6	5.0	1.413
44	PK10938-3-1-1	9.10	1.74	1.30	16.8	1.0	1.846
45	PK10939-1-2-1	7.04	1.94	1.44	9.3	1.0	1.321
46	PK10663-6-1-2-1	9.10	1.54	1.22	13.8	2.0	1.516
47	PK10345-11-2-3-1	7.32	1.54	1.44	11.7	20.0	1.598
48	PK10352-12-1-1-2	7.32	1.44	1.32	11.3	18.0	1.544
49	PK10352-16-1-1-3	8.28	1.44	1.20	14.8	10.0	1.787
50	PK10352-16-1-1-4	9.14	1.48	1.38	16.4	4.0	1.794
51	PK10352-16-1-1-5	7.98	1.56	1.40	12.2	25.0	1.529
52	PK10355-7-1-1-1	7.50	1.54	1.34	11.6	30.0	1.547
53	PK10355-7-2-1-1	7.80	1.46	1.30	7.9	30.0	1.013
54	PK10355-18-1-1-1	8.60	1.56	1.28	14.5	6.0	1.686
55	PK10358-2-1-2-1	8.25	1.58	1.44	16.5	2.0	2.000
56	PK10358-7-2-1-1	8.68	1.60	1.40	13.7	5.0	1.578
57	PK10381-5-1-1-1	8.75	1.54	1.38	14.6	1.0	1.668
58	PK10459-9-1-2-1	9.32	1.62	1.28	15.6	5.0	1.673
59	PK10461-7-2-1-1	8.64	1.52	1.32	15.8	3.0	1.828
60	PK10461-7-2-1-2	8.70	1.44	1.36	15.3	4.0	1.758
61	PK10473-3-1-2-2	7.90	1.50	1.44	14.8	6.0	1.873
62	PK10473-3-1-2-3	7.80	1.40	1.30	14.0	3.0	1.795
63	PK10479-11-1-1-1	7.44	1.38	1.26	16.1	4.0	2.164
64	PK10479-11-3-1-3	8.76	1.62	1.40	16.2	1.0	1.849
65	PK10479-11-3-1-4	7.84	1.56	1.42	13.7	6.0	1.747
66	PK10481-4-2-1-2	7.50	1.50	1.28	14.4	11.0	1.920
67	PK10481-4-2-1-3	8.38	1.48	1.28	15.0	4.0	1.790
68	PK10481-7-1-1-3	9.30	1.48	1.20	15.3	8.0	1.645
69	PK10493-1-1-1-2	8.22	1.78	1.46	13.8	3.0	1.679
70	PK10496-10-1-2-2	8.58	1.56	1.40	16.3	4.0	1.900
71	PK10498-3-1-1-2	9.10	1.40	1.30	14.4	3.0	1.582
72	PK10498-8-1-2-4	9.46	1.72	1.34	15.5	2.0	1.638
73	PK10502-1-3-2-2	8.30	1.56	1.40	15.3	6.0	1.843
74	PK10532-4-2-1-2	9.28	1.54	1.22	16.7	1.0	1.800
75	PK10532-4-2-1-3	7.20	1.48	1.26	13.1	20.0	1.819
76	PK10534-7-2-1-1	7.64	1.54	1.36	14.0	4.0	1.832
77	PK10424-4-2-1-2	7.98	1.66	1.34	12.7	10.0	1.591

Sr. #	OP #	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thick-ness	CGL (mm)	Br (%)	E/R
78	PK10436-4-2-2-1	8.36	1.60	1.30	11.5	6.0	1.376
79	PK10438-10-1-1-4	8.60	1.54	1.28	13.2	6.0	1.535
80	PK10438-19-1-1-2	7.94	1.60	1.36	12.3	9.0	1.549
81	PK10324-4-2-1-1-1	7.72	1.56	1.40	11.8	25.0	1.528
82	PK10324-23-1-1-1-1	7.48	1.48	1.32	13.3	10.0	1.778
83	PK10324-30-1-1-1-1	8.10	1.44	1.26	13.0	7.0	1.605
84	PK10324-30-4-1-1-2	7.36	1.58	1.24	14.1	4.0	1.916
85	PKBB 150702	7.76	1.58	1.32	13.5	6.0	1.740
86	PKBB 150703	7.72	1.56	1.34	14.0	10.0	1.813
87	PKBB 150704	7.68	1.60	1.32	12.7	7.0	1.654
88	PKBB 150707	7.75	1.58	1.42	13.2	10.0	1.703
89	PKBB 150710	7.94	1.56	1.28	16.2	12.0	2.040
90	PKBB 150711	8.20	1.48	1.28	13.0	20.0	1.585
91	PKBB 150711-2	8.54	1.68	1.36	14.7	0.0	1.721
92	PKBB 150720	8.92	1.70	1.44	14.0	7.0	1.570
93	PS 2 (Check)	8.32	1.50	1.45	16.8	2.0	2.019
94	Basmati 515 (Check)	7.60	1.56	1.42	14.2	4.0	1.868
95	Super Basmati (Check)	7.40	1.74	1.64	13.7	3.0	1.851
96	KSK 434 (Check)	7.10	1.80	1.62	12.0	2.0	1.690

CGL = Cooked Grain Length; B = Bursting upon cooking E/R= elongation ratio

Table 3: Physicochemical Characteristics of OP- II Lines

Sr. #	Line #/ variety	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thick-ness	CGL (mm)	Br (%)	E/R
1	OP-II-1	6.70	2.04	1.44	11.0	4.0	1.642
2	OP-II-2	6.18	1.82	1.22	13.0	5.0	2.104
3	OP-II-3	6.34	1.78	1.26	11.3	2.0	1.782
4	OP-II-4	7.20	1.76	1.34	12.5	3.0	1.736
5	OP-II-5	6.86	1.86	1.38	11.2	4.0	1.633
6	OP-II-6	7.22	1.86	1.40	11.0	5.0	1.524
7	OP-II-8	6.98	1.84	1.40	10.7	4.0	1.533
8	OP-II-9	7.18	2.16	1.52	10.8	0.0	1.504
9	OP-II-10	6.90	1.82	1.24	11.5	4.0	1.667
10	OP-II-13	6.88	1.92	1.48	11.2	4.0	1.628
11	OP-II-14	7.08	1.86	1.40	12.0	2.0	1.695
12	OP-II-15	7.94	1.56	1.36	13.0	3.0	1.637
13	OP-II-16	7.16	1.90	1.38	12.8	2.0	1.788
14	OP-II-17	7.14	1.90	1.42	14.1	3.0	1.975
15	OP-II-18	7.80	2.08	1.46	13.2	0.0	1.692
16	OP-II-19	6.72	1.78	1.38	13.0	3.0	1.935
17	OP-II-23	6.98	1.80	1.61	11.5	3.0	1.648
18	OP-II-24	7.25	1.76	1.55	11.0	3.0	1.517
19	OP-II-25	7.30	1.82	1.44	13.0	3.0	1.781
20	OP-II-27	7.98	1.62	1.40	11.8	2.0	1.479
21	OP-II-28	6.60	1.96	1.46	12.8	1.0	1.939
22	OP-II-29	7.58	1.54	1.36	14.0	2.0	1.847
23	OP-II-30	7.45	1.60	1.39	12.6	20.0	1.691
24	OP-II-31	7.68	1.58	1.41	12.9	4.0	1.680
25	OP-II-32	7.64	1.56	1.40	12.8	2.0	1.675
26	OP-II-38	7.80	1.58	1.40	10.4	2.0	1.333
27	OP-II-39	7.74	1.60	1.36	12.5	4.0	1.615
28	OP-II-43	7.24	1.82	1.42	12.3	5.0	1.699
29	OP-II-44	7.70	1.56	1.40	12.8	4.0	1.662
30	OP-II-46	7.16	1.42	1.36	10.0	2.0	1.397
31	OP-II-48	7.18	1.44	1.34	11.3	2.0	1.574
32	OP-II-49	7.04	1.42	1.36	10.4	1.0	1.477
33	OP-II-50	8.18	1.88	1.42	12.9	3.0	1.577
34	OP-II-51	7.88	1.58	1.40	11.2	2.0	1.421
35	OP-II-52	7.70	1.54	1.34	12.4	3.0	1.610
36	OP-II-53	6.90	2.00	1.66	9.9	0.0	1.435
37	OP-II-54	6.72	2.20	1.54	10.8	1.0	1.607
38	OP-II-55	7.92	1.84	1.48	12.5	2.0	1.578
39	OP-II-57	7.86	1.78	1.44	13.3	4.0	1.692
40	OP-II-58	7.68	1.52	1.32	13.8	2.0	1.797
41	OP-II-60	8.12	1.56	1.34	13.5	3.0	1.663

Sr. #	Line #/ variety	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thick-ness	CGL (mm)	Br (%)	E/R
42	OP-II-61	7.48	1.60	1.48	14.3	2.0	1.912
43	OP-II-62	7.51	1.56	1.41	14.4	3.0	1.917
44	OP-II-63	8.30	1.68	1.36	15.9	2.0	1.916
45	OP-II-64	8.34	1.60	1.26	16.0	0.0	1.918
46	OP-II-69	7.48	1.50	1.30	14.0	3.0	1.872
47	PS 2 (Check)	8.32	1.50	1.45	16.8	2.0	2.019
48	Basmati 515 (Check)	7.60	1.56	1.42	14.2	4.0	1.868
49	Super Basmati (Check)	7.40	1.74	1.64	13.7	3.0	1.851
50	KSK 434 (Check)	7.10	1.80	1.62	12.0	2.0	1.690

3. Studies on Physiochemical Characteristics of Coarse Grain Rice Yield Trial-A

The purpose of this experiment is to evaluate coarse or coarse grain rice lines on the basis of their physiochemical characteristics. Thirteen coarse grain lines were tested for grain length, width, and thickness and cooking quality against standard check variety KSK 434.

The results (Table 4) showed that maximum average grain length of 7.46 mm was recorded for line KSK 506 followed by 7.36 mm by KSK 505. Maximum cooked grain length (CGL) of 13.7 mm was recorded for line KSK 506 followed by line KSK 501 with 13.0 mm. Bursting upon cooking percentage of all lines ranged from 0.0 to 10.0% which is under acceptable limit. Maximum elongation ratio of 2.077 was shown by line KSK 501 followed by KSK 500. Overall, lines KSK 500, KSK 501, KSK 500 and KSK 506 performed exceptionally well by exceeding the standard check variety.

Table 4: Physicochemical characteristics of coarse grain yield trial- A

S. #	Line # / variety.	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thickness	CGL (mm)	Bursting (%)	E/R
1	KSK 499	6.78	1.70	1.34	10.5	2.0	1.549
2	KSK 500	6.30	1.64	1.32	12.2	1.0	1.937
3	KSK 501	6.26	1.64	1.26	13.0	8.0	2.077
4	KSK 502	6.20	1.48	1.22	11.5	2.0	1.855
5	KSK 503	6.60	1.60	1.28	11.5	4.0	1.742
6	KSK 504	6.68	1.60	1.26	12.2	7.0	1.826
7	KSK 505	7.36	1.52	1.26	12.5	2.0	1.698
8	KSK 506	7.46	1.70	1.42	13.7	2.0	1.836
9	KSK 507	6.38	1.48	1.20	11.4	9.0	1.787
10	KSK 508	5.78	1.90	1.32	9.8	3.0	1.696
11	KSK 509	5.70	1.92	1.32	10.2	1.0	1.789
12	KSK 510	6.82	1.72	1.40	10.6	10.0	1.554
13	KSK 511	6.04	1.68	1.28	11.1	4.0	1.838
14	KSK 434 (Check)	7.06	1.50	1.36	11.7	1.0	1.657

CGL = Cooked Grain Length; B = Bursting upon cooking E/R= elongation ratio

4. Studies on Physiochemical Characteristics of Coarse Grain Rice Yield Trial-B

The breeding section provided Ten lines in Trial-B of coarse grain Rice. These lines were evaluated for grain length, width, and thickness and cooking quality parameters of cooked grain length (CGL), bursting upon cooking % and elongation ratio (E/R) against standard check KSK 434. Table 5 depicted that maximum average grain length (AGL) 7.54mm was recorded for line KSK 492 followed by KSK 496 with 7.16 mm AGL. Maximum cooked grain length (CGL) of 12.8mm was shown by line KSK 492 followed by line KSK 497 with 11.5mm CGL. Maximum elongation ratio of 1.701 was exhibited by line KSK 491 followed by line KSK 492 with 1.698 E/R value. Bursting upon cooking percentage values of lines ranged from 0.0% to 6.0% which is under acceptable limit. Overall, lines KSK 491 and 492 performed well in terms of cooking quality and elongation ratios, respectively.

Table 5: Physicochemical characteristics of coarse grain yield trial-B

Sr. #	Line #/ variety	Rice grain measurements (mm)			Cooking quality		
		Length	Width	Thickness	CGL (mm)	Burst. %	E/R
1	KSK 489	6.88	1.82	1.48	9.9	0.0	1.439
2	KSK 490	7.14	1.72	1.46	11.3	4.0	1.583
3	KSK 491	6.82	1.74	1.40	11.6	3.0	1.701
4	KSK 492	7.54	1.48	1.36	12.8	6.0	1.698
5	KSK 493	7.08	1.78	1.34	9.5	4.0	1.342
6	KSK 494	6.90	1.60	1.42	9.8	3.0	1.420
7	KSK 495	6.62	1.64	1.30	10.7	0.0	1.616
8	KSK 496	7.16	1.56	1.30	11.7	4.0	1.634
9	KSK 497	6.86	1.64	1.34	11.5	6.0	1.676
10	KSK 498	6.72	1.62	1.40	12.3	2.0	1.830
11	KSK 434 (Check)	7.26	1.62	1.30	11.5	0.0	1.584

CGL = Cooked Grain Length; B = Bursting upon cooking %, E/R= elongation ratio

5. Studies on Physiochemical Characteristics of Coarse Grain Rice Yield Trial-C

The breeding section provided nine lines in C Trial of coarse grain group. These lines were evaluated for grain dimensions, cooking quality (CGL), bursting upon cooking % and elongation ratio (E/R) against standard check KSK 434.

The results (Table 6) show that maximum grain length (AGL) 7.56 mm was observed in KSK-484, KSK-487 followed by KSK-486 with 7.44 grain length. Maximum cooked grain length (CGL) of 16.0 mm was observed in line KSK-487 followed by lines KSK-484 with 15.1 mm. Maximum elongation ratio of 2.116 was traced in line KSK-487 followed by KSK-486 with elongation ratio 2.016. Bursting upon cooking was ranged from 0.0 % to 5.0 % which was under acceptable limits. In all, coarse grain varieties KSK-484, 486, 487 performed excellent in comparison with standard check variety KSK 434.

Table 6: Physicochemical characteristics of coarse grain yield trial- C

Sr. #	Line # / variety	Rice grain measurements (mm)			Cooking quality		
		Length	Width	Thickness	CGL (mm)	Burst. %	E/R
1	KSK 482	7.28	1.72	1.36	12.6	3.0	1.731
2	KSK 483	7.20	1.54	1.36	11.9	3.0	1.653
3	KSK 484	7.56	1.72	1.30	15.1	2.0	1.997
4	KSK 485	6.72	1.70	1.36	11.9	5.0	1.771
5	KSK 486	7.44	1.80	1.30	15.0	4.0	2.016
6	KSK 487	7.56	1.72	1.24	16.0	2.0	2.116
7	KSK 488	7.76	1.66	1.26	14.1	3.0	1.817
8	PK 9259-4-1-1-1	6.66	1.54	1.24	11.7	2.0	1.757
9	PK 9379-45-1-4-1-1	7.16	1.60	1.36	12.8	4.0	1.788
10	KSK 434 (Check)	6.84	1.62	1.32	12.2	3.0	1.784

CGL = Cooked Grain Length; B = Bursting upon cooking %, E/R= elongation ratio,

6. Studies on Physiochemical Characteristics of Fine Grain Rice Yield Trial-A

The objective of this trial is to evaluate fine grain rice lines possessing desired physiochemical features. 13 lines in A-1 trial and 12 lines in A-2 trial were evaluated for grain dimensions, cooking quality against standard check Basmati 515 and PS 2.

Table 7 shows that maximum AGL 8.44 mm was shown by line PK10350-7-2-1 followed by line PK10348-7-1-3 with 8.38mm. Maximum CGL 17.5 mm was shown by the line PK10683-12-1 followed by PK10350-7-2-1 with 16.0mm. Maximum E/R ratio of 2.098 was shown by the PK10683-12-1 followed by PK10350-7-2-1 with 1.896. Bursting upon cooking % of all lines including check varieties ranged from 0 to 60.0% which was highest for PK10348-7-1-3 followed by PK10383-5-1-1 with 25.0%. Overall, in trial A-1, PK10683-12-1, PK10350-7-2-1 and line PK10350-7-2-1 performed well against standard check.

Table 7: Physicochemical characteristics of fine grain yield trial A-1

Sr. #	Line # / variety	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thickness	CGL (mm)	Br (%)	E/R
1	PK10683-12-1	8.34	1.44	1.14	17.5	1.0	2.098
2	PK10820-8-1	7.76	1.40	1.14	14.6	2.0	1.881
3	PK10344-12-1-1	7.32	1.36	1.30	12.4	0.0	1.694
4	PK10348-7-1-3	8.38	1.48	1.34	14.5	60.0	1.730
5	PK10350-7-2-1	8.44	1.40	1.36	16.0	12.0	1.896
6	PK10355-13-1-1	8.02	1.36	1.28	14.4	4.0	1.796
7	PK10355-13-2-1	8.34	1.34	1.22	14.0	1.0	1.679
8	PK10356-10-1-1	7.64	1.38	1.32	13.5	7.0	1.767
9	PK10473-3-1-1	8.32	1.44	1.36	15.3	11.0	1.839
10	PK10495-7-3-1	7.74	1.46	1.36	11.6	0.0	1.499
11	PK10383-5-1-1	7.88	1.5	1.32	13.4	25.0	1.701
12	PK10395-1-1-1	7.68	1.48	1.26	13.5	10.0	1.758
13	PK BB 15-11	7.90	1.48	1.26	14.0	20.0	1.772
14	PS-2 (Check)	8.5	1.54	1.30	17.0	7.0	2.000
15	Bas 515 (Check)	7.70	1.42	1.34	13.8	14.0	1.792
16	Super Bas (Check)	7.68	1.44	1.32	13.7	3.0	1.784

CGL = Cooked Grain Length; B = Bursting upon cooking E/R= elongation ratio

Table 8: Physicochemical characteristics of fine grain yield trial A-2

Sr. #	Line # / variety	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thickness	CGL (mm)	Br (%)	E/R
1	PK10395-8-1-1	7.40	1.44	1.32	13.0	2.0	1.757
2	PK10419-2-1-1	8.19	1.46	1.34	15.0	0.0	1.832
3	PK10434-6-2-1	8.12	1.44	1.36	13.2	1.0	1.626
4	PK10436-2-1-1	9.12	1.46	1.34	16.2	1.0	1.776
5	PK10437-14-2-1	8.30	1.44	1.30	14.0	3.0	1.687
6	PK10198-19-1-1-1	6.84	1.50	1.30	11.2	4.0	1.637
7	PK 9963-4-1-2-1-1	6.48	1.48	1.32	10.8	5.0	1.667

Sr. #	Line # / variety	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thickness	CGL (mm)	Br (%)	E/R
8	PK 9986-6-2-1-1-1	7.04	1.48	1.34	10.7	7.0	1.520
9	PK 10045-7-3-2-2-1	7.74	1.40	1.30	12.3	5.0	1.589
10	PK9832-4-1	8.84	1.50	1.42	12.8	0.0	1.448
11	PK9847-10-1	8.40	1.48	1.38	13.2	2.0	1.571
12	PKBB 15-8	6.86	1.48	1.38	10.2	16.0	1.487
13	PS-2 (Check)	8.70	1.48	1.30	17.4	2.0	2.000
14	Bas 515 (Check)	7.64	1.50	1.36	13.7	14.0	1.793
15	Super Bas (Check)	7.42	1.44	1.28	13.5	4.0	1.819

CGL = Cooked Grain Length; B = Bursting upon cooking E/R= elongation ratio

Table 8 shows that maximum average grain length of 9.12 mm was shown by line PK10436-2-1-1 followed by line PK9832-4-1 with 8.84 mm AGL. Maximum CGL of 16.2 mm was also shown by the line PK10436-2-1-1 followed by line PK10419-2-1-1 with 15.0 mm CGL. Maximum elongation ratio of 1.832 was shown by the line PK10419-2-1-1 followed by the line PK10436-2-1-1 with 1.776 elongation ratio. Bursting upon cooking % of all lines including check varieties ranged from 0.0 % to 16. 0% highest for line PKBB 15-8. In all, none of the line exceeds or meets the cooking standard of check varieties. Although we have AGL of 9.12 mm in, but its elongation ratio is not at par with standard check.

7. Physiochemical Characteristics of Fine Grain Rice Yield Trial-B

The objective of this to evaluate fine grain rice lines possessing desirable physiochemical characteristics. Twelve lines in B trial were evaluated for grain dimensions and cooking quality against standard check varieties of Super Basmati, Basmati 515 and PS 2.

Table 9 shows that maximum average grain length (AGL) of 9.12 mm was recorded for line PK 10101 followed by line PK10161-1-5-1 with 9.02 mm grain length. Maximum cooked grain length of 17.0 mm was recorded for line PK9966-10-1 followed by PK 10101 with 16.5 mm CGL. Maximum elongation ratio of 1.932 was shown by the line PK9966-10-1 followed by line PK9533-9-6-1-1 with 1.879. Bursting upon cooking % of all lines ranged from 0.0 % to 6.0% which is under acceptable limit. Overall, in trial B, lines PK9966-10-1

performed very well along with other lines like P K9533-9-6-1-1 and PK 10101 against check varieties.

Table 9: Characteristics of fine grain yield trial B

Sr. #	Line #	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thickness	CGL (mm)	B (%)	E/R
1	PK 10198-7-2	8.76	1.46	1.34	16.0	1.0	1.826
2	PK 10306-15-5	8.94	1.46	1.36	13.3	4.0	1.488
3	PK 10324-1-1	9.00	1.46	1.32	13.1	2.0	1.456
4	PK 9533-9-6-1-1	8.62	1.46	1.32	16.2	3.0	1.879
5	PK 9966-10-1	8.80	1.50	1.38	17.0	1.0	1.932
6	PK 9444-8-1-2	8.90	1.46	1.32	14.1	4.0	1.584
7	PK 9563-3-2-2-1	7.78	1.42	1.32	12.6	3.0	1.620
8	PK 9924-5-1-1	7.00	1.38	1.28	12.8	6.0	1.829
9	PK 10029-13-2-1	8.46	1.36	1.26	14.6	1.0	1.726
10	PK 10161-1-5-1	9.02	1.54	1.40	15.0	3.0	1.663
11	PK 10101	9.12	1.48	1.30	16.5	4.0	1.809
12	PK PB-8	8.96	1.52	1.38	16.2	2.0	1.808
13	PS 2 (Check)	8.86	1.46	1.32	16.4	0.0	1.851
14	Basmati 515 (Check)	7.46	1.38	1.30	12.9	7.0	1.729
15	Super Basmati (Check)	7.52	1.42	1.34	11.5	8.0	1.529

CGL = Cooked Grain Length; B = Bursting upon cooking; E/R= elongation ratio

8. Studies on Physiochemical Characteristics of Fine Grain Rice Yield Trial-C

The objective of this trial is to evaluate fine grain rice lines possessing desirable physiochemical characteristics in yield trial C. There are seven lines in this trial which provided by the breeding section. These lines were evaluated for grain dimensions and cooking quality against standard check varieties of Super Basmati, Basmati 515 and PS 2.

Table 10: Physicochemical characteristics of fine grain yield trial C

Sr. #	Line #	Rice grain measurements (mm)			Cooking Quality		
		Length	Width	Thickness	CGL (mm)	B (%)	E/R
1	PK9699-6-2-1	9.36	1.50	1.40	14.9	2.0	1.592
2	PK9435-4-1-1	8.48	1.46	1.36	14.2	1.0	1.675
3	PK9748-16-2-1	8.46	1.18	1.16	12.8	3.0	1.513
4	PKBB 15-1	8.70	1.22	1.20	12.2	1.0	1.402
5	PKBB 15-6	8.56	1.38	1.16	12.5	4.0	1.460
6	PKBB 15-11	7.42	1.28	1.22	11.5	3.0	1.550
7	PK10963-3-1	8.62	1.46	1.36	14.4	80.0	1.671
8	PK10967-30-1	9.06	1.60	1.32	16.0	50.0	1.766
9	PK10967-36-1	7.22	1.44	1.30	14.2	2.0	1.967
10	PK10967-37-1	7.66	1.50	1.30	14.3	2.0	1.867
11	PK10969-39-1	9.36	1.42	1.18	16.3	5.0	1.741
12	PK10749-18-1-1	8.72	1.52	1.32	15.8	2.0	1.812
13	PS-2 (Check)	8.70	1.48	1.24	15.7	2.0	1.805
14	Bas 515 (Check)	7.74	1.46	1.26	14.0	1.0	1.809
15	Super Bas (Check)	7.60	1.44	1.30	12.5	1.0	1.645

CGL = Cooked Grain Length; B = Bursting upon cooking; E/R= elongation ratio

Table 10 shows that maximum grain length (AGL) 9.36 mm was observed in PK9699-6-2-1 and PK10969-39-1 followed by PK10967-30-1 with 9.06 grain length. Maximum cooked grain length (CGL) of 16.3 mm was observed in PK10969-39-1 followed by PK10967-30-1 with 16.0 mm. Maximum elongation ratio of 1.967 was traced in PK10967-36-1 followed by PK10967-37-1 with elongation ratio 1.867. Bursting upon cooking was ranged from 0.0 % to 80.0 % which was highest for PK10963-3-1. In all, Fine grain varieties PK9699-6-2-1, PK10969-39-1 performed excellent in comparison with standard checks.

9. Studies on Physiochemical Characteristics of Coarse Grain National Uniform Yield Trials

To evaluate coarse grain rice breeding material provided by Pakistan Agricultural Research Council, fourteen lines in this trial were tested for milling recovery, grain dimensions and cooking quality.

Table 11 shows that maximum Total Milled Rice (TMR) of 72.0 % was observed in KSK 480 and NIBGE GSR6 followed by ST-5 and KSK 481 with 71.0 % TMR. Maximum Head Rice (HR) 68.0 % was observed in KSK 481 followed by NIBGE GSR6 with 67.0 % HR. Maximum grain length (AGL) 8.28

mm was observed in IAGS-PU-1 and NOBGE GSR-5 with 7.46 mm AGL. Maximum cooked grain length (CGL) of 11.5 mm was observed in NIBGE GSR-5 followed by IAGS-PU-1 with 11.3 mm CGL. However, these CGL values are far below the CGL of check variety KSK 133 (12.5 mm). Maximum elongation ratio of 1.692 was traced in KSK 480 followed by ST-10 with 1.625 elongation ratio; again much less elongating ratio than standard check variety of KSK 133 (1.776). Bursting upon cooking was ranged from 0.0 % to 10.0 % which was highest for ST-9. In all, none of line in this trail exceeded the cooking quality of standard check variety of KSK 133.

Table 11: Characteristics of coarse grain national uniform rice yield trials

Sr. #	Code #	Milling Recovery (%)			Rice grain measurements (mm)			Cooking Quality		
		BR	TMR	HR	Len-gth	Width	Thick-ness	CGL (mm)	Br (%)	E/R
1	ST-5	80.0	71.0	37.0	6.86	1.54	1.40	10.2	8.0	1.487
2	ST-9	77.7	66.6	46.0	6.68	1.60	1.40	10.4	10.0	1.557
3	KSK 476	70.0	64.0	46.6	7.00	1.46	1.36	10.7	4.0	1.529
4	ST-10	78.0	68.0	55.0	6.40	1.70	1.32	10.4	3.0	1.625
5	KSK 480	82.0	72.0	60.0	6.56	1.56	1.28	11.1	4.0	1.692
6	NIBGE GSR3	74.0	58.0	42.5	7.02	1.46	1.24	10.7	2.0	1.524
7	KSK 481	81.0	71.0	68.0	6.42	1.88	1.28	9.5	0.0	1.480
8	NIBGE GSR4	76.0	64.7	40.0	6.98	1.70	1.40	11.0	7.0	1.576
9	DR-60	80.0	69.0	42.0	6.76	1.62	1.38	10.8	6.0	1.598

Sr. #	Code #	Milling Recovery (%)			Rice grain measurements (mm)			Cooking Quality		
		BR	TMR	HR	Len-gth	Width	Thick-ness	CGL (mm)	Br (%)	E/R
10	NIBGE GSR-5	78.0	69.0	56.0	7.46	1.60	1.48	11.5	0.0	1.542
11	IAGS-PU-1	77.5	69.0	50.0	8.28	1.50	1.36	11.3	5.0	1.365
12	NIBGE GSR6	78.0	72.0	67.0	6.70	1.60	1.60	9.4	7.0	1.403
13	CKD 2338	79.0	68.0	62.0	6.46	1.70	1.70	10.7	4.0	1.656
14	NIBGE GSR7	79.0	68.0	49.0	6.32	1.60	1.60	9.6	3.0	1.519
15	KSK 133 (Check)	80.0	70.0	61.0	7.04	1.60	1.40	12.5	0.0	1.776

TMR = Total milled rice, HR = Head rice, CGL = Cooked Grain Length; B= Bursting upon cooking, E/R= elongation ratio

10. Studies on Physiochemical Characteristics of Fine Grain National Uniform Yield Trial (FGYT)

The objective of this trial is to evaluate fine grain rice breeding material provided by Pakistan Agricultural Research Council (PARC) Rice Program Unit, Kala Shah Kaku. Seven rice lines were provided by PARC excluding standard check varieties of PS 2 and Basmati 515. These lines were checked for their milling recovery, grain dimensions and cooking quality.

Table 12 shows that maximum Total Milled Rice (TMR) of 68.8 % PK BB-15-1 followed by line PK 91994-54-1-1-2-2 with 63.2 % TMR. Maximum was Head Rice recovery (HR) of 46.2 % was recorded for line PK BB-15-1 followed by line PK 91994-54-1-1-2-2 with 31.6 % HR. Maximum Average Grain Length (AGL) of 8.86 mm was shown by line PK BB-15-1 followed by PK BB-15-6 with 8.72 mm average grain length. Maximum cooked grain length (CGL) of

17.5 mm was exhibited by line PK BB-15-6 followed by line PK BB-8 with 17.0 mm CGL. Maximum elongation ratio of 2.007 was exhibited by the PK BB-15-6 followed by line RRI-3 with 1.988 elongation ratio. Bursting percentage of all lines ranged from 1.0 % to 7.0 % which is under acceptable limits. Overall, lines PK BB-15-6, PK BB-15-1 and RRI-3 performed exceptionally well as discussed above.

Table 12: Physicochemical characteristics of FGYT

Sr. #	Line #	Milling Recovery (%)			Rice grain measurements (mm)			Cooking Quality		
		BR	TMR	HR	Length	Width	Thickness	CGL (mm)	B (%)	E/R
1	NS-5	60.0	51.7	20.0	8.50	1.48	1.22	15.5	3.0	1.824
2	RRI-3	67.0	57.6	25.8	8.40	1.46	1.10	16.7	7.0	1.988
3	NIAB 201002	56.0	44.0	28.0	7.36	1.36	1.16	12.0	5.0	1.630
4	PK BB-15-1	77.4	68.8	46.2	8.86	1.40	1.24	11.7	11.0	1.321
5	PK BB-15-6	55.6	49.3	27.8	8.72	1.46	1.18	17.5	1.0	2.007
6	PK PB-8	50.0	44.3	18.2	8.66	1.38	1.12	17.0	2.0.0	1.963
7	PK 91994-54-1-1-2-2	73.4	63.2	31.6	7.40	1.34	1.30	12.6	14.0	1.703
8	PS-2 (Check)	56.5	48.9	44.5	7.96	1.44	1.12	13.2	4.0	1.658
9	Bas 515 (Check)	66.6	59.2	41.9	7.34	1.44	1.20	13.8	16.0	1.880

TMR = Total milled rice, HR = Head rice, CGL = Cooked Grain Length; B= Bursting upon cooking, E/R= elongation ratio

11. Physiochemical Characteristics of Coarse Grain Regional Adaptability Yield Trial

The objective of this trial is to evaluate the quality performance of the most promising rice lines in coarse grain category at different locations of the Punjab province. Plant breeding section provided 6 rice lines which were planted at five different locations across Punjab province viz. Farooqabad, Gujranwala, Faisalabad, Sargodha and Kala Shah Kaku. These lines were

tested for milling recovery i.e. Total Milled Rice (TMR), Head Rice (HR) percentage and cooking quality i.e. Cooked Grain Length (CGL) and Bursting upon cooking percentage against check variety of KSK 133.

Table-13: Milling recovery of coarse grain rice regional adaptability yield trials

Line/ Variety	Farooqabad		Gujranwala		Faisalabad		KSK		Average	
	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)
KSK 434 (check)	72.0	62.0	73.0	60.0	74.0	63.0	71.0	62.0	72.5	61.8
KSK 449	73.0	57.0	71.0	58.0	73.0	61.5	71.0	61.0	72.0	59.4
KSK 476	72.0	58.0	72.0	61.0	73.0	64.0	71.0	61.0	72.0	61.0
KSK 480	73.0	62.0	72.0	65.0	73.0	62.0	71.0	61.5	72.3	62.6
KSK 481	73.0	61.0	68.8	54.4	71.5	68.0	70.0	59.0	70.8	60.6
PK 7688-1-1-2-2	73.0	67.0	71.0	62.0	74.0	61.0	72.0	60.0	72.5	62.5
PK 9379-45-1	71.0	59.0	73.0	66.0	72.0	68.0	71.0	57.0	71.8	62.5
Average	72.4	60.9	71.5	60.9	72.9	63.9	71.0	60.2	--	--

TMR = Total milled rice, HR = Head rice

Table 13 shows that maximum head rice % (HR) 68 was observed in PK 9379-45-1 and KSK 481 from Faisalabad region followed by 67% for PK 7688-1-1-2-2 from Farooqabad. On an average basis maximum HR was observed for KSK 480. On region basis average, Faisalabad rice samples show maximum HR % (63.9 %) followed by Gujranwala and Farooqabad locations (60.9 %). Individually, highest (TMR 74.0 %) was observed in PK 7688-1-1-2-2 at Faisalabad which is equivalent to check variety at the same location. On average basis, line KSK 480 gave maximum HR % (60.6 %) followed by lines PK 7688-1-1-2-2 and PK 9379-45-1 with 60.5 % HR recovery and these lines on overall basis performed well against standard check variety.

The data (Table 14) show that the maximum cooked grain length (CGL) of 13.0 mm was observed in PK 7688-1-1-2-2 from KSK region followed by PK 9379-45-1 with 12.5mm from same region. Maximum CGL was traced in KSK on an average basis. On varietal basis, PK 7688-1-1-2-2 showed maximum CGL. Bursting upon cooking was ranged from 0.0 % to 9.0 % which was highest for PK 9379-45-1.

Table-14: Cooking quality of coarse grain rice regional adaptability yield trials

Line/ Variety	Farooqabad		Gujranwala		Faisalabad		KSK		Average	
	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)
KSK 434 (Check)	11.5	2.0	11.4	1.0	11.2	7.0	12.1	1.0	11.6	2.8
KSK 449	11.2	4.0	10.6	2.0	11.0	3.0	11.2	2.0	11.0	2.8
KSK 476	11.7	2.0	12.0	2.0	11.2	3.0	11.7	0.0	11.7	1.8
KSK 480	11.4	5.0	10.2	1.0	11.0	2.0	12.0	2.0	11.2	2.5
KSK 481	10.2	3.0	9.8	2.0	9.8	4.0	11.6	1.0	10.4	2.5
PK 7688-1-1-2-2	10.6	2.0	11.9	3.0	12.0	3.0	13.0	4.0	11.9	3.0
PK 9379-45-1	12.5	3.0	12.7	2.0	12.3	9.0	12.8	2.0	12.6	4.0
Average	11.3	3.0	11.2	1.9	11.2	4.4	12.1	1.7	--	--

CGL = Cooked Grain Length; B= Bursting upon cooking

12. Physiochemical Characteristics of Fine Grain Rice Regional Adaptability Yield Trials

The objective of this trial is to evaluate the quality performance of the most promising fine grain rice strains at different locations of the Punjab province. Plant breeding section provided seven rice lines in fine grain group which were planted at five different locations across Punjab province viz. Farooqabad, Gujranwala, Faisalabad, Sargodha and Kala Shah Kaku. These seven lines were tested for milling recovery i.e. Total Milled Rice (TMR), Head Rice (HR), and cooking quality parameters i.e. Cooked Grain Length (CGL) and Bursting upon Cooking percentage (B %) against check variety of PS 2.

Table 15 shows that on average with respect to lines/varieties, maximum TMR of 70.5% was recorded for line PK BB-15-6 followed by 70% TMR by the lines RRi-3 and PK BB-15-1 with 70.0 % TMR. Likewise, maximum HR of 51.0 % was recorded for line PK BB-15-1 followed by line PK BB-15-6 with 50.3 % HR. On looking location-wise, best Head Rice recovery of 55.0 % was observed at Kala Shah Kaku followed by Faisalabad with 50.6 % HR. Overall, line PK BB-15-1 performed reasonably well in terms of milling recovery. Whereas best milling recovery results were recorded at Kala Shah Kaku.

Table-15: Milling recovery of fine grain rice regional adaptability yield trials

Line/ Variety	Farooqabad		Gujranwala		Faisalabad		KSK		Average	
	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)
RRI-3	73.0	50.0	67.0	39.0	70.0	48.0	70.0	56.0	70.0	43.5
PK 9194	71.0	46.0	68.0	47.0	70.0	50.0	71.0	55.0	69.8	49.8
PK BB-15-1	70.0	44.0	68.0	49.0	71.0	56.0	70.0	40.0	70.0	51.0
PK BB-15-6	71.0	54.0	70.0	52.0	71.0	55.0	72.0	54.0	70.5	50.3
PK PB-8	70.0	42.5	67.0	44.0	68.0	46.5	78.0	50.0	69.3	46.8
PS-2 (Check)	72.0	46.0	69.5	45.0	69.0	48.0	70.0	56.0	72.1	47.3
Average	71.2	47.1	68.3	46.0	69.8	50.6	71.0	55.0	--	--

TMR = Total milled rice, HR = Head rice

The data (Table 16) show that on average with respect to locations, maximum CGL was observed at KSK followed by Farooqabad region. Minimum bursting upon cooking of 1.0 % was witnessed at Gujranwala. However, maximum bursting upon cooking was recorded at Farooqabad with 2.7 % bursting. On average with respect to lines, maximum CGL of 16.3 mm was recorded for lines RRI-3 and PK BB-8.1 in all selected regions. Overall, best cooking quality was observed at KSK followed by Farooqabad. Whereas lines RRI-3 and PK BB-8 performed well in cooking quality but could not exceed check variety PS 2 in CGL.

Table 16: Cooking quality of fine grain rice regional adaptability yield trials

Line/ Variety	Farooqabad		Gujranwala		Faisalabad		KSK		Average	
	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)
RRI-3	16.5	3.0	16.5	1.0	16.0	0.0	16.3	3.0	16.3	1.8
PK 9194	13.8	2.0	12.1	1.0	11.2	1.0	14.5	4.0	12.9	2.0
PK BB-15-1	11.7	6.0	14.1	3.0	13.4	2.0	14.0	3.0	13.3	3.5
PK BB-15-6	16.5	2.0	14.0	0.0	13.2	5.0	16.7	2.0	15.1	2.3
PK PB-8	18.5	2.0	17.0	0.0	13.7	1.0	15.8	1.0	16.3	1.0
PS-2 (Check)	17.2	1.0	17.3	1.0	17.2	2.0	17.4	1.0	17.3	1.3
Average	15.7	2.7	15.2	1.0	14.1	1.8	15.8	2.3	--	--

CGL = Cooked Grain Length; B= Bursting upon cooking

13. Effect of Transplanting Time on Grain Quality Characteristics of Different Coarse Grain Rice Lines

Objective of this experiment was to establish the optimum time (date) of transplanting for obtaining higher milling recovery and best cooking quality in advanced coarse grain rice lines. There were five advance coarse grain lines planted and transplanted at four different dates by the Agronomy Section of Institute. Transplanting dates were kept in the main plots while varieties / lines in sub plots. After harvesting from the field, paddy samples were cleaned, dried to 10 % moisture content and milled in the Rice Technology Laboratory. The data on milling recovery and cooking quality of these eight lines were determined and compared with standard check variety of KSK 133.

Table 17 reveals that maximum head rice % (HR) 69 was observed at 18th June in KSK 481 followed by 65% for same variety at 10th July. On an average basis maximum HR was observed for KSK 481 followed by PK 9388-45-1-4-1. On transplanting date basis average, 27th May show maximum HR recovery. Highest TMR 72.4% was also observed at same date of Transplanting.

Table 17: Milling Recovery of different coarse grain rice lines

Line/ Variety	5th May 2016		27th May 2016		18th June 2016		10th July 2016		Average	
	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)
KSK 133 (Check)	72.0	67.0	72.0	66.5	66.0	47.0	71.0	61.0	70.3	60.4
KSK 434 (Check)	70.0	50.0	73.0	56.0	72.0	57.0	72.0	58.0	71.8	55.3
KSK 476	72.0	53.0	73.0	62.0	72.0	62.0	69.0	52.0	71.5	57.3
KSK 480	72.0	56.0	73.0	62.0	73.0	54.5	75.0	63.0	73.3	58.9
KSK 481	71.0	61.5	70.0	54.0	74.0	69.0	73.0	65.0	72.0	62.4
PK 7688-1-1-2-2	72.0	55.0	73.0	59.0	74.0	61.0	67.0	53.0	71.5	57.0
PK 9388-45-1-4-1	72.0	64.0	73.0	58.0	72.0	52.0	74.0	62.0	72.8	59.0
Average	71.6	58.1	72.4	59.6	71.9	57.5	71.6	59.1	--	--

TMR = Total milled rice, HR = Head rice

Table 18: Cooking Quality of different coarse grain rice lines

Line/ Variety	5TH May 2016		27th May 2016		18th June 2016		10th July 2016		Average	
	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)
KSK 133 (Check)	12.1	4.0	12.1	3.0	12.0	3.0	12.0	2.0	12.1	3.0
KSK 434 (Check)	11.2	3.0	11.5	3.0	11.0	4.0	11.4	1.0	11.3	2.8
KSK 476	10.9	4.0	11.4	4.0	10.8	3.0	11.4	3.0	11.1	3.5
KSK 480	10.3	8.0	10.9	3.0	10.5	6.0	10.8	6.0	10.6	5.8
KSK 481	9.9	10.0	10.3	7.0	10.0	5.0	9.8	3.0	10.0	6.3
PK 7688-1-1-2-2	11.4	5.0	11.8	5.0	12.0	3.0	11.5	2.0	11.7	3.8
PK 9388-45-1-4-1	11.6	3.0	11.6	2.0	11.6	1.0	11.6	1.0	11.6	1.8
Average	11.1	5.3	11.4	3.9	11.1	3.6	11.2	2.6	--	--

CGL = Cooked Grain Length; B = Bursting upon cooking

As per Table 18, maximum cooked grain length (CGL) of 12 mm was observed in PK 7688-1-1-2-2 at 18th June followed by same variety at 27th May. Maximum CGL was traced in PK 7688-1-1-2-2 at 27th May on an average basis. Bursting upon cooking was ranged from 0.0 % to 10.0 % which was highest for KSK-481 at 5th May.

14. Effect of Transplanting Time on Grain Quality Characteristics of Different Fine Grain Rice Lines

The objective of this experiment was to ascertain the optimum time (date) of transplanting for obtaining higher milling recovery and best cooking quality in advanced fine grain rice lines. Six advance fine grain lines were planted and transplanted at four different dates by the Agronomy Section of this institute. Transplanting dates were kept in the main plots while varieties / lines in sub plots. After harvesting from the field, paddy samples were cleaned, dried to 10 % moisture content and milled in the Rice Technology Laboratory. The data on milling recovery and cooking quality was determined of these lines and compared with standard check Varieties of Basmati 515 and PS 2.

Table 19 shows that on average with respect to date of transplanting, maximum TMR (68.0%) was recorded at transplanting date of 1st June 2016. Maximum Head Rice (39.9 %) was recorded at transplanting date of 5th August 2016 followed by 14th July 2015 with 38.9 % HR. Considering average data with respect to varieties/lines, maximum TMR (70.8 %) was observed for line PK 9194-54-1-1-2-2 followed by line PK BB-15-6 with 67.8 % TMRs. Overall, best milling recovery was observed at transplanting date of 5th August 2016 whereas lines PK 9194-54-1-1-2-2 and PK BB-15-6 performed well in terms of milling recovery.

Table 19: Milling Recovery of different fine grain rice lines

Line/ Variety	1st June 2016		23rd June 2016		14th July 2016		5th Aug. 2016		Average	
	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)	TMR (%)	HR (%)
Basmati 515 (Check)	77.0	64.0	75.0	65.0	75.0	64.0	73.0	52.0	75.0	61.3
RRI-3	65.0	18.0	66.0	18.0	59.0	13.5	65.0	29.0	63.8	19.6
PK 9194-54-1-1-2-2	73.0	60.0	72.0	53.0	68.0	53.0	70.0	61.0	70.8	56.8
PK BB-15-1	69.0	31.0	67.0	32.0	56.0	31.0	57.5	34.4	62.4	32.1
PK BB-15-6	67.1	42.0	70.0	55.0	66.0	52.0	68.0	58.0	67.8	51.8
PK PB-8	65.0	22.0	59.0	19.0	64.0	34.0	62.0	27.0	62.5	25.5
PK 10683-12-1	64.0	19.0	67.0	29.0	66.5	32.0	67.0	25.0	66.1	26.3
PS-2 (Check)	64.0	18.0	62.0	17.0	65.0	32.0	64.0	33.0	63.8	25.0
Average	68.0	34.3	67.3	36.0	64.9	38.9	65.8	39.9	--	--

TMR = Total milled rice, HR = Head rice

The Table 20 shows that on average with respect to date of transplanting, maximum cooked grain length (CGL) of 14.9 mm was recorded for transplanting dates of 5th August 2016 followed by transplanting date of 14th July and 23rd June 2016 with 14.8 mm CGL and. Minimum bursting of 2.1 % was observed at transplanting date of 14th July followed by date 5th August 2016 with 2.8 % bursting. When we consider average date for individual lines, maximum CGL of 16.6 mm was recorded for line RRI-3 with 3.0 % bursting followed by line PK 10683-12-1 with 16.5 mm CGL with 2.3 % bursting. Overall, best cooking quality was observed at transplanting date of 5th August followed by 14th July. Whereas lines PK 10683-12-1 and RRI-3 performed well in terms of cooking quality by exceeding check varieties Basmati 515 and PS 2 as discussed.

Table 20: Cooking Quality of different fine grain rice lines

Line	1st June 2016		23rd June 2016		14th July 2016		5th Aug. 2016		Average	
	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)	CGL (mm)	B (%)
RRI-3	16.4	7.0	16.5	1.0	16.2	2.0	17.3	2.0	16.6	3.0
PK 9194-54-1-1-2-2	13.5	5.0	14.0	2.0	13.0	2.0	13.2	3.0	13.4	3.0
PK BB-15-1	11.4	6.0	11.3	3.0	11.7	1.0	11.0	1.0	11.4	2.8
PK BB-15-6	13.2	4.0	13.9	2.0	13.3	2.0	13.3	4.0	13.4	3.0
PK PB-8	16.5	7.0	16.2	3.0	17.3	3.0	17.0	2.0	16.8	3.8
PK 10683-12-1	16.2	5.0	16.3	2.0	17.0	2.0	16.5	0.0	16.5	2.3
Basmati 515 (Check)	13.1	5.0	13.5	7.0	13.7	4.0	13.7	9.0	13.5	6.3
PS-2 (Check)	16.5	6.0	16.5	4.0	16.3	1.0	16.8	1.0	16.5	3.0
Average	14.6	5.6	14.8	3.0	14.8	2.1	14.9	2.8	--	--

CGL = Cooked Grain Length; B = Bursting upon cooking

15. Studies on Rice Aroma Compounds by Gas Chromatograph Technique

The objective of this trial is to investigate and to quantity main aroma compound 2-acetyl-1-pyrroline along with other notable aromatic compounds like Hexanol, Nonanal, Decanal, Vanillin, Indole and Benzyl alcohol in different Basmati rice lines. The method and technique used for this purpose was Head Space Solid Phase Micro Extraction Technique (HS-SPME) on Gas Chromatograph. About 01 g of rice flour was placed in 1L glass vial. These vials were placed in GC auto-sampler along with SPME mode. SPME and Head-inject the collected gases into GC and FID detector of GC detects the target compounds and the results are shown as chromatograms.

The Table 21 shows that the main aroma compound 2-acetyl-1-pyrroline (2AP) was found in all Basmati varieties. The maximum concentration of 2AP (0.97 ppm) was found in Basmati 370 followed by Super Basmati with 0.79

ppm. The minimum concentration of 2AP (0.17 ppm) was found in Kissan Basmati. Nonanal was found maximum 6.43 ppm in Chenab Basmati and minimum 0.00 ppm in Basmati 515. Indole was mostly absent in Basmati varieties except for Basmati 385 (0.30 ppm) and Basmati 515 (1.10ppm). This study showed that highest concentration of 0.97 ppm of 2AP was found in Basmati-370. On the other hand, least aromatic of varieties is Kissan Basmati with 0.17 ppm concentration of 2AP. These findings proved an old notion or thought about Basmati 370 which states that Basmati 370 is the most aromatic variety among the Basmati varieties followed by Super Basmati and Basmati 515.

Table 21: Aromatic compounds in basmati rice varieties

Sr. #	Variety Name	2AP	Nonanal	Decanal	Benzyl Alcohol	Indole	Vanillin
1	Basmati 515	0.59	0.00	0.63	0.60	1.10	4.24
2	Punjab Basmati	0.37	4.98	0.48	1.18	0.00	3.63
3	Chenab Basmati	0.24	6.43	0.57	0.44	0.00	2.17
4	Kissan Basmati	0.17	2.38	0.39	0.00	0.00	2.54
5	Super Basmati	0.79	2.69	0.29	0.96	0.00	1.79
6	Basmati 385	0.59	0.00	0.37	1.45	0.30	2.53
7	Basmati 2000	0.32	0.00	0.41	1.39	0.00	3.07
8	Basmati 370	0.97	0.34	1.18	1.23	0.00	4.19

ppm = Parts per Million (mg/ Kg)

B. RICE RESEARCH STATION, BAHAWALNAGAR

Overview:

Rice area in the Punjab is scattered from Gujrat to Rahim Yar Khan. It can be divided into two different areas keeping in view of different agro-ecological conditions. One is traditional rice area called “Kallar tract” and the other is non-traditional rice area. There is a great variation in both the environments. Different methods are used for crop establishment and processing in both the environments.

In Bahawalnagar, rice is cultivated on an area of about two lac acres. Rice produced in this area is especially used for parboiling. Parboiled rice has a great demand in the international market including Saudi Arabia, UAE, and Iran.

Rice Research Station was established under the Chief Minister Punjab Directive in 2009 with the following objectives:

Objectives:

- To develop extra long grain rice varieties suitable for different agro-ecological conditions of southern Punjab.
- To popularize rice production technology in the southern Punjab.
- To impart training on different aspects of rice.
- To increase paddy yield per unit area of the Punjab.
- To boost up rice export and foreign exchange earnings.

1. Breeding Generations F0 to F4

Tested/ Evaluated	F_0	F_1	F_2	F_3	F_4
Material sown	61 new crosses were attempted.	09 sown	05 were sown	195 lines were sown	102 lines were sown
Selected/ Harvested	14 successful.	09	106 panicles selected and harvested	255 panicles selected and harvested	65 panicles selected and harvested

2. Hybridization and evaluation of advance generations

New Crosses

To induce genetic variability for selecting desirable recombinants possessing high yielding potential, earliness, insect pests and disease resistance/ tolerance, extra-long grain size and better grain quality for the development of new rice varieties, 61 target oriented crosses were attempted with special emphasis to induce Extra-long grain size, earliness in maturity, short stature, high yielding, lodging resistance and insect pest/ disease resistance.

3. Evaluation of Filial Generations from F_1 to F_4:

To evaluate lines of F-1 to F-4 generations for the improved rice varieties.

The progenies of nine (09) new crosses made during the previous year were planted and evaluated for their field performance and generation advance.

F_2 populations of five (05) different crosses were sown at the station during the year under report. Single panicle selection was made in each population to select desirable segregates and 106 panicles were selected and harvested in the field.

195 F_3 lines of 39 cross combinations were sown. 255 panicles were selected on the basis of field performance

102 F_4 lines of were sown and 65 panicles were selected on the basis of field performance

4. Evaluation Trials

a) Fine Grain Yield Trial

To evaluate high yielding, early maturing, lodging resistant with best grain quality and insect pests and disease tolerant fine grain strains, seven promising strains were tested. The layout of the experiment was RCBD with three replications and sowing done on 28.6.2016. The data for the yield in t/ha, Days to 50% flowering, Plant height (cm), No. of tillers per plant, Panicle length (cm), No. of grains per panicle and 1000 grain weight (gm) was recorded.

The data (Table 1) indicates that the strain PK 8749 produced the highest paddy yield of 5.9 t/ha followed by PK8431 with 5.5 t/ha as compared to standard variety Basmati 515 (5.2 t/ha).

Table 1: Results of fine grain yield trial

Varieties/ Strains	Days to 50% flowering	Final plant height (cm)	No of tillers per plant	Panicle length (cm)	No of grains per panicle	1000 grain weight (gm)	Yield t/ha
PK 8749	65	133	16	29	144	22.5	5.9
PK 8431	66	143	11	34	132	23.5	5.5
PK 8662	68	143	12	31	133	23.3	5.3
Basmati 515	74	151	15	30	129	21.9	5.2
PK 8649	67	102	10	28	118	22.6	4.6
PK 10052	69	145	13	32	121	21.7	4.4
SR-12	70	130	12	35	124	24.1	4.4
						LSD	0.18

b) Coarse Grain Yield Trial

To evaluate high yielding, early maturing and insect pest and disease resistant medium grain lines in Bahawalnagar conditions, five promising strains were tested. The layout of the experiment was RCBD with three replications and sowing done on 22.6.2016. The data for the yield in t/ha, ,Days to 50% flowering, Plant height (cm), No. of tillers per plant, Panicle

length (cm), No of grains per panicle and 1000 grain weight (gm) was recorded.

The data (Table 2) indicates that the strain KSK 462 produced the highest paddy yield of 8.7 t/ha followed by KSK 464 with 7.7 t/ha as compared to standard variety KSK 133 (7.1 t/ ha).

Table 2: Results of coarse grain yield trial

Varieties/ Strains	Days to 50% flowering	Final plant height (cm)	No of tillers per plant	Panicle length (cm)	No of grains per panicle	1000 grain weight (gm)	Yield t/ha
KSK 462	59	102	20	25	178	27.75	8.7
KSK 464	63	103	17	26	159	23.54	7.7
KSK 434	63	96	18	25	141	26.00	7.5
KSK 133	61	95	15	24	147	26.77	7.1
KSK 463	62	102	14	27	123	24.03	6.3
KSK 462	59	102	20	25	178	27.75	8.7
						LSD	0.15

5. Extra Long Grain Yield Trial

Eight promising extra-long grains strains were tested in the trial to screen out the most promising and climate adopted variety for Bahawalnagar zone. The layout of the experiment was RCBD with three replications. The data for the yield in t/ha, Plant height (cm), No. of tillers per plant, Panicle length (cm) ,No of grains per panicle, 1000 grain weight (gm) and grain length (mm) was recorded.

The data (Table 3) indicates that the strain PK 8649 produced the highest paddy yield of 5.7 t/ha as compared to standard variety PS 2 (3.3 t/ ha) and the strain PGR1/03/98 produce the maximum grain length i.e. 12.3 mm than the standard variety PS 2 with grain length of 11.6 mm.

Table 3: Results of extra long grain yield trial

Varieties/ Strains	Grain length (mm)	Final plant height (cm)	No of tillers per plant	Panicle length (cm)	No of grains per panicle	1000 grain weight (gm)	Yield t/ha
PK 8649-8-2	11.8	101	18	25	143	23.23	5.7
PGR1/03/83C	12.2	137	18	27	128	22.6	4.9
PGR1/03/83B	11.7	118	25	29	140	23.6	4.5
4068x Shaheen Basmati	11.6	146	11	32	106	22.56	4.3
PGR1/03/98	12.3	117	16	29	126	21.81	4.2
Basmati 515	10.0	128	15	28	114	22.34	3.7
PS 2	11.6	114	17	30	105	22.43	3.3
Basmati 2000 x CEMB 1-6-3	11.1	145	14	33	96	22.23	2.6
						LSD	0.15

6. Screening of herbicides for the effective control of different rice weeds

The experiment was conducted to select suitable pre and post emergence herbicides for effective weed control in transplanted rice. The design of the experiment was RCBD with three replications. The data presented (Table 4) indicates that the treatment (Butachlor+Winsta) produced the highest paddy yield of 3.4 t/ha as compared to control with 2.3 t/ ha and also gave efficient weed control.

Table 4: Effectiveness of weedicides with respective yield comparison

Treatments	Final plant height (cm)	No of tillers per plant	Panicle length (cm)	No of grains per panicle	1000 grain weight (gm)	Total No of weeds/ sq. meter	Yield t/ha
Butachlor +Winsta	113	23	29	142	20.48	-	3.4
Butachlor +Clover	112	21	29	136	20.47	1	3.1
Winsta	109	20	28	133	20.40	5	2.9
Clover	108	19	28	126	20.36	5	2.7
Butachlor	107	18	28	124	20.30	8	2.6
Control/ No spray	103	16	27	117	20.20	25	2.3
						LSD	0.23

7. Screening of fungicides for the effective control of rice blast

The experiment was conducted to find effective control of blast through spray fungicides. The design of the experiment was RCBD with three replications. The data (Table 5) indicates that Amistar Top gave efficient blast control with highest paddy yield of 5.0 t/ha as compared to control with 2.3 t/ ha.

Table 5: Effectiveness of fungicides with respective yield comparison

Treatments/ Dose per acre	Final plant height (cm)	No of tillers per plant	Panicle length (cm)	No of grains per panicle	1000 grain weigh t (gm)	Disease incidence %	Yield t/ha
Amistar Top @ 200ml	150	22	29	139	22.8	2.3	5.0
State @ 150 gm	151	20	29	130	22.2	4.3	4.1
Contaf plus @ 400ml	146	20	31	127	21.2	4.6	4.0
Score @ 125 ml	151	19	29	122	20.8	21.66	3.6
Cabriotop @ 300 gm	152	18	29	118	19.4	33.3	3.4
T Zole @ 200 ml	144	19	29	120	20.4	23.0	3.4
Cardate @ 500gm	152	19	31	120	20.0	26.33	3.1
Control	150	17	28	103	17.2	55.00	2.3
						LSD	0.12

8. Effect of potash on rice growth and yield

The experiment was conducted to test the effect of different potassium doses on the yield and yield components of PS 2 under Bahawalnagar condition. The design of the experiment was RCBD with three replications.

The data (Table 6) indicates that the treatment (90 Kg potash /ha) produced the highest paddy yield (5.1 t/ha) as compared to control (3.0 t/ ha).

Table 6: Paddy yield comparison of different Potash fertilizer treatments

Treatments/ Dose/ ha	Final plant height(cm)	No of tillers per plant	Panicle length (cm)	No of grains per panicle	1000 grain weight (gm)	Disease incidence%
90 kg Potash	117	28	29.2	153	23.7	5.1
80 kg Potash	116	27	28.6	145	23.6	4.5
70 kg Potash	114	25	28.3	141	23.6	4.0
60 kg Potash	111	23	28.2	133	23.5	3.7
50 kg Potash	110	20	27.9	126	23.4	3.5
0 Potash	107	18	26.7	118	23.2	3.0
					LSD	0.19

C. RICE SCIENTISTS

I. Rice Research Institute, Kala Shah Kaku

Sr. #	Name, Designation Section and Email	
a)	**PLANT BREEDING & GENETICS**	
1.	**DR. MUHAMMAD AKHTER** ***Director*** director_rice[at]yahoo.com	
2.	**DR. MUHAMMAD SABAR** ***Rice Botanist*** muhammadsabar[at]gmail.com	
3.	**SYED SULTAN ALI** ***Rice Botanist*** alisyedsultan[at]yahoo.com	
4.	**MR. MUHAMMAD IQBAL** ***Associate Rice Botanist*** iqbalrriksk[at]yahoo.com	
5.	**DR. MUHAMMAD IJAZ** ***Assistant Botanist*** cmijaz66[at]gmail.com	
6.	**MR. TAHIR LATIF** ***Assistant Botanist*** tlatif_2008[at]yahoo.com	

7. **MR. RANA AHSAN RAZA KHAN**
Assistant Research Officer
ahsenreza[at]gmail.com

8. **MS. MISBAH RIAZ**
Assistant Research Officer
misha_riaz99[at]hotmail.com

9. **MR. ZULQARNAIN HAIDER**
Assistant Research Officer
z.haider.breeder[at]gmail.com

10. **MS. TAHIRA BIBI**
Assistant Research Officer
tahira167_uaar[at]yahoo.com

11. **MR. AWAIS RIAZ**
Assistant Research Officer
awais2426[at]gmail.com

12. **MS. FARIHA SHAHZADI**
Assistant Research Officer
farihasarwar15[at]gmail.com

13. **MS. HIRA SAHER**
Assistant Research Officer
hirashar.09[at]gmail.com

b) AGRONOMY

14. **MR. MUHAMMAD USMAN SALEEM**
Assistant Agronomist
usman1015_uaf[at]yahoo.com

15. **DR. JAVED IQBAL**
Assistant Agronomist
drjavediqbalwahla60[at]gmail.com

16. **DR. TAHIR HUSSAIN AWAN**
Assistant Research Officer
tahirawanrri[at]gmail.com

17. **DR. NADEEM IQBAL**
Assistant Research Officer
nadeemaro[at]yahoo.co.uk

18. **MR. USAMA BIN KHALID**
Assistant Research Officer
usama.bink[at]gmail.com

19. **MR. SHAWAIZ IQBAL**
Assistant Research Officer
shawaiziqbal[at]gmail.com

20. **MS. ADILA IRAM**
Assistant Research Officer
iramadila[at]gmail.com

c) FOOD TECHNOLOGY

21. **MR. MOHSIN ALI RAZA**
Assistant Technologist
mohsin.aliraza[at]yahoo.com

22. **MS. FARAH SHAMIM**
Assistant Research Officer
farah_tirmzi[at]yahoo.com

d) ENTOMOLOGY

23. **DR. ARSHED MAKHDOOM SABIR**
Assistant Entomologist
amsabir[at]yahoo.co.uk

24. **MR. MUHAMMAD RIZWAN**
Assistant Research Officer
ranarizwanjabbar[at]yahoo.com

e) PLANT PATHOLOGY

25. **MR. MUHAMMAD SALEEM JAVED**
Assistant Plant Pathologist
msjaved33[at]gmail.com

26. **DR. AYESHA BIBI**
Assistant Research Officer
ayeshachaudhary_iags[at]yahoo.com

27. **MS. HALIMA QUDSIA**
Assistant Research Officer
h.qudsia08[at]yahoo.com

f) AGRICULTURAL ENGINEERING

28. **MR. MUDDASSAR ALI**
Assistant Agricultural Engineer
muddassir.lik[at]gmail.com

g) ECONOMICS & STATISTICS

29. **MS. NEELUM SHAHZADI**
Statistical Officer
so_rriksk09[at]yahoo.com

II. Rice Research Station, Bahawalnagar

a) PLANT BREEDING & GENETICS

30. **MR. MUHAMMAD SHAFIQ TARIQ**
Rice Botanist
shafiqtariq61[at]yahoo.com

31. **MR. MUHAMMAD RIZWAN ANWAR**
Assistant Research Officer
muhammad.rizwan.a[at]gmail.com

b) AGRONOMY

32. **MR. SOHAIL RASHID**
Assistant Agronomist
sohailrashidaa[at]gmail.com

c) PLANT PROTECTION

33. **MR. SHAHBAZ MUSTAFA**
Assistant Research Officer
(qazishahbaz35[at]gmail.com

d) SOIL SCIENCE

34. **MR. MUHAMMAD AAMER**
Assistant Research Officer
raomaamer[at]gmail.com

D. PUBLICATIONS

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E. METEROLOGY

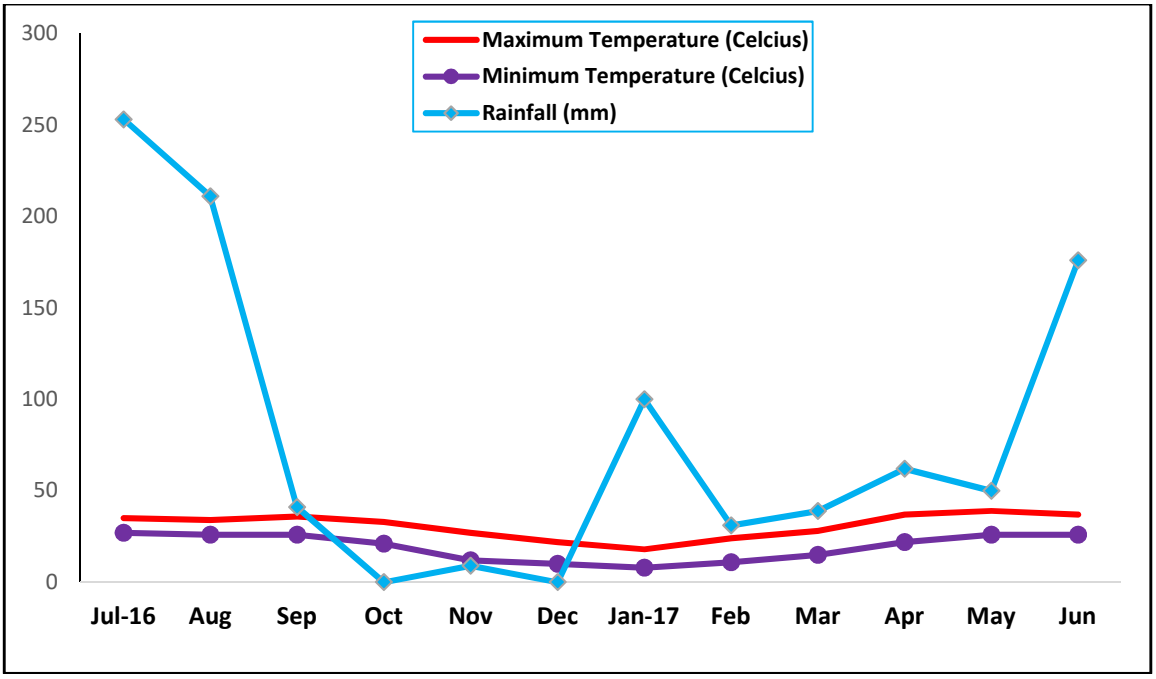

Fig. 34: Metrological data of Kala Shah Kaku