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D Dev Kumar
Department of Crop Physiology, College of Agriculture, Rajendranagar, Hyderabad, Telangana, India

D Vishnu Vardhan Reddy
Department of Crop Physiology, College of Agriculture, Rajendranagar, Hyderabad, Telangana, India

P Raghuveer Rao
Department of Plant Physiology, Indian Institute of Rice Research, Rajendranagar, Hyderabad, Telangana, India

M Sheshu Madhav
Biotechnology Division, Indian Institute of Rice Research, Rajendranagar, Hyderabad, Telangana, India

V Gouri Shankar
Department of Genetics and Plant Breeding, College of Agriculture, Rajendranagar, Hyd.
Prof. Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, Telangana, India

B Vishalakshi
Biotechnology Division, Indian Institute of Rice Research, Rajendranagar, Hyderabad, Telangana, India

Corresponding Author:
D Dev Kumar
Department of Crop Physiology, College of Agriculture, Rajendranagar, Hyderabad, Telangana, India

Morphological and phenological characterization with grain yield in advanced breeding lines of Rice (*Oryza sativa* L.)

D Dev Kumar, D Vishnu Vardhan Reddy, P Raghuveer Rao, M Sheshu Madhav, V Gouri Shankar and B Vishalakshi

Abstract
Rice (*Oryza sativa* L.) is the most important staple food crops in the world. In Asia, more than two billion people are getting 60-70 per cent of their energy requirement from rice and its derived products. Samba Mahsuri (BPT-5204) is premium quality aromatic and light weight rice. Due to its excellent grain character, variety being regularly used in hybridization programmes to meet current breeding objectives. Therefore, use of advanced breeding lines generated from BPT-5204 would only be appropriate and evaluation of available germplasm or mutants for various physiological and yield attributes is essential. It was proposed to characterize the advanced EMS mutated lines for their important morphological, physiological, yield attributing traits, grain characteristics as compared to the wild type (untreated Samba Mahsuri). The experimental field was laid in RBD replicated thrice with 30 high yielding rice genotypes which includes 26 advanced breeding lines (ABL) and four checks. Morphological parameters were measured at periodical intervals. Plant height among genotypes ranged from 92 to 131cm. Genotype, SP-70 (126 cm) showed maximum plant height and followed by SP-355 (124 cm) compared BPT-5204 (98 cm). Mean plant height increased by 44.3% from active tillering to panicle initiation stage and then by 28.4% from PI to physiological maturity. Higher number of tillers per plant was observed in SP-08 and SP-70 (23) compared to check BPT-5204 (18). Among the duration groups, the short duration (116 to 122 days) lines were SP-08, SP-72, SP-70 and SP-69. The medium duration (125 to 133 days) lines, SP-351, SP-353, SP-355, SP-357, SP-80 and SP-25 and long duration (140 to 148 days) lines, SP-02, SP-03 and SP-37 found superior in terms of grain yield as compared to their respective check varieties. Two advanced breeding lines namely SP-08 and SP-70 can be further probed thoroughly for further increasing in yield and yield attributes.

Keywords: Morphological, phenological, *Oryza sativa* L

Introduction
Rice (*Oryza sativa* L.) belongs to the family graminae and sub family Oryzoideae. As a cereal grain, it is the most important staple food crops in the world. In Asia, more than two billion people are getting 60-70 per cent of their energy requirement from rice and its derived products. In the twenty-first century, the world faces a serious challenge in that agricultural land area has sharply decreased in contrast to a population explosion. To solve the crisis of food shortage, there is necessity to increase crop productivity of rice as rice is the primary staple food for one third of the world population after wheat and maize. Worldwide rice is cultivated in an area of 160.6 million hectares with a production of 740.9 million tonnes during the year 2014-15. Among the rice growing countries, India has the largest area (42.27 mha) and production (105.24 mt) next to China (144 mt) with an average productivity of 2.49 t ha^{-1}, and is well below the world's average yield of 4.36 tha^{-1}(FAOSTAT, 2014). In A.P area under rice is 43.87lakh ha^{-1} and production is 84.78 lakh tonnes and productivity is 3333 kg ha^{-1}. At the current population growth rate (1.5%), rice requirement of India by 2025 would be around 125 mt (Kumar *et al*., 2009) [4]. So far, several high yielding and management responsive varieties have been developed and released for improved crop production. Among which Samba Mahsuri, a hybrid derived from the cross (GEB 24 x TN1) rice is otherwise called Sona Mahsuri/ Samba Mahsuri/ BPT-5204 which is premium quality aromatic and light weight rice. Due to its excellent grain character, variety being regularly used in hybridization programmes to meet current breeding objectives. Therefore, use of advanced breeding lines generated from BPT-5204 would only be appropriate and evaluation of available germplasm or mutants for various physiological and yield attributes is essential (Babaei *et al.*, 2011) [1].

Material and Methods

1. Plant Height (cm)

The height of the five plants was measured in centimeters from the ground level to the tip of the youngest leaf at active tillering, panicle initiation and to the tip of the panicle at physiological maturity.

2. Total Number of Tillers per Hill

The number of tillers in five hills was counted at harvest.

3. Number of Productive Tillers per Hill

At harvest the tillers bearing panicles per hill were counted and expressed as number of productive tillers per hill.

4. Days to 50 Percent Flowering

Number of days taken for 50 percent of the tillers to flower in a plot was recorded in all the treatments.

5. Days to Maturity

Number of days taken for yellowing of the leaves and stem (Symptoms of maturity) as days in each plot and each replication was recorded and reported as maturity in different treatments.

6. Grain Yield (Tonnes ha^{-1})

Grain from net plot area was thoroughly sun dried and weighed, and then yield per hectare was determined based on net plot area.

Results and Discussion

1. Morphological Parameters

1.1 Plant height at Active Tillering (AT), Panicle Initiation (PI) and Physiological Maturity (PM) Stages

The plant height is a major trait that influences the seed yield in paddy. Plant height increased with age of the crop and reached maximum at physiological maturity. Similarly, Paul *et al.* (2016) [7] showed that plant height increases progressively with the advancement of time from 15 to 75 DAT. In the present study at active tillering (AT), panicle initiation (PI) and physiological maturity (PM), plant height differed significantly among the genotypes (Table 1). The mean plant height across the seasons at the active tillering stage, PI and PM was 77, 102 and 126 cm respectively highest in SP-70 against the check variety, BPT-5204 (48, 75 and 98 cm respectively). The least plant height was observed in the genotype, SP-03 (49, 69, and 87 cm respectively).

Plant height increases mainly during vegetative phase (active tillering to panicle initiation) and it was by 44.3% across the varieties and 56.3% in BPT-5204. The plant height have shown positive relationship with both biomass and grain yield, but significantly with yield only at physiological maturity stage (Table 2). However, maximum yield was attained in a variety having plant height of 84 cm and 111 cm respectively at PI and PM stage, beyond which there was no improvement in grain yield (Figure 1). The dwarf types have less biomass and thus lower seed yield, but a medium plant height would produce more biomass, panicle length and higher seed yields (Zhang *et al.*, 2017) [11]. The tall plant height may lead to lodging problem; photosynthates may locked up in stem with longer distance for translocation of photosynthates from leaves to panicle. Therefore, it appears that plant height in paddy for better yields would be nearly 110 cm, a medium plant height types as compared to BPT-5204.

Table 1: Plant height (cm) at active tillering, panicle initiation and physiological maturity in advanced breeding lines of rice

	Plant height (cm)									
	Active Tillering				Panicle Initiation			Physiological Maturity		
S. No	Genotypes	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
1	SP-351	59	61	60	95	100	98	119	121	120
2	SP-352	56	53	55	89	92	91	111	114	113
3	SP-353	56	59	58	89	91	90	109	111	110
4	SP354	54	50	52	85	81	83	114	112	113
5	SP-355	75	73	74	97	104	101	123	125	124
6	SP-356	68	72	70	88	93	91	120	115	118
7	SP-357	62	65	64	92	103	98	110	107	109
8	SP-358	66	61	64	91	98	95	116	120	118
9	SP-359	63	65	64	94	99	97	111	114	113
10	SP-360	56	58	57	91	93	92	120	123	122
11	SP-70	78	75	77	98	106	102	124	127	126
12	SP-72	61	65	63	86	91	89	113	115	114
13	SP-63	65	62	64	92	90	91	110	114	112
14	SP-61	64	66	65	94	95	95	113	119	116
15	SP-69	70	68	69	90	89	90	120	123	122
16	SP-55	55	54	53	92	90	91	110	115	113
17	SP-80	69	73	71	88	94	91	103	105	104
18	SP-25	63	64	64	96	98	97	110	114	112
19	SP-13	61	68	65	86	89	88	114	119	117
20	SP-08	60	66	63	82	86	84	109	112	111
21	SP-75	63	65	64	78	79	79	108	109	109
22	SP-57	64	68	66	76	81	79	114	121	118
23	SP-03	43	52	49	67	71	69	85	89	87
24	SP-02	59	61	60	80	84	82	115	120	118
25	SP-34	69	70	70	81	87	84	103	107	105
26	SP-37	53	55	54	80	88	84	116	119	118
27	NDR-359	54	59	57	75	80	78	101	104	103
28	BPT-5204	52	50	48	72	77	75	97	100	98
29	IR-64	51	53	51	73	83	78	100	103	101
30	Jaya	52	56	54	85	88	87	113	114	114
	Mean	60	62	61	86	90	88	111	114	113
	SE (m)	9.73	8.63	2.36	11.98	13.08	12.78	6.90	11.80	2.95
	CD at 5%	19.90	17.65	14.67	18.52	16.76	14.62	20.13	21.15	20.85
	CV (%)	2.23	2.60	4.87	3.25	3.53	5.54	4.31	6.88	3.08

Table 2: Correlation coefficient values between plant height at different stages with biomass production and grain yield at harvest in elite rice genotypes

Crop stage	Plant height with biomass	Plant height with grain yield
Active Tillering (AT)	0.351*	0.278
Panicle Initiation (PI)	0.196	0.416*
Physiological Maturity (PM)	0.231	0.231

*: Denotes significance at 5% level of confidence.

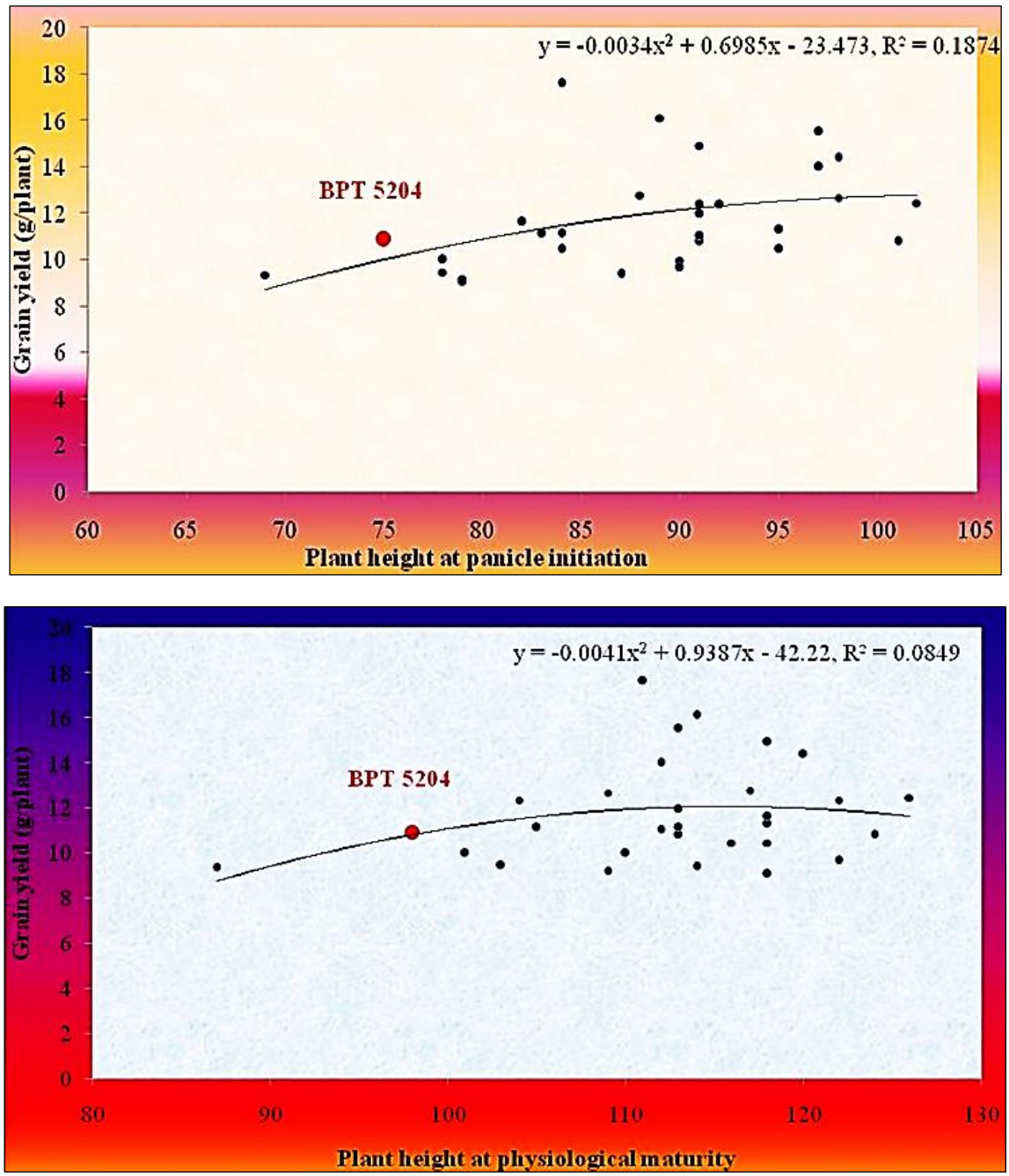

Fig 1: Relationship between plant height at different crop growth stages and grain yield.
(**Note:** Red spot denotes BPT-5204; a blue spot indicates advanced breeding lines).

1.2 Total Number of Tillers and Productive Tillers

Total number of tillers generally determines the biomass production, more the tillers per hill, more will be the biomass production. In the present study, except the released varieties including BPT-5204, all the breeding lines possess higher biomass compared to BPT-5204. The tiller number in BPT-5204 is 21 per hill as against the genotypic mean of 24 tillers per hill (Table 3). The relationship between the tiller number and biomass is not significant ($r = 0.16^{NS}$) because all the breeding lines, except four lines (SP-355, SP-360, SP-70, SP-69 significantly superior over BPT-5204) were similar medium plant height to that of BPT-5204. Therefore, it is not only the number of tillers but also tiller height is important in biomass production.

With respect to yield, it is not the total tillers per hill, but it is the effective tillers (productive tillers) are important. Direct relationship between productive tillers and grain yield has been reported with significant genotypic variations in paddy (Chaturvedi, 2004; Zahid *et al.*, 2005) [2, 10]. The ratio of effective tillers to total tillers per hill is 87.4%. Similar observation of >85% effective tillers in paddy has been documented. The mean productive tillers over the seasons were 21 per hill. The BPT-5204 had 18 tillers per hill and the breeding lines with significantly high yield possess higher productive tillers respectively. No significant relationship was observed between productive and grain yield ($r = 0.24^{NS}$) might be due to all the breeding lines are derived from same parentage although the range statistic is 23.8 per cent. However, the highest yielders had higher productive tiller number per hill (Figure 2). It appears that the productive tillers could be 23 per hill for higher productivity in derivatives of BPT-5204.

Table 3: Number of tillers and productive tillers at physiological maturity in advanced breeding lines of rice

		Number of tillers			Number of productive tillers		
S.No	**Genotypes**	**2014**	**2015**	**Pooled**	**2014**	**2015**	**Pooled**
1	SP-351	23	21	22	20	18	19
2	SP-352	26	22	24	23	19	21
3	SP-353	26	22	24	23	19	21
4	SP354	28	24	26	25	21	23
5	SP-355	23	20	21	20	17	18
6	SP-356	27	24	25	24	21	22
7	SP-357	26	22	24	23	19	21
8	SP-358	26	22	24	23	19	21
9	SP-359	25	22	24	22	19	21
10	SP-360	27	22	24	24	19	21
11	SP-70	28	24	26	25	21	23
12	SP-72	28	23	25	25	20	22
13	SP-63	27	23	25	24	20	22
14	SP-61	25	21	23	22	18	20
15	SP-69	26	23	25	23	20	22
16	SP-55	27	22	25	24	19	22
17	SP-80	28	23	25	25	20	22
18	SP-25	21	19	20	18	16	17
19	SP-13	26	22	24	23	19	21
20	SP-08	28	24	26	25	21	23
21	SP-75	28	22	25	25	19	22
22	SP-57	27	23	25	24	20	22
23	SP-03	20	18	19	17	15	16
24	SP-02	27	23	25	24	20	22
25	SP-34	28	22	25	25	19	22
26	SP-37	26	23	24	23	20	21
27	NDR-359	23	22	23	20	19	20
28	BPT-5204	22	19	21	19	16	18
29	IR-64	24	20	22	21	17	19
30	Jaya	26	22	24	23	19	21
	Mean	26	22	24	23	19	21
	SE (m)	2.69	3.52	0.87	2.10	2.45	0.72
	CD at 5%	5.50	4.02	4.27	4.31	5.01	4.42
	CV (%)	10.42	20.00	6.93	10.48	16.55	7.14

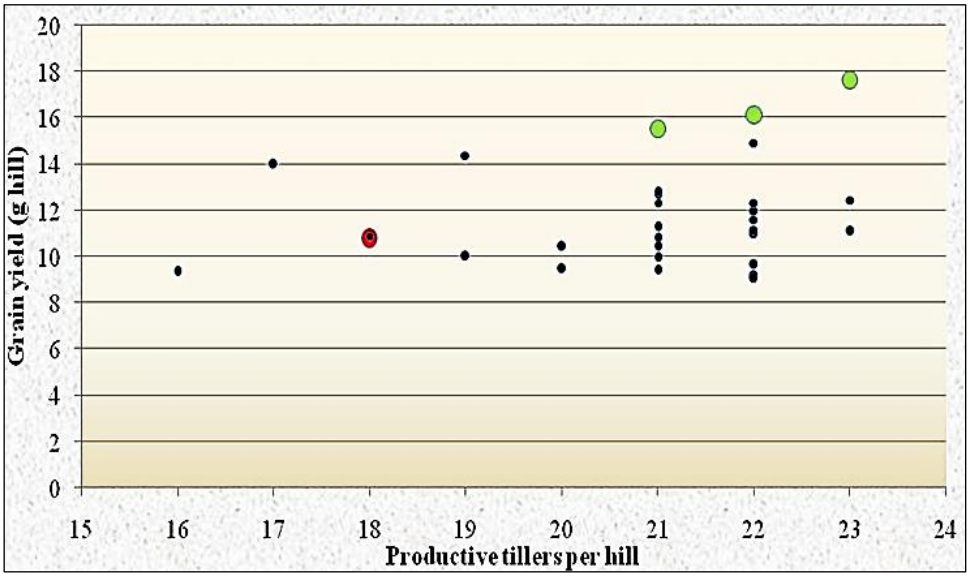

Fig 2: Relationship between productive tillers and grain yield in advanced rice breeding lines
(**Note:** Red spot denotes BPT-5204; green spots indicate SP-359, SP-72 and SP-08 from lower to higher grain yield).

2. Phenological Parameters

Rice crop phenology or duration forms the major determinant of the agro-ecological and agronomic fit of rice cultivars in to any cropping situation. The physiological age of the crop has been characterized by the formation of the various organs and their appearance (Yoshida, 1981). Based on duration of growth, rice genotypes have been classified into early duration (110-120), medium duration (125-135) and long duration (more than 150). Days to flowering and maturity of different rice varieties grown under field conditions were presented in table 4.

2.1. Days to 50% Flowering

Flowering time plays an important role in regulating the biomass of crops by affecting their duration of basic vegetative growth, and thereby grain yield. In the present study significant difference was observed for days to 50% flowering among genotypes. During first season, the genotype SP-03 and BPT-5204 (95 days and 93 days) recorded maximum values, SP-08 and SP-72 (80 days and 81 days) recorded minimum days for 50% flowering. During second season, the genotype SP-03 and BPT-5204 (97 days), recorded maximum value respectively while, SP-08 and SP-72 recorded (82 days and 83 days) minimum values. Pooled data revealed that SP-03 and BPT-5204 showed maximum value under control (96 days and 95 days). The minimum value was recorded under control and elevated temperature in the genotypes SP-08 and SP-72 (81 days and 82 days).

2.2 Days to Physiological Maturity

The crop duration was reduced under elevated temperature (Rani and Maragatham, 2007) [5]. In the present study significant difference was observed among the genotypes for days to maturity. During first season, BPT-5204 (146 days), SP-03 (145 days), SP-352 (145 days) and SP-37 (144 days) recorded maximum while, SP-08 (114 days), SP-72 (114 days) and SP-70 (117 days) recorded minimum values respectively. During second season, BPT-5204 (149 days), SP-03 (147 days), SP-352 (143 days) and SP-37 (142 days) recorded maximum value while, SP-08 (113 days), SP-72 (118 days) and SP-70 (119 days) recorded minimum values, respectively. Pooled data revealed that BPT-5204 (148 days), SP-03 (146 days), SP-352 (144 days) and SP-37 (143 days) showed maximum value while, minimum in SP-08 (114 days), SP-72 (116 days) and SP-70 (118 days) respectively. This reduction in days to maturity might be due to earliness in the flowering in the elevated temperature stress environment. Similar observations were also reported by Venkatramanan and Singh (2009) [9].

2.3 Grain Yield (t/ha)

Pooled data revealed that SP-08 (7.80tonnes ha^{-1}), SP-70 (7.68 tonnes ha^{-1}), SP-69 (7.25 tonnes ha^{-1}) and SP-72 (6.77 tonnes ha^{-1}) displayed higher grain yield compared to quality check BPT-5204 (6.20tonnes ha^{-1}) (Table 4). Such significant differences among genotypes have been reported by Renante *et al.* (2006) [6].

Table 4: Days to 50%flowering and days to physiological maturity in advanced breeding lines of rice

	Days to 50% flowering				Days to Physiological Maturity			Grain yield (tonnes ha^{-1})		
S.No	**Genotypes**	**2014**	**2015**	**Pooled**	**2014**	**2015**	**Pooled**	**2014**	**2015**	**Pooled**
1	SP-351	88	86	87	131	132	132	6.77	5.72	6.24
2	SP-352	83	86	85	145	143	144	3.66	4.89	4.27
3	SP-353	89	86	88	126	128	127	7.72	4.55	6.13
4	SP354	82	87	85	135	131	133	5.05	3.16	4.11
5	SP-355	84	87	86	127	129	128	3.77	3.91	3.84
6	SP-356	80	91	86	122	124	123	6.30	6.72	6.51
7	SP-357	86	86	86	124	126	125	6.23	6.44	6.39
8	SP-358	85	86	85	141	140	140	5.11	3.27	4.19
9	SP-359	87	90	89	139	136	138	5.50	6.00	5.75
10	SP-360	83	90	87	120	121	121	7.11	4.33	5.97
11	SP-70	83	88	86	117	119	118	6.89	6.66	6.77
12	SP-72	80	82	81	114	118	116	7.85	7.50	7.68
13	SP-63	82	84	83	119	121	120	4.72	4.33	4.52
14	SP-61	86	94	90	142	142	142	4.66	4.11	4.47
15	SP-69	92	87	90	125	126	126	7.55	6.95	7.25
16	SP-55	82	89	86	128	130	129	5.55	3.89	4.72
17	SP-80	82	88	85	124	125	125	7.50	5.22	6.36
18	SP-25	82	88	85	124	126	125	6.83	4.05	5.44
19	SP-13	86	87	87	120	124	122	5.77	5.33	5.05
20	SP-08	81	83	82	114	113	114	7.94	7.66	7.80
21	SP-75	84	85	85	120	122	121	3.39	5.67	4.53
22	SP-57	84	88	86	128	130	129	4.77	3.89	4.33
23	SP-03	95	97	96	145	147	146	6.50	6.77	6.64
24	SP-02	86	88	87	143	142	142	6.20	6.22	6.21
25	SP-34	84	95	90	140	141	140	4.44	4.05	4.25
26	SP-37	81	84	83	144	142	143	6.13	6.12	6.11
27	NDR-359	82	90	86	125	122	124	6.23	6.25	6.24
28	BPT-5204	93	97	95	146	149	148	6.28	6.11	6.20
29	IR-64	84	87	86	130	132	131	4.44	5.00	4.72
30	Jaya	91	85	88	134	132	133	3.56	3.86	3.71
	Mean	84	88	86	126	127	126	5.19	4.61	4.87
	SE (m)	6.65	6.18	5.64	10.28	11.28	9.41	4.56	6.02	9.45
	CD at 5%	8.91	4.13	6.26	21.04	20.44	18.76	7.56	2.31	4.87
	CV (%)	18.23	12.64	14.29	5.70	5.62	4.25	2.49	4.59	6.04

Conclusion

Mean plant height was increased by 44.3% from active tillering to panicle initiation stage and then by 28.4%. Most of the genotypes show significantly superior plant height over the BPT-5204 at active tillering and panicle initiation stage. While at physiological maturity, a few genotypes SP-70 (126 cm), SP-355 (124 cm), SP-69 (122 cm), SP-360 (122 cm) and SP-351 (120 cm) were superior to BPT-5204. Number of

tillers per plant was maximum in SP-08 and SP-70 (23) as compared to BPT-5204 (18).

Among the duration groups, the short duration (116 to 122 days) lines were SP-08, SP-72, SP-70 and SP-69. The medium duration (125 to 133 days) lines, SP-351, SP-353, SP-355, SP-357, SP-80 and SP-25 and long duration (140 to 148 days) lines, SP-02, SP-03 and SP-37 found superior in terms of grain yield as compared to their respective check varieties. Two advanced breeding lines namely SP-08, SP-70 can be further probed thoroughly for further increasing yield and yield attributes.

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