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Screening of rice (*O. sativa* L.) genotypes for heat tolerance to develop climate resilient rice genotypes

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Abstract
Rice (*O. sativa* L.) is sensitive to high temperatures, especially at the time of reproductive stage.Screening of wide range of germplasm against to high temperature conditions in field level is reliable and superior to all the screening procedures to identify suitable genetic donors to develop climate resilient genotypes. The experimental material showed a wide range of variation in spikelet fertility from 98.6% to 16.3% due to climatic conditions. 65entries identified as genetic donors based on spikelet fertility, which recorded more than 90% fertility. Among them, Acc no 2012-130(98.8, 48.6), EC 448(98, 30), 2012-133 (98, 35.9), 2012-149(97, 44) and 2012-129(95.5, 55.6) noted highest fertility percentage and Single plant yield respectively. The daily temperature is typically higher during the spikelet flowering period for *japonica* rice, resulting in severe spikelet sterility, which suggests that early flowering cultivar type could reduce the high temperature damage.EC series (exotic collection) from Africa accessions are flowering and anthesis in the early morning due to early nature it escapes from the heat stress.

Keywords: rice, heat tolerance, high temperature, spikelet fertility, anther indehiscence grain yield

Introduction
Rice (*O. sativa* L.) is one of the most important cereal crops in the world and staple food for nearly half of the world population. Its cultivation is of immense importance for food security of Asia, where more than 90% of the global Rice is produced and consumed, global warming has a significant effect on rice production. Rice is sensitive to high temperature, especially at the reproductive stage, which causes spikelet sterility and yield losses. The main cause of floret sterility, which is induced by high temperature at the flowering stage, is anther indehiscence (Satake and Yoshida, 1978; Mackill *et al.*, 1982; Matsui *et al.*, 1997a, b, 2001) [6, 2, 3, 4] Increasing severity of the problem in rice-growing areas in Asia is due to rising temperatures (Catherine *et al.*, 2012) [1]. The rabi crop is sown in the month of November-December which is exposed to severe hot summer temperatures (36-45 ^{0}C) during flowering stage causing spikelet sterility. Long season high-temperature stress, reduces yield, grain size and shape, biomass production, seed number per panicle. The mean temperatures are predicted to rise by 1.4 ^{0}C to 5.0 ^{0}C thereby drastically reducing crop yields & undermining food security. For every 1 ^{0}C increase in temperature a yield reduction of 0.6 tons/ha (10%) in RICE & 5-7% for other major crops. The changing climate warrants developing climate resilient genotypes.

Materials and Methods
Germplasm for heat tolerance
A study was conducted with 249 genotypes for three consecutive seasons of Rabi 2013, 2014 and 2015 following Augment design with 7 checks. Total of 249 genetically diverse genotypes were collected and evaluated for present study. Which include germplasm collected from different parts of India, exotic germplasm from IRRI Philippines and NERICA lines. The field experiments were conducted for 3 consecutive seasons of Rabi 2013, 2014 and 2015 at Indian Institute of Rice Research Farm, ICRISAT campus, Patancheru, Hyderabad, India. This is situated at 17.53o N latitude, 78.27o E longitude and altitude of 545m above mean sea level. The experiment was laid out in augment design (249 accessions + 7 checks included). These checks are different flowering duration early, medium, late duration, yield, heat tolerance and susceptible checks included. Thirty days old seedlings of each genotype were transplanted in 3 rows of 5m length by adopting a spacing of 20 cm between rows and 15 cm between plants

with in arrow, which replicated thrice. All the necessary precautions were taken to maintain uniform plant population of each genotype per replication. All the recommend package of practices was adopted besides providing necessary prophylactic plant protection measures to raise a good crop. Data were recorded on a total of nine agro-morphological characters *viz* Days to 50% flowering, Days to maturity, Plant height (cm), Panicle length(cm) Number of tillers per plant, Number of productive tillers per plant, Spikelet fertility/ Sterility percentage, Single plant yield (gm), Test weight (gm).

Total list of accessions

S. No	Entry	Name of the Acc.
1	2009-104	CHECK(ERRAMALLELU)
2	2009-106	KCN 80152 (ACC 55676)
3	2009-110	GIZA 176
4	2009-111	WAB96-1-1
5	2009-114	CUIABANA
6	2009-115	ZARDROME (ACC 32379)
7	2009-116	IR 36
8	2009-118	IR 2307-247-2-2-3
9	2009-120	MULAI (ACC 32318)
10	2009-121	SAUNFI (ACC 76402)
11	2009-123	IDSA 77
12	2009-124	IR 60
13	2009-125	WAB56-125
14	2009-126	DULAR (ACC 32561)
15	2009-127	IR 20
16	2009-128	TCHAMPA (ACC32368)
17	2009-130	CR 547-1-2-3
18	2009-131	IR 19746-28-2-2
19	2009-133	BALILLA
20	2010-101	KHASRAN (ACC 76382)
21	2010-103	DOMSIAH (ACC 32294)
22	2010-104	GANJA CHOOTA
23	2010-105	SADRI (ACC 32339)
24	2010-107	ZAKHA (ACC 67859)
25	2010-109	ATTEY (ACC 32382)
26	2010-110	DOM SIAH (ACC 32291)
27	2010-114	GIZA 159
28	2010-115	ZARDROME (ACC 32379)
29	2010-116	MRC 603-383
30	2010-117	FIROOZ (ACC 39261)
31	2010-118	ZAKHA (ACC 86915)
32	2010-120	JIJAI (ACC 76357)
33	2010-121	KHAU MA TUOI
34	2010-122	ARC 15210 (ACC 41956)
35	2010-125	ZAKHA (ACC 86841)
36	2010-126	LIETO
37	2010-127	N 22 (ACC 46458)
38	2010-128	IR 73055-1-2-2-3-3
39	2010-129	TAREME (ACC 32361)
40	2010-131	IR 65192-4B-17-3
41	2010-132	IR 61250-3B-7-1-2
42	2010-135	CHECK(Erramallelu)
43	2010-137	GANJA CHOOTA
44	2010-138	SADRI (ACC 32339)
45	2010-139	N 22 (ACC 117273)
46	2010-141	ATTEY (ACC 32382)
47	2010-142	DOM SIAH (ACC 32291)
48	2010-143	N 22 (ACC 6264)
49	2010-144	N 22 (ACC 4819)
50	2010-146	-
51	2010-147	-
52	2011-101	KHARA GANJA (ACC 76363)
53	2011-102	IR 2307-247-2-2-3
54	2011-103	JAMREE
55	2011-104	IR 50
56	2011-107	GIZA 176
57	2011-108	SADRI (ACC 32331)
58	2011-109	IR 71864-3R-1-1-3-1

59	2011-110	BR 26
60	2011-111	IR 61336-4B-14-3-2 (PSB RC94)
61	2011-112	IR 70031-4B-R-9-3-1
62	2011-113	TODOROKIWASE
63	2011-114	JATTA
64	2011-115	XUE HE (ACC 76826)
65	2011-116	TOOR THULLA (ACC 76420)
66	2011-117	AS 996-HR 1
67	2011-118	DULAR (ACC 32561)
68	2011-119	MALA
69	2011-120	FIROZ (ACC 39261)
70	2011-121	WAB96-1-1
71	2011-122	IR 28
72	2011-123	CUIABANA
73	2011-124	PEH-KUH-TSAO-TU (ACC 8237)
74	2011-125	RATRIA (ACC 28500)
75	2011-126	JIJAI NIKI (ACC 76358)
76	2011-127	NAN-GUANG-ZHAN (ACC 59316)
77	2011-129	GUANG JIANG 1 (ACC 82336)
78	2011-131	GANJA RANGWALA
79	2011-132	IR 6 (ACC 51504)
80	2011-133	BR 7232-6-2-3
81	2011-135	CR 547-1-2-3
82	2011-136	CO 18 (ACC 6331)
83	2011-137	N12 (ACC 6298)
84	2011-138	TAM CAU 9 A (ACC 8228)
85	2011-139	BAKTULSHI
86	2011-140	TAK RATIA (ACC 76415)
87	2011-141	RJT 74 (ACC 53688)
88	2011-143	BALILLA
89	2011-144	BR 7414-22-1
90	2011-145	BRRI DHAN 28
91	2011-146	BRRI DHAN 48
92	2011-147	IR 8866-30-3-1-4-2
93	2011-148	IR 72
94	2011-149	GANJAY (ACC 76349)
95	2011-150	KALAHITTA
96	2012-101	IR 10C110
97	2012-102	IR 10C172
98	2012-103	IR 10C139
99	2012-104	IR 83142-B-36-B
100	2012-105	HHZ 17 Y16 Y3 Y2
101	2012-106	HHZ 8 SAL6 SAL 3 Y1
102	2012-107	HHZ 5 DT 1 DT1
103	2012-108	IR 10C137
104	2012-109	IR 83142-B-32-B
105	2012-110	IR 10C132
106	2012-111	IR 10C 108
107	2012-112	IR 83143 B 151 B
108	2012-113	HHZ 12 SAL2 Y3 Y2
109	2012-114	IR 10C 153
110	2012-115	HHZ 12 SAL8 Y1 Y2
111	2012-116	IR 10C 103
112	2012-118	HHZ 17 Y16 Y3 Y1
113	2012-119	IR 10C174
114	2012-120	HHZ 12 SALB Y1 SAL1
115	2012-121	HHZ 8 SAL12 Y2 DT1
116	2012-123	IR 10C138
117	2012-124	HHZ 12 Y4DT1 Y2
118	2012-125	HHZ 5 SAL 14 SAL2 Y1
119	2012-126	HHZ 8 SAL14 SAL1 SUB1
120	2012-127	IR 10C157
121	2012-128	HHZ 8 SAL6 SAL 3 Y2
122	2012-129	HHZ 17 DT6 Y1 DT1
123	2012-130	HHZ 8 SAL6 SAL3 SAL1
124	2012-131	HHZ 5 DT20 DT2 DT1
125	2012-133	HHZ 5 SAL 10 DT3 Y2
126	2012-134	IR 10C113

127	2012-136	HHZ 11 DT7 SAL1 SAL1
128	2012-137	IR 10C 136
129	2012-138	IR 10C 143
130	2012-139	HHZ 12 Y4DT1 Y3
131	2012-140	HHZ 5 SAL8 DTZ SAL 1
132	2012-142	IR 10C126
133	2012-143	IR 10C 173
134	2012-145	HHZ 5 SAL14 SAL2 Y2
135	2012-146	IR 10C179
136	2012-147	IR 10G103
137	2012-148	IR 64197 3B 15 2
138	2012-149	HHZ 5 Y3 Y1 DT1
139	2012-150	HHZ 12 Y4 Y1 DT1
140	2012-151	IR 10C114
141	2014-301	IR 10C112
142	2014-302	IR 10C146
143	2014-303	IR 11C114
144	2014-305	IR 11C120
145	2014-306	IR 11C126
146	2014-308	IR 11C130
147	2014-309	IR 11C134
148	2014-310	IR 11C138
149	2014-311	IR 11C149
150	2014-312	IR 11C169
151	2014-313	IR 11C170
152	2014-314	IR 65199-4B-19-1-1
153	2014-315	IR 68144-2B-4-2-3-2
154	2014-316	IR 70031-4B-R-2-2-1
155	2014-317	IR 70865-B-P-6-2
156	2014-318	IR 70868-B-P-11-3
157	2014-319	IR 71895-3R-26-2-1-2B-2
158	2014-321	IR 72593-B-3-2-3-3-2B-1
159	2014-322	IR 74099-3R-5-1
160	2014-323	IR 11C119
161	2014-324	IR 11C127
162	2014-325	IR 11C173
163	2015-102	IR 64197-3B-15-2
164	2015-103	IR 11C219
165	2015-104	IR 11C206
166	2015-105	IR 83142-B-36-B
167	2015-106	HHZ 5-DT20-DT2-DT1
168	2015-108	IR 11C202
169	2015-109	IR 11C221
170	2015-111	IR 11C228
171	2015-112	FIROOZ (ACC 39261)
172	2015-113	IR 11C186
173	2015-115	IR 11C123
174	2015-116	IR 11C214
175	CPAU-1	CPAU-1
176	CPAU-10	CPAU-10
177	CPAU-11	CPAU-11
178	CPAU-12	CPAU-12
179	CPAU-13	CPAU-13
180	CPAU-14	CPAU-14
181	CPAU-16	CPAU-16
182	CPAU-19	CPAU-19
183	CPAU-2	CPAU-2
184	CPAU-20	CPAU-20
185	CPAU-21	CPAU-21
186	CPAU-22	CPAU-22
187	CPAU-23	CPAU-23
188	CPAU-24	CPAU-24
189	CPAU-25	CPAU-25
190	CPAU-26	CPAU-26
191	CPAU-27	CPAU-27
192	CPAU-28	CPAU-28
193	CPAU-29	CPAU-29
194	CPAU-3	CPAU-3

195	CPAU-30	CPAU-30
196	CPAU-4	CPAU-4
197	CPAU-5	CPAU-5
198	CPAU-6	CPAU-6
199	CPAU-8	CPAU-8
200	CPAU-9	CPAU-9
201	EC 423	NERICA 12
202	EC 424	NERICA 13
203	EC 425	NERICA 14
204	EC 426	NERICA 15
205	EC 427	NERICA 17
206	EC 428	NERICA 18
207	EC 429	NERICA-L-1
208	EC 430	NERICA-L-2
209	EC 431	NERICA-L-3
210	EC 432	NERICA-L-4
211	EC 433	NERICA-L-5
212	EC 434	NERICA-L-6
213	EC 435	NERICA-L-8
214	EC 436	NERICA-L-9
215	EC 437	NERICA-L-11
216	EC 438	NERICA-L-12
217	EC 439	NERICA-L-13
218	EC 440	NERICA-L-15
219	EC 442	NERICA-L-18
220	EC 444	NERICA-L-20
221	EC 445	NERICA-L-21
222	EC 446	NERICA-L-22
223	EC 448	NERICA-L-25
224	EC 449	NERICA-L-26
225	EC 450	NERICA-L-29
226	EC 451	NERICA-L-31
227	EC 452	NERICA-L-32
228	EC 454	NERICA-L-34
229	EC 456	NERICA-L-38
230	EC 458	NERICA-L-40
231	EC 459	NERICA-L-41
232	EC 460	NERICA-L-42
233	EC 461	NERICA-L-44
234	EC 462	NERICA-L-45
235	EC 463	NERICA-L-46
236	EC 465	NERICA-L-49
237	EC 466	NERICA-L-52
238	EC 467	NERICA-L-54
239	EC 468	SARDEUM
240	EC 470	DOM ZARD
241	EC 471	LAROME
242	EC 472	SATHI 34-36
243	EC 473	BALA
244	EC 474	KINMAZE
245	EC 478	LEMONT
246	EC 480	HUANG ANZHAN
247	EC 482	TEQING
248	EC 485	CT 9993-5-10-M
249	EC 486	NIPPONBARE

Sampling and measurements

The experiment was under taken in heading and flowering occurred between late April and late May 2013, 2014 and 2015 three years to ensure that samples were exposed to different heat doses (Table 1).

Flowering date was recorded by observing 50% plants heading. Spikelet fertility was determined manually by pressing the spikelet between the thumb and index finger at harvest. Both partially and fully filled spikelet's were categorized as a filled spikelet. Spikelet fertility was calculated as follows:

$$\text{Spikelet fertility (\%)} = \frac{\text{No. of fertile spikelet's per panicle}}{\text{Total No. of spikelet's per panicle}} \times 100$$

Table 1: Details of meteorological conditions during the study

Year	Month	Rain	Evap	Max Temp	Min Temp	Rel Humidity1	Rel Humidity2	Wind Velocity	Solar Radiation	Bright Sunshine
2013	4	60.3	276.5	37.47	22.53	73.33	33.53	7.49	22	9.15
2013	5	3.3	365.1	40.23	25.85	60.67	29.12	9.27	21.84	8.47
2013	6	102.4	188.2	32.78	22.4	82.33	53.96	13.03	15.7	4.31
2014	4	85.4	236.4	37.1	23.17	69.79	28.83	5.58	19.76	7.93
2014	5	40.8	246.4	37.06	24.79	69.61	33.61	6.94	20.95	8.47
2014	6	42.2	285	36.54	24.98	74.7	42.5	11.82	19.91	7.41
2015	4	96.8	234.9	35.32	22.07	79.53	37.83	7.43	21.56	8.74
2015	5	20.3	321.6	39.19	26.02	68.64	31.61	7.88	22.02	8.47
2015	6	109.3	195.3	33.84	23.5	84.03	51.86	11.07	16.56	4.46

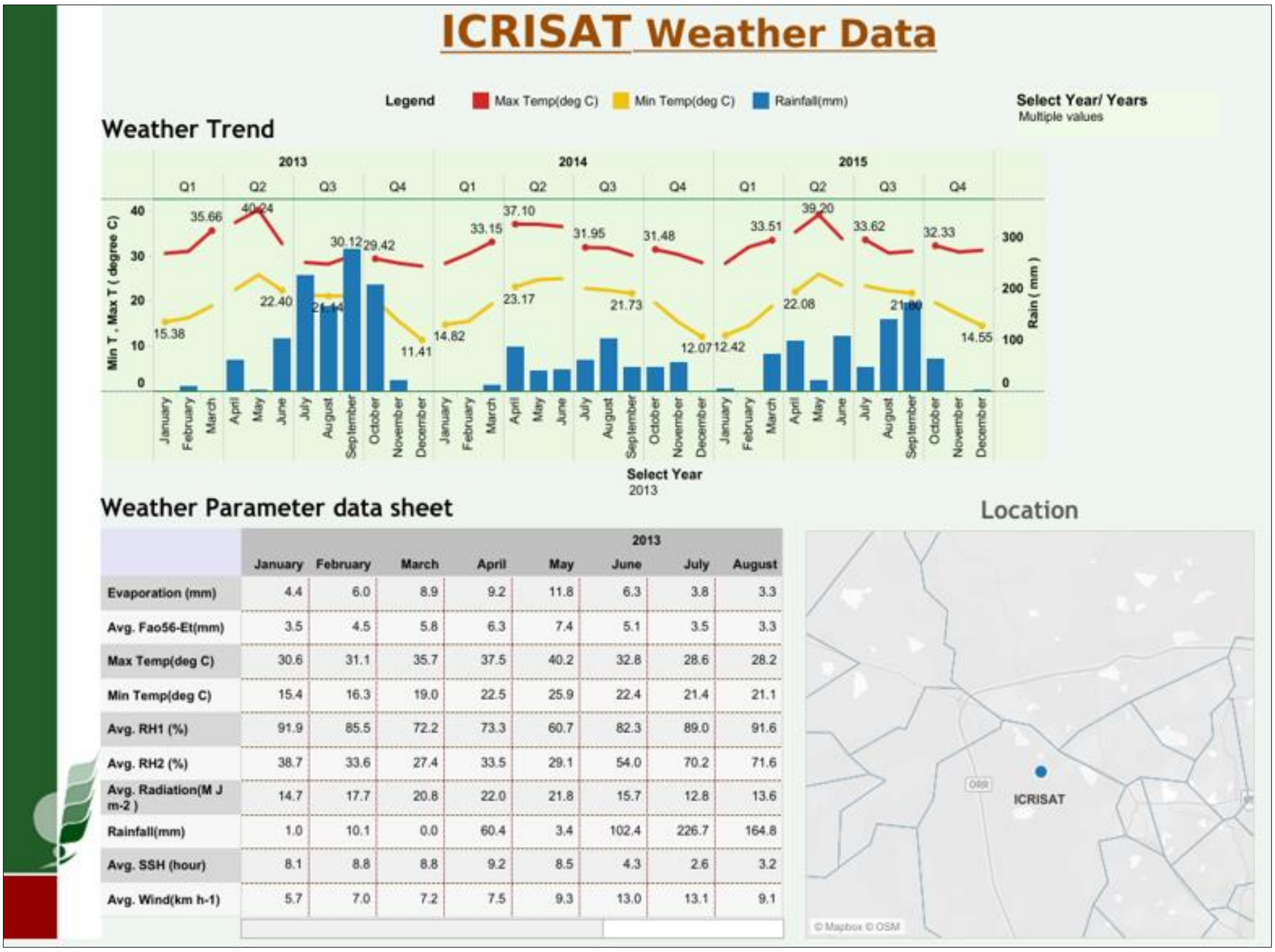

Fig 1: ICRISAT Weather Data

The pattern of flowering and hence the total number of spikelet's that reached anthesis per day differed significantly between genotypes and in response to temperature. Days to heading of the cultivars in the trials ranged mean performance from 71.46 To 130 days with the maximum/minimum temperatures at 40/22 °C, heat temperature in the experimental period during 2013, 2014 and 2015 seasons, thus the cultivars subjected to higher temperature stress in the heat

Results and Discussion

In the present study results revealed significant difference among genotypes for all traits studied under stress, indicating presence of considerable amount of genetic variation among the population. The large genetic variability among the germplasm towards different characters indicates the scope for improving the heat tolerance and its attributing traits. The Mean performance for the heat related and yield attributing traits are shown in Table 2.

Table 2: Predicted Mean performance for the studied traits of the selected accessions

Entry	Single plant yield	Test weight	Panicle length	Total number of tillers	Plant height	Days to 50% flowering	Days to maturity	Number of effective tillers	Fertility percentage
2009-104	19.91	20.72	24.35	14.19	92.83	95.96	125.60	13.42	91.54
2009-106	18.31	16.69	21.45	21.51	95.49	83.96	113.26	19.97	89.41
2009-110	31.25	19.66	23.88	16.68	95.91	93.96	123.93	15.20	85.91
2009-111	19.91	20.92	24.79	16.35	100.9	90.62	119.93	14.86	72.71
2009-114	32.38	25.62	24.45	16.68	95.26	99.96	130.26	14.31	78.51
2009-115	27.81	21.22	24.77	14.68	103.8	83.62	113.93	13.20	66.91
2009-116	30.81	18.79	24.08	24.35	98.32	102.96	133.26	20.20	81.61
2009-118	24.25	18.76	21.65	16.68	74.23	102.96	132.60	14.53	84.44
2009-120	26.25	20.29	25.45	11.68	85.12	96.96	126.26	10.53	84.94
2009-121	23.58	18.99	21.47	10.68	86.15	96.29	126.26	9.86	61.14
2009-123	22.31	18.79	23.52	13.89	68.46	89.62	119.60	12.08	74.47
2009-124	17.98	19.12	21.25	13.68	73.99	114.29	144.93	11.53	84.94
2009-125	20.91	20.16	21.55	20.68	81.15	92.62	122.26	19.53	71.47
2009-126	22.91	19.76	21.93	18.35	71.03	95.29	125.26	17.86	91.91
2009-127	27.15	23.52	26.12	15.01	98.46	105.96	135.93	14.53	70.81
2009-128	24.91	20.96	23.02	16.90	84.12	87.96	117.93	15.20	54.34
2009-130	23.91	19.39	23.42	15.11	78.22	110.96	140.93	13.53	54.47
2009-131	21.35	18.46	23.45	19.35	62.66	88.62	118.60	18.20	92.47
2009-133	19.45	21.26	23.25	20.35	62.04	103.96	134.26	18.20	87.17
2010-101	13.58	20.36	17.42	20.01	71.12	106.29	136.60	18.20	88.27
2010-103	11.35	16.99	23.28	18.45	82.02	107.62	137.93	16.53	73.27
2010-104	17.15	18.99	25.02	20.35	118.5	119.29	149.60	18.86	34.91
2010-105	20.25	20.29	23.95	14.11	101.9	117.96	146.93	12.63	86.51
2010-107	12.78	18.59	24.45	18.11	103.4	117.62	146.93	16.40	94.47
2010-109	18.31	20.22	20.68	21.46	75.26	117.96	146.60	20.08	82.81
2010-110	19.35	13.59	24.78	22.68	110.9	117.29	145.60	20.86	81.27
2010-114	12.31	21.09	25.45	12.56	111.1	114.62	144.60	11.20	52.57
2010-115	19.35	21.22	24.12	20.78	111.3	89.62	118.26	16.96	55.94
2010-116	21.85	20.76	23.78	11.35	96.36	114.96	144.26	10.53	88.64
2010-117	20.81	19.02	24.45	17.21	95.46	100.29	130.60	15.86	92.11
2010-118	16.81	18.49	21.02	21.89	85.12	99.96	130.26	20.53	60.37
2010-120	43.08	17.39	21.45	18.68	78.02	116.62	146.26	17.53	91.97
2010-121	16.38	16.39	21.04	14.57	101.12	109.29	139.26	13.31	68.97
2010-122	16.25	17.29	23.42	17.65	94.12	105.62	135.60	15.20	63.74
2010-125	17.81	18.46	16.32	22.35	108.22	85.62	115.60	21.86	86.94
2010-126	19.35	18.76	20.92	13.01	91.46	99.96	130.60	11.86	61.47
2010-127	16.15	17.39	19.78	21.11	113.12	94.62	123.93	18.96	91.77
2010-128	14.81	19.29	20.68	17.68	64.82	116.62	147.93	15.86	72.31
2010-129	17.98	20.96	22.98	14.78	94.32	109.62	140.26	13.53	54.14
2010-131	24.21	23.42	25.22	12.55	97.46	118.96	149.93	11.06	62.94
2010-132	19.71	18.12	21.47	24.45	86.86	117.96	147.26	22.86	76.97
2010-135	13.75	16.59	14.25	21.68	76.79	100.62	131.93	20.73	81.97
2010-137	19.45	16.79	18.35	17.11	120.22	89.62	120.26	14.53	88.61
2010-138	18.91	17.52	24.78	17.85	117.47	94.96	124.93	16.63	73.47
2010-139	21.15	21.56	22.32	14.31	80.92	107.96	135.93	13.20	57.57
2010-141	18.25	22.72	20.45	16.01	100.59	108.29	138.93	14.53	84.41
2010-142	20.58	22.36	16.25	20.78	113.36	100.96	130.93	18.08	65.14
2010-143	23.11	21.22	25.02	12.56	100.82	97.96	128.26	11.07	55.57
2010-144	33.98	21.12	25.32	13.88	94.49	115.62	143.93	13.20	88.74
2010-146	33.62	17.23	25.28	12.59	95.66	102.67	131.64	10.64	70.11
2010-147	33.22	16.43	22.48	21.61	82.82	102.67	132.64	20.86	78.94
2011-101	22.65	18.47	18.48	15.28	91.72	101.01	130.31	15.19	77.84
2011-102	23.05	19.27	22.20	14.67	84.86	90.67	119.98	13.69	87.94
2011-103	23.05	18.90	18.48	20.17	102.06	87.01	116.98	17.52	85.84
2011-104	13.82	18.17	21.12	17.61	58.82	94.67	124.64	15.86	83.74
2011-107	14.89	16.70	21.15	14.27	96.01	92.67	122.64	13.62	84.91
2011-108	19.99	17.07	20.82	14.95	92.26	102.67	132.31	13.86	82.17
2011-109	21.15	18.57	20.55	18.05	73.52	112.67	142.31	17.19	79.51
2011-110	18.95	22.60	20.48	17.81	89.86	112.01	141.98	16.19	87.34
2011-111	19.55	21.67	21.05	18.95	72.16	116.67	146.64	17.52	77.17
2011-112	30.92	17.30	23.54	16.61	110.60	108.67	138.64	15.86	81.81
2011-113	31.19	17.57	24.12	20.38	87.59	100.67	130.31	18.19	86.11
2011-114	16.99	17.40	18.48	17.81	103.26	102.01	131.98	16.86	78.01
2011-115	16.92	17.23	20.38	19.05	111.36	110.67	140.31	18.19	66.51
2011-116	22.79	21.70	21.48	16.17	125.17	109.67	139.64	14.86	74.61

2011-117	23.75	21.30	20.58	15.95	65.72	110.01	139.98	14.86	72.51
2011-118	22.65	18.97	19.38	22.95	89.96	97.67	127.64	20.96	81.84
2011-119	22.72	18.23	21.25	18.71	66.06	89.67	119.64	16.96	84.94
2011-120	20.62	19.63	21.25	14.61	109.17	95.34	125.31	13.52	78.61
2011-121	16.69	26.63	24.82	15.71	87.96	110.67	141.64	12.29	73.94
2011-122	23.39	24.23	20.23	19.48	64.06	115.67	145.64	17.72	74.64
2011-123	23.59	23.60	21.25	12.73	105.11	91.67	121.31	12.52	62.07
2011-124	13.95	23.03	22.72	14.95	81.86	119.67	149.64	13.86	80.51
2011-125	13.95	24.20	25.25	14.71	97.32	99.67	127.98	13.86	54.17
2011-126	15.82	26.77	20.62	18.95	126.82	92.34	122.31	17.86	81.61
2011-127	30.39	16.43	20.78	17.61	96.11	112.34	142.31	16.86	87.84
2011-129	15.69	21.10	18.38	18.71	66.06	108.67	138.31	17.49	58.11
2011-131	15.65	21.13	24.38	22.28	89.29	129.34	159.31	20.52	61.04
2011-132	17.52	21.37	21.37	15.47	91.16	85.67	115.64	14.19	66.27
2011-133	19.32	21.53	24.27	20.05	97.45	107.67	137.64	17.72	67.84
2011-135	15.95	21.80	20.28	15.71	74.07	99.67	128.31	13.97	79.37
2011-136	18.92	21.60	20.73	17.61	125.86	111.67	141.64	16.86	45.84
2011-137	20.99	21.90	23.72	19.38	117.18	102.67	132.64	18.19	45.51
2011-138	17.99	21.43	21.09	18.71	95.56	102.34	132.31	15.86	85.17
2011-139	17.69	21.20	20.90	16.83	102.31	102.34	131.98	15.39	55.84
2011-140	25.62	18.87	20.82	14.71	95.96	107.01	136.64	13.19	83.91
2011-141	18.12	22.57	21.70	16.28	96.82	106.34	136.31	14.86	77.31
2011-143	19.12	20.70	21.71	14.28	97.72	113.67	143.64	12.86	77.17
2011-144	18.52	20.80	23.78	17.28	91.29	112.01	141.64	14.86	92.94
2011-145	19.39	20.60	21.38	15.28	74.86	102.67	132.64	13.19	90.27
2011-146	22.82	19.30	21.28	12.48	87.92	110.67	140.64	11.50	85.14
2011-147	20.72	19.03	21.16	14.17	92.16	107.01	137.31	13.08	76.61
2011-148	23.55	19.20	22.38	17.28	88.37	103.01	132.98	16.41	91.37
2011-149	23.65	21.70	24.50	17.28	102.38	111.67	141.64	16.06	84.34
2011-150	10.59	18.90	18.05	20.05	86.26	109.01	138.98	17.72	77.44
2012-101	25.95	20.63	23.77	15.94	95.39	95.01	125.31	15.18	85.91
2012-102	38.65	19.77	21.80	16.67	86.16	104.34	133.98	14.61	64.31
2012-103	34.09	19.60	23.26	16.71	75.96	116.67	146.64	16.41	84.61
2012-104	21.92	22.95	24.19	19.44	75.24	114.01	143.22	17.49	84.22
2012-105	26.29	15.72	24.00	17.98	80.07	110.01	139.88	16.29	87.29
2012-106	20.25	17.55	23.02	11.55	80.40	112.01	141.88	10.62	85.72
2012-107	28.15	20.52	22.02	17.64	89.84	125.01	154.55	16.15	80.76
2012-108	26.59	21.12	23.07	19.11	88.52	97.01	126.88	18.29	90.59
2012-109	24.72	23.52	21.55	17.54	83.94	112.01	141.88	15.29	92.62
2012-110	24.19	21.45	20.48	20.11	75.36	115.01	144.88	18.29	90.12
2012-111	22.95	24.98	20.90	14.80	71.60	112.34	141.55	13.29	83.16
2012-112	25.42	21.95	21.67	18.78	79.40	113.01	142.88	16.95	84.62
2012-113	27.95	22.05	22.07	19.89	81.40	119.67	147.88	17.95	90.39
2012-114	25.02	20.15	21.34	21.11	81.44	105.67	135.88	19.95	91.19
2012-115	21.06	20.98	24.48	16.44	80.85	120.34	149.88	14.62	38.52
2012-116	34.85	21.62	22.37	18.21	84.70	113.01	142.88	15.82	87.52
2012-118	25.95	17.22	23.70	14.31	97.31	110.67	140.22	12.62	89.82
2012-119	22.79	17.95	20.67	20.31	97.88	112.34	142.22	18.29	86.86
2012-120	21.95	17.32	21.47	16.44	74.07	108.01	138.22	14.95	91.32
2012-121	40.59	18.55	22.90	19.44	76.74	106.67	136.22	17.72	86.42
2012-123	39.22	26.48	24.79	18.00	80.40	110.67	140.55	16.62	88.32
2012-124	21.85	16.78	20.47	17.44	73.97	112.67	142.55	15.95	86.52
2012-125	35.29	26.65	21.67	21.11	67.40	116.01	144.88	19.51	92.89
2012-126	31.32	22.35	21.33	17.44	72.47	106.67	136.55	14.95	89.66
2012-127	57.69	18.82	24.80	20.54	84.49	115.34	145.22	17.82	89.29
2012-128	56.59	18.88	22.74	17.94	72.50	115.34	145.22	15.29	90.76
2012-129	55.12	18.72	23.90	16.31	77.30	118.34	148.22	14.62	93.09
2012-130	45.05	21.42	23.54	14.78	81.62	110.01	140.22	13.62	93.16
2012-131	34.82	23.72	24.80	15.78	82.17	122.67	151.88	14.62	91.32
2012-133	33.92	22.38	27.23	15.10	99.06	107.67	137.55	13.72	91.62
2012-134	32.95	21.98	24.00	20.44	75.30	112.01	142.22	18.95	90.62
2012-136	20.92	21.05	21.69	18.31	83.74	107.34	137.22	15.82	91.39
2012-137	47.59	20.88	22.67	16.64	79.30	107.01	137.88	15.49	88.39
2012-138	52.32	22.65	22.47	24.44	80.64	116.67	143.88	23.29	92.22
2012-139	37.75	20.52	21.90	12.89	96.39	107.67	137.22	12.62	90.26
2012-140	18.29	23.52	23.09	16.64	76.84	118.34	147.88	15.72	86.92
2012-142	41.15	22.35	23.20	17.11	84.84	116.01	144.55	15.15	86.02
2012-143	33.22	24.05	22.40	15.98	73.94	107.67	137.88	15.62	89.36

2012-145	28.25	22.32	24.03	20.11	67.17	108.67	139.22	19.25	89.12
2012-146	52.92	21.52	22.23	20.11	74.30	117.34	145.88	18.62	92.72
2012-147	36.39	21.78	23.67	19.64	93.40	102.01	131.55	18.29	92.96
2012-148	41.72	22.02	24.80	18.44	86.74	120.01	150.88	16.62	93.26
2012-149	43.49	21.42	24.57	16.77	94.50	112.01	141.55	16.06	92.82
2012-150	20.92	22.15	23.69	14.98	91.50	110.01	139.88	13.73	81.79
2012-151	17.72	22.15	21.47	17.98	89.94	100.34	130.22	16.29	90.86
2014-301	43.92	22.05	20.37	14.11	85.74	102.01	131.88	12.62	88.51
2014-302	44.62	21.32	23.00	18.00	83.06	95.34	125.22	17.29	84.02
2014-303	38.09	21.45	21.70	18.11	79.94	98.34	128.22	16.39	84.49
2014-305	33.92	21.45	24.01	18.11	84.28	98.67	128.55	16.72	72.99
2014-306	39.59	21.22	20.57	18.75	85.38	101.01	130.88	16.29	89.62
2014-308	41.95	21.75	21.90	15.21	80.05	95.34	125.22	13.73	90.09
2014-309	38.02	19.92	24.02	19.11	86.95	111.01	141.22	18.49	89.32
2014-310	26.77	20.71	22.42	15.85	75.82	111.05	140.93	15.43	95.81
2014-311	23.27	21.48	24.23	16.85	83.62	115.05	144.26	15.43	93.21
2014-312	28.90	21.04	24.34	15.50	78.19	88.72	118.60	13.76	91.98
2014-313	33.14	20.14	28.60	18.08	102.85	106.72	136.60	16.10	89.05
2014-314	30.90	20.04	21.93	16.72	82.51	93.72	123.60	15.30	81.45
2014-315	24.20	20.38	24.05	13.62	83.75	94.72	124.60	12.20	92.58
2014-316	27.24	19.98	19.94	22.95	98.72	116.72	146.60	20.86	93.01
2014-317	29.74	18.54	21.63	16.52	83.50	90.39	120.60	15.43	88.68
2014-318	27.84	21.21	23.35	13.74	82.52	95.72	125.60	11.98	88.31
2014-319	24.10	21.18	24.42	14.73	87.76	100.39	129.93	12.96	92.75
2014-321	30.24	21.11	22.36	13.06	84.58	102.39	132.60	11.86	87.78
2014-322	30.20	22.14	21.46	17.74	86.82	110.39	139.93	15.21	91.95
2014-323	26.47	20.88	23.30	17.62	88.92	110.72	140.60	15.64	84.18
2014-324	18.74	20.08	22.60	15.85	89.98	101.05	128.60	13.76	90.05
2014-325	20.44	21.94	22.93	20.62	73.39	111.72	141.26	19.30	87.95
2015-102	31.10	20.81	24.53	16.61	76.41	120.72	150.60	15.43	81.91
2015-103	24.57	19.21	24.43	18.68	85.32	98.05	127.60	15.07	84.05
2015-104	39.57	23.34	23.83	15.83	86.63	102.05	131.93	14.32	75.75
2015-105	35.04	21.94	24.73	13.85	85.69	96.72	126.60	12.76	71.88
2015-106	35.34	21.41	25.94	16.19	89.39	113.05	142.93	13.98	91.68
2015-108	32.80	21.31	25.60	19.19	84.53	102.72	132.60	16.98	84.58
2015-109	40.24	21.64	21.60	19.19	104.75	88.72	114.93	16.65	85.48
2015-111	39.80	22.28	24.37	15.48	91.53	103.72	132.93	13.42	74.21
2015-112	34.80	22.51	24.05	18.74	97.86	95.05	124.93	16.32	65.08
2015-113	30.37	20.74	23.61	20.41	73.03	115.72	145.60	17.87	80.71
2015-115	17.57	21.21	25.92	19.52	105.53	86.72	116.60	17.76	65.15
2015-116	32.70	20.78	26.53	19.74	102.65	100.72	130.60	17.98	92.51
CPAU-1	26.14	17.28	22.26	19.39	72.52	95.72	125.93	17.10	90.58
CPAU-10	18.14	20.64	23.93	19.05	86.82	106.05	135.93	16.53	89.75
CPAU-11	15.37	21.11	16.26	19.52	142.32	110.72	140.60	17.76	92.31
CPAU-12	30.67	21.24	22.26	17.52	106.99	110.05	139.26	16.53	94.11
CPAU-13	28.10	21.28	18.03	18.95	91.72	104.72	134.26	17.43	76.61
CPAU-14	28.14	20.51	16.83	15.52	60.96	85.05	115.60	15.43	88.85
CPAU-16	26.80	16.91	21.70	15.29	76.76	93.05	122.93	13.76	83.11
CPAU-19	30.47	15.91	20.83	15.85	124.32	107.72	136.93	14.43	76.95
CPAU-2	23.80	18.24	22.60	19.95	109.86	85.72	110.93	18.20	56.05
CPAU-20	30.90	18.38	21.66	13.05	104.42	101.05	131.93	12.10	92.38
CPAU-21	31.67	21.28	26.28	19.19	95.09	101.39	132.26	17.10	78.85
CPAU-22	26.90	18.81	25.13	15.72	93.72	101.05	131.26	14.76	95.91
CPAU-23	17.90	18.41	24.70	20.19	87.66	91.05	120.60	18.76	93.18
CPAU-24	20.47	19.11	23.90	18.52	89.52	104.72	134.60	16.76	90.01
CPAU-25	27.80	20.58	20.76	17.19	92.32	107.72	137.60	15.43	85.05
CPAU-26	27.24	18.51	21.16	17.52	94.62	109.72	139.60	16.43	79.61
CPAU-27	24.90	20.01	21.90	19.52	95.32	109.39	138.93	18.43	80.81
CPAU-28	23.47	18.94	24.70	20.85	121.76	110.72	140.60	20.10	66.28
CPAU-29	22.24	19.91	24.60	17.85	142.99	101.05	130.60	15.76	81.88
CPAU-3	28.90	19.98	21.00	18.82	112.09	96.39	126.60	17.30	86.35
CPAU-30	24.80	19.08	24.66	17.85	102.76	100.72	129.60	16.43	42.61
CPAU-4	28.14	19.01	18.66	16.85	113.09	90.05	119.93	15.76	76.01
CPAU-5	17.99	18.82	22.36	17.52	98.05	110.62	140.60	15.54	82.66
CPAU-6	16.56	16.89	19.16	18.86	96.08	88.62	118.26	17.44	82.26
CPAU-8	16.23	16.92	21.16	16.29	89.05	89.62	119.60	14.91	92.82
CPAU-9	12.89	19.52	25.46	18.52	104.71	104.62	134.60	18.24	68.86
EC 423	25.23	19.19	22.16	20.76	89.78	92.62	122.26	18.91	77.62

EC 424	22.23	20.96	24.03	16.09	94.18	100.62	130.60	15.02	60.96
EC 425	27.23	23.16	19.88	19.64	89.10	92.96	122.93	17.77	93.96
EC 426	30.56	20.59	22.03	16.42	89.27	93.96	122.60	14.02	83.06
EC 427	29.99	18.49	20.69	23.09	84.85	110.96	140.93	20.79	77.52
EC 428	23.23	19.39	22.69	17.42	65.61	110.96	140.60	16.67	87.52
EC 429	17.63	20.76	22.04	12.53	73.75	113.62	143.60	11.24	80.19
EC 430	26.56	20.72	20.59	20.76	65.95	90.96	120.93	19.44	82.96
EC 431	27.56	20.36	20.49	18.74	65.62	90.29	120.26	17.57	77.19
EC 432	29.89	18.92	20.36	16.42	75.08	92.62	121.93	15.56	71.19
EC 433	29.23	21.82	20.06	13.09	76.07	92.96	122.93	11.68	74.19
EC 434	20.56	22.82	21.59	13.98	85.65	110.29	139.93	12.35	70.02
EC 435	27.99	25.32	20.95	16.64	83.61	109.96	139.93	12.31	88.66
EC 436	42.23	21.02	19.43	20.97	73.02	94.62	124.60	17.11	86.86
EC 437	20.03	20.72	20.93	17.42	65.28	110.62	140.60	16.24	90.96
EC 438	22.33	20.59	20.61	14.62	78.75	87.96	117.60	13.44	89.86
EC 439	42.56	20.99	20.71	14.87	65.41	100.62	130.93	13.79	90.52
EC 440	22.99	20.59	23.73	12.98	86.75	111.29	141.26	11.91	74.52
EC 442	22.69	20.99	24.94	16.18	67.96	96.29	125.93	14.12	85.52
EC 444	26.13	21.89	25.09	20.19	92.31	110.62	140.60	18.34	59.99
EC 445	18.56	20.42	21.76	18.64	77.75	100.29	130.26	17.57	85.19
EC 446	30.09	20.96	22.93	13.98	68.63	120.29	149.60	13.24	87.06
EC 448	28.56	21.12	22.05	16.09	85.75	112.29	141.93	15.24	97.96
EC 449	29.56	21.32	21.17	16.20	76.40	113.29	144.26	14.46	84.52
EC 450	29.89	20.96	20.28	16.76	68.95	118.62	148.60	15.24	89.62
EC 451	25.53	21.06	21.49	16.86	78.07	92.29	122.60	15.91	84.52
EC 452	26.66	22.39	21.76	19.20	72.92	119.62	148.60	17.77	90.06
EC 454	23.66	22.12	22.05	18.09	76.97	95.29	124.60	15.91	91.19
EC 456	21.56	23.42	24.16	17.52	76.48	105.96	135.93	16.87	92.52
EC 458	24.99	22.09	20.49	14.76	99.71	111.29	141.60	13.44	92.36
EC 459	37.83	21.69	22.45	17.87	80.01	116.29	146.60	15.46	76.82
EC 460	37.73	21.52	25.49	19.76	91.05	118.29	148.26	18.91	80.19
EC 461	35.66	22.39	24.93	19.42	73.75	113.29	143.26	18.57	79.82
EC 462	31.43	21.86	23.86	19.76	78.98	100.62	130.60	18.77	84.86
EC 463	34.56	22.89	25.06	18.71	85.05	108.29	138.26	15.88	86.79
EC 465	26.23	21.69	23.69	18.98	83.61	105.96	136.60	17.24	91.02
EC 466	30.23	21.76	20.89	17.62	76.20	113.29	142.60	15.91	90.49
EC 467	31.23	21.02	21.36	23.76	78.75	94.62	122.60	21.24	72.19
EC 468	32.89	21.32	24.49	16.76	97.05	105.62	133.93	15.91	60.52
EC 470	25.56	22.32	29.23	19.76	127.75	105.29	134.93	18.31	80.96
EC 471	22.23	22.96	21.13	20.09	96.98	86.29	116.26	17.91	59.86
EC 472	22.89	21.09	21.06	15.31	64.75	103.29	132.93	13.79	92.62
EC 473	22.23	21.29	20.73	13.42	64.98	108.29	138.26	11.57	95.52
EC 474	31.13	22.16	20.49	11.09	78.08	100.96	130.93	10.57	92.19
EC 478	28.99	17.46	19.26	16.09	91.18	108.62	138.60	13.57	86.86
EC 480	28.59	18.82	20.69	14.09	88.98	78.29	108.26	12.57	87.46
EC 482	27.99	21.56	18.06	23.76	94.71	77.29	106.26	22.91	85.06
EC 485	31.23	21.46	17.06	14.76	96.35	100.62	130.26	12.24	73.72
EC 486	25.23	20.46	20.49	11.76	107.98	99.29	129.26	10.24	67.86
Erramallelu	26.56	21.26	24.20	18.54	80.10	100.53	129.60	17.13	89.42
IR-64	29.57	24.46	24.62	15.60	74.48	100.40	129.06	14.73	91.53
MTU-1010	30.13	24.65	24.70	16.34	86.64	100.53	130.13	14.60	84.99
N-22	22.54	20.72	24.05	16.87	115.92	108.33	137.80	15.04	89.49
SWARNA	29.54	21.17	24.54	20.27	58.46	130.00	159.33	18.67	93.29
Todorokiwase	16.70	21.37	24.28	16.98	97.67	91.46	121.60	14.62	16.32
Varalu	23.44	18.65	17.74	16.71	65.62	71.46	102.00	15.87	85.88
AVG	26.18	20.52	22.37	17.36	88.22	104.4	134.2	15.82	81.11
Min	10.59	13.59	14.25	10.68	58.46	71.46	102	9.862	16.32
Max	57.69	26.77	29.23	24.45	142.9	130	159.3	23.29	97.96
MS	165.21	14.01	15.95	22.53	716.4	370.22	368.82	20.66	625.75
Probability	<.001	<.001	<.001	0.419	<.001	<.001	<.001	<.001	<.001
Residual	1.44	0.35	0.582	2.225	1.49	1.493	1.595	1.785	3.218
Se	0.73	0.36	0.464	1.492	0.74	0.7437	0.7701	0.813	1.09
SED	1.05	0.52	0.666	2.159	1.06	1.06	1.1025	1.1663	1.566
LSD	2.08	1.03	1.326	4.297	2.12	2.123	2.194	2.321	3.116
CV	4.59	2.86	3.39	8.59	1.39	1.17	0.94	8.45	2.22

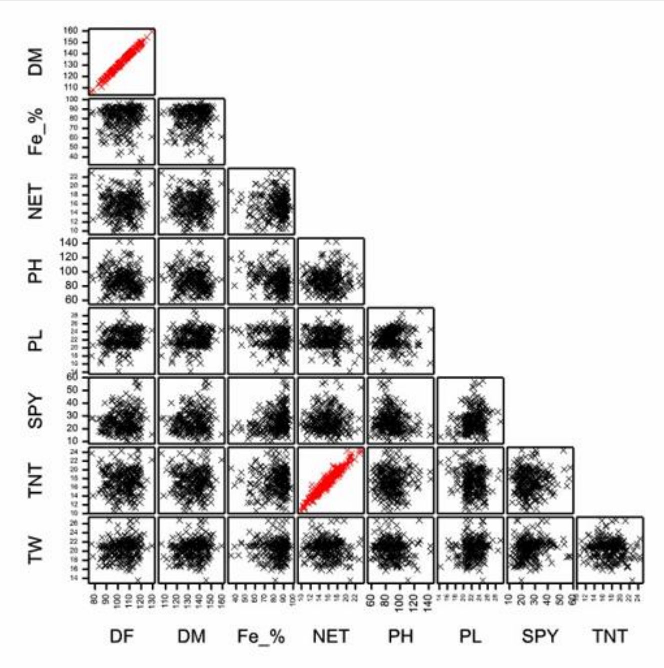

Fig 2: Graphical representation of correlation for various characters in rice genotypes.

With respect to plant height, the mean values ranged between 58.4 cm for Swarna and 142.3 cm for CPAU-11comparing with the check variety N-22(115.2 cm), For panicle length, EC 470 followed by 2014-313, these rice genotypes reached the longest panicles, while, 2010-135, 2010-142 was found to have the shortest panicle comparing with other cultivated genotypes under heat stress condition.

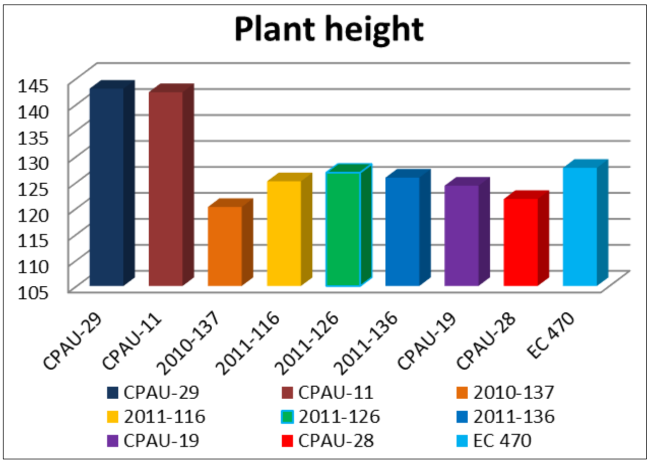

Fig 3: Frequency distribution of Plant height

Regarding total number of tillers /plant, the studied genotypes ranged from 10.68-24.4 under heat conditions. The highest number of tillers /plant occurred in the case of the genotypes 2010-132, 2012-138 under heat stress conditions. The mean values for number of tillers of these genotypes ranged 17.36 under heat conditions. Regarding number of effective tillers/plant, the studied genotypes ranged from 9.8-23.2 the minimum value genotype is 2019-121 and maximum range one is 2012-138. The single plant yield is ranged between 10.5-57.6 under heat conditions. The analysis of variance showed that significant differences among genotypes were detected under each condition test weight ranged between 13.59-26.77. The highest values of test weight were obtained for the genotypes 2011-156.

The days to 50% flowering were ranged minimum 71 days for varalu and 130 days for Swarna. The days to maturity ranged between 102-159 days. The daily temperature is typically higher during the spikelet flowering period, resulting in severe spikelet sterility, which suggests that early flowering cultivar type like Varalu (71), EC 482 (77), EC 480 (78) and 2009-115(83) could be used as genetic donors to reduce the high temperature damage.

The important trait for heat stress is fertility percentage. Spikelet fertility under heat stress ranged from 98.6% to 16.3% due to climatic conditions. Lowest spikelet fertility observed in Todorokiwase, 2010-104 and 2012-115 with 16.32%, 34.91% and 38.52% respectively. 65entries identified as genetic donors based on spikelet fertility, which recorded more than 90% fertility. Among them, Acc. no 2012-130(98.8, 48.6), EC 448(98, 30), 2012-133 (98, 35.9), 2012-149(97, 44) and 2012-129(95.5, 55.6) noted highest fertility percentage and Single plant yield respectively. These genotypes showing constant results in three years under heat stress conditions. This result indicates that these genotypes would be more able to recover after a period of stress. Heat stress during vegetative growth causes many physiological and metabolic changes, including alterations in hormone homeostasis. Some of the heat-induced processes at the cell, organ and whole-plant levels may be hormone regulated; others may be the consequence of a new hormonal status, altered by heat stress (Matsui & Omasa, 2002) [5]. Flowering (anthesis and fertilization), and to a lesser extent booting (microsporogenesis), are the most susceptible stages of development to temperature in rice (Satake & Yoshida, 1978 and Farrell *et al.*, 2006) [6]. Sterility is caused by poor anther dehiscence and low pollen production, and hence low numbers of germinating pollen grains on the stigma (Matsui *et al.*, 2000, 2001 and Prasad *et al.*, 2006) [5]. There is genotypic variation in spikelet sterility at high temperature (Matsui *et al.*, 2001; Satake & Yoshida, 1978 and Prasad *et al.*, 2006) [5, 6] that can be defined by different temperature thresholds (Nakagawa *et al.*, 2002).

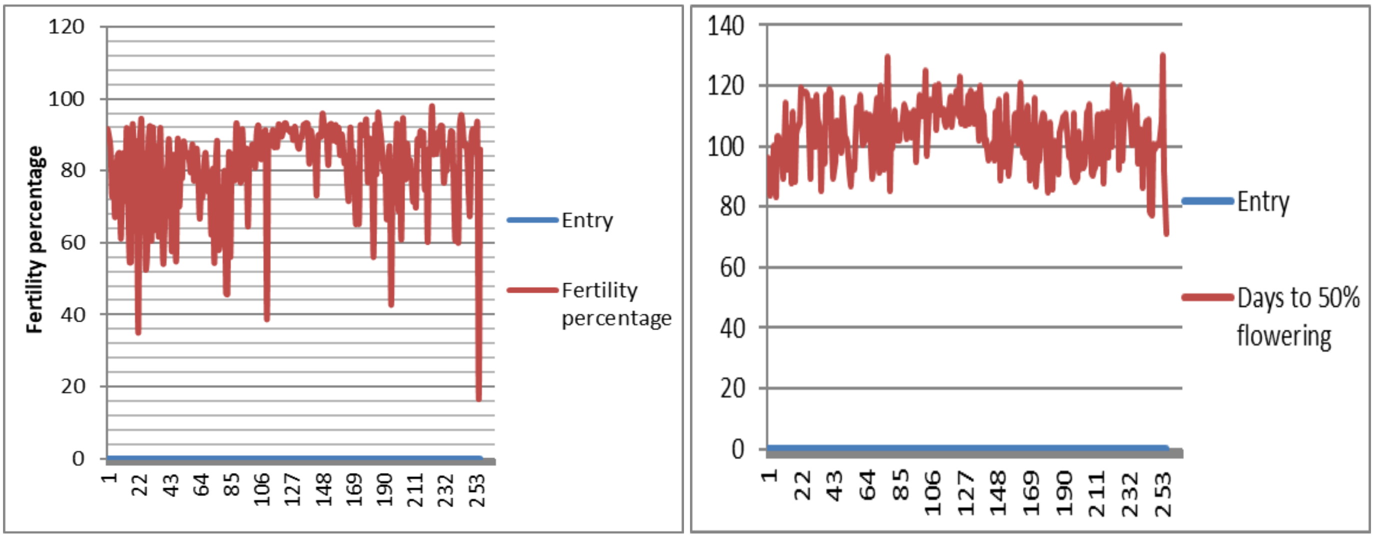

Fig 4: Frequency distribution of fertility percentage of grains, Days to 50% flowering

Temperature differences result in various degree of heat injury. Satake and Yoshida (1978) [6] reported different heat tolerances among three *indica* rice varieties at Grain filling is the final stage of growth in cereals, where fertilized ovaries develop into caryopses. Its duration and rate determine the final grain weight, a key component of the total yield. High temperature is the major stress factor during the maturation and ripening of rice in many production areas. Periods of high temperature during grain development cause large yield losses in cereals. This reduction is mainly caused by a reduction in starch accumulation, because, in general, over 65% of cereal dry weight (DW) is related to starch. The reduction in 100 grain weight in response to heat stress during the early periods of grain filling can mainly be attributed to the lower number of endosperm cells, while during the later stages stress results in the impairment of starch synthesis either because of the limited supply of assimilates for the grain or the direct effects on the biosynthesis processes in the grain. It could be concluded that high-temperature stress during the vegetative and reproductive growth phases caused greater reduction in grain yield as compared with that during the ripening phase, which caused low reduction in grain yield. Among yield components, the number of panicles/plant and grains/panicle showed greater sensitivity to high-temperature stress, whereas 1000-grain weight was less affected by the same level of heat stress. The marked reduction in grain yield of rice under high-temperature stress during vegetative growth was mainly attributed to the significant reduction in the number of panicles/plant followed by the number of grains/panicle. The reduction in grain yield by high-temperature stress during the reproductive growth phase was caused by significant decreases in the number of panicles/plant and number of grains/ panicle and the marginal reduction in 1,000-grain weight. However, the relatively low reduction in grain yield due to heat stress during ripening was probably caused by the small reduction in 1000-graier of grains per panicle.

Conclusion

High temperature stresses adversely affect the performance of rice genotypes. Screening of wide range of germplasm against to high temperature conditions in field level is reliable and superior to all the screening procedures to identify suitable genetic donors to develop climate resilient genotypes. In this investigation, 255 entries and 7 checks were screened to identify heat tolerant donors. 65entries identified as genetic donors based on spikelet fertility, which recorded more than 90% fertility. Among them, Acc no 2012-130(98.8, 48.6), EC 448(98, 30), 2012-133 (98, 35.9), 2012-149(97, 44) and 2012-129(95.5, 55.6) noted highest fertility percentage and Single plant yield respectively. Early flowering duration check Varalu (77 days), entries like EC 482 (77), EC 480 (78) and 2009-115(83), could be used to develop heat avoidance lines, which is a particularly favorable trait for heat-resistant rice cultivar. These genotypes can be used as a genetic donors in rice breeding program by crossing with local varieties which having high yield potential, to combine heat tolerance with high yield traits. The daily temperature is typically higher during the spikelet flowering period for *japonica* rice, resulting in severe spikelet sterility, which suggests that early flowering cultivar type could reduce the high temperature damage.

EC series (exotic collection) from Africa accessions are flowering and anthesis in the early morning due to that early nature it escapes from the heat stress.

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