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Characterization of Dry Matter Partition with Grain Yield in Advanced Breeding Lines of Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author DDK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors DVVR and MSM managed the analyses of the study. Authors PRR and VGS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The experimental field was laid in RBD replicated thrice with 30 high yielding rice genotypes which includes 26 advanced breeding lines (ABL) (SP-351, SP-352, SP-353, SP-354, SP-355, SP-356, SP-357, SP-358, SP-359, SP-360, SP-70, SP-72, SP-63, SP-61, SP-69, SP-55, SP-80, SP-25, SP-13, SP-03, SP-02, SP-34, SP-37, SP-08, SP-75 and SP-57) and four checks (NDR-359, BPT-5204, IR-64, Jaya). Seven genotypes showed significantly higher leaf weight over the BPT-5204. Further,

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leaf weight at panicle initiation stage showed a positive relationship with TDM (Total Dry Matter) (r=0.51**). At the panicle initiation stage, only three genotypes (SP-354, SP-358, and SP-72) were superior to BPT-5204 in leaf weight. The shoot biomass and total dry weight was superior only in one genotype SP-72 as compared to BPT-5204. Similarly, the net assimilation rate at panicle initiation stage was maximum in SP-08 (9.92g m^{-2} day^{-1}) and SP-72 (9.35g m^{-2} day^{-1}) as compared to check BPT-5204 (6.47g m^{-2} day^{-1}). These genotypes maintained higher photosynthetic rate (SP-72) and higher grain yield (SP-08). The relationship between CGR (Crop Growth Rate) and TDM (Total Dry Matter) and grain yield (r=0.61**) was positive and significant at physiological maturity. Genotypes SP-08 and SP-72 showed significantly higher CGR (Crop Growth Rate) over BPT-5204 and hence, yielded higher. In the present study compared to BPT-5204, genotypes SP-72, SP-08 maintained higher lea area index at all crop growth stages. These genotypes maintained higher photosynthetic rate (SP-72) and higher grain yield (SP-08). Positive significant relationship between LAI (Leaf Area Index) and total dry matter at harvest and; grain yield has been observed.

Keywords: Total dry matter; crop growth rate; grain yield; advanced breeding lines; rice (Oryza sativa).

1. 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 crop 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 a necessity to increase the 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. Rice (*Oryza sativa* L.) is the staple food of mankind and provides 35%–60% of the dietary calories consumed by three billion people, making it inarguably the most important crop worldwide [1]. The demand for increasing rice production is particularly urgent, because the population of traditional rice-producing countries will require 70% more rice by 2025 [2]. 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} [3]. In A.P area 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%), the rice requirement of India by 2025 would be around 125 mt [4]. Therefore 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 a premium quality aromatic and light weight rice. Due to its excellent grain character, the variety is being regularly used in hybridization programmes to meet current breeding objectives. Therefore, the 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 [5].

2. MATERIALS AND METHODS

2.1 Destructive Analysis

Five adjacent hills from each plot were pulled carefully from the third row at active tillering, panicle initiation, and physiological maturity and they were brought to the laboratory and separated in to different components *viz.,* leaves, stems and roots for generating the following data.

2.2 Dry Matter Assimilation

Dry matter of the plant was recorded at fortnightly interval by uprooting of 5 hills in the third row of every plot. Component parts were separated after shade drying, the samples were subjected to 70°C temperature in a hot air oven till constant weights were obtained and expressed as g m^{-2}.

2.3 Grain Yield Per Plant

The grain yield per plant of five healthy plants was counted and mean values were worked out.

2.4 Grain Yield (Tonnes ha^{-1})

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

3. RESULTS AND DISCUSSION

3.1 Dry Matter Accumulation

Dry matter accumulation and its components were observed at different crop growth stages (Tables 1, 2, and 3).

3.1.1 Dry matter accumulation at active tillering stage

Dry matter accumulation and its components were observed at different crop growth stages at the active tillering stage (Table 1). The pooled leaf weight was highest in genotype SP-72 (76.0 g m^{-2}, Table 1) which was superior over BPT-5204 (63.0 g m^{-2}). Leaf weight showed a positive relationship with TDM (r=0.51*) but with a poor relationship with grain yield (r=0.09^{NS}). The genotypic differences in leaf weight may be due to the differences in the anatomical structure of leaves such as the shape of chloroplasts, clumpy vacuoles that change the structural organization of thylakoids and form antenna-depleted PS II [6].

Pooled stem dry weight revealed that SP-72 (380 g) and SP-358 (318 g) displayed the maximum stem dry weight comparing with the check BPT-5204. The minimum stem dry weight was recorded by NDR-359 and Jaya (200 g and 204 g).

Root dry weight at tillering stage was superior in most of the genotypes over the BPT-5204 (Table 1). Although the root characteristics are genetically controlled, they are strongly affected by soil conditions and crop management practices [7]. The rice root system under aerobic condition has the unique property of transformation of ammonia into nitrate. On the other hand, elongated roots favoured nutrient uptake and translocation, which could increase photosynthetic rate. The photosynthates which were re-translocated to the roots could lead to greater root activity and dry weight [8]. In recent times, root studies have been emphasized towards achieving the second green revolution [9]. With respect to total dry matter, the genotypes SP-72 (511 g) and SP-358 (424 g) showed maximum compared to check BPT-5204.The ultimate partitioning of dry matter between grain and vegetative parts is indicated by the grain-to-straw ratio or harvest index (HI). It is one of the yield determining factors. The partitioning of dry matter to grain and straw varied among the genotypes [10].

3.1.2 Dry matter accumulation at panicle initiation stage

In the present study, significant differences in dry matter and its components were observed among the genotypes at panicle initiation stage (Table 2).

Pooled data revealed that SP-72 (130 g) and SP-358 (125 g) showed maximum leaf dry weight in BPT-5204. This difference in leaf weight might be due to differences in anatomical structure of leaves such as the shape of chloroplasts and clumpy vacuoles, which results in differences in photosynthetic and respiratory activities [6]. Similar results about changes of leaf dry weight under nitrogen fertilizer application were reported by Bannayan et al. [11]. More length of vegetative growth, to a certain extent, the more LAI (Leaf Area Index) is produced, absorbs more solar radiation, more photosynthesis, and ultimately leads to higher yield. One of the most important growth indicators which are used as a measure of dry matter accumulation in leaf is leaf dry weight. The curve of leaf dry weight is sigmoid and over time, the growth of leaves is increased and at the end of the growth season it is reduced because of senescence and abscission.

Pooled data revealed that, stem dry weight at panicle initiation stage was highest in SP-72 (567 g) and SP-358 (473 g) as compared to the check BPT-5204.

The genotypes SP-72 and SP-358 recorded maximum root dry weight compared to quality check BPT-5204 at panicle initiation stage in both seasons and pooled. Pooled data revealed that SP-72 (86 g) and SP-358 (83 g) displayed maximum root dry weight compared to the quality check BPT-5204. In terms of root weight, no genotype was significant superior over the BPT-5204, suggesting that, as rice is cultivated with adequate irrigations, no difference in root weight was observed (Table 2).

Table 1. Dry weight of leaves, shoots, root, and total dry weight (g m^{-2}) at active tillering in advanced breeding lines of rice

		Active Tillering (g m^{-2})											
S. No	Genotypes	Leaf			Shoot			Root			Total Dry Weight		
		2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
1	SP-351	64	71	67	245	261	253	48	52	50	358	383	371
2	SP-352	61	67	64	233	249	241	35	38	36	328	354	341
3	SP-353	69	75	72	289	305	297	25	29	27	383	409	396
4	SP354	77	59	68	182	208	195	35	51	43	294	318	306
5	SP-355	57	63	60	310	326	318	41	44	43	407	433	420
6	SP-356	70	76	73	300	316	308	47	51	49	417	443	430
7	SP-357	69	76	73	248	264	256	34	38	36	352	378	365
8	SP-358	81	87	84	310	326	318	52	55	54	424	450	437
9	SP-359	68	74	71	233	249	241	47	50	48	347	373	360
10	SP-360	61	67	64	235	251	243	42	45	43	338	363	350
11	SP-70	65	71	68	300	316	308	33	37	35	399	424	412
12	SP-72	85	91	88	372	388	380	54	57	56	511	536	523
13	SP-63	73	80	76	256	272	264	49	52	50	377	403	390
14	SP-61	66	72	69	243	259	251	43	47	45	353	378	365
15	SP-69	63	69	66	270	286	278	39	42	40	371	397	384
16	SP-55	61	68	64	248	264	256	37	40	39	346	371	359
17	SP-80	68	74	71	248	264	256	41	44	43	357	383	370
18	SP-25	67	74	71	247	263	255	40	44	42	355	380	368
19	SP-13	66	73	69	297	313	305	44	48	46	407	433	420
20	SP-08	64	71	67	243	259	251	43	47	45	351	376	363
21	SP-75	61	67	64	272	288	280	33	36	35	385	411	398
22	SP-57	69	75	72	254	270	262	46	49	47	369	394	381
23	SP-03	61	67	64	290	306	298	39	42	40	389	415	402
24	SP-02	64	70	67	233	249	241	41	45	43	338	364	351
25	SP-34	64	71	67	247	263	255	48	51	50	359	385	372
26	SP-37	67	74	70	309	325	317	49	52	50	425	451	438
27	NDR-359	55	61	58	192	208	200	25	28	27	272	298	285
28	BPT-5204	60	66	63	210	226	218	34	37	36	303	329	316
29	IR-64	67	73	70	178	194	186	36	39	38	281	307	294
30	Jaya	57	63	60	196	212	204	31	35	33	285	310	297

S. No	Genotypes	Active Tillering ($g\ m^{-2}$) Leaf			Shoot			Root			Total Dry Weight		
		2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
	Mean	66	71	69	256	273	264	40	44	42	363	388	375
	SE (m)	9.39	9.56	4.65	61.28	60.48	68.78	10.30	10.38	3.21	70.63	70.72	74.37
	CD at 5%	19.21	19.57	9.22	125.34	120.68	117.3	21.07	21.23	6.37	144.47	144.65	128.46
	CV (%)	10.07	9.46	8.30	16.90	15.68	14.06	18.03	16.62	9.32	13.77	12.88	14.68

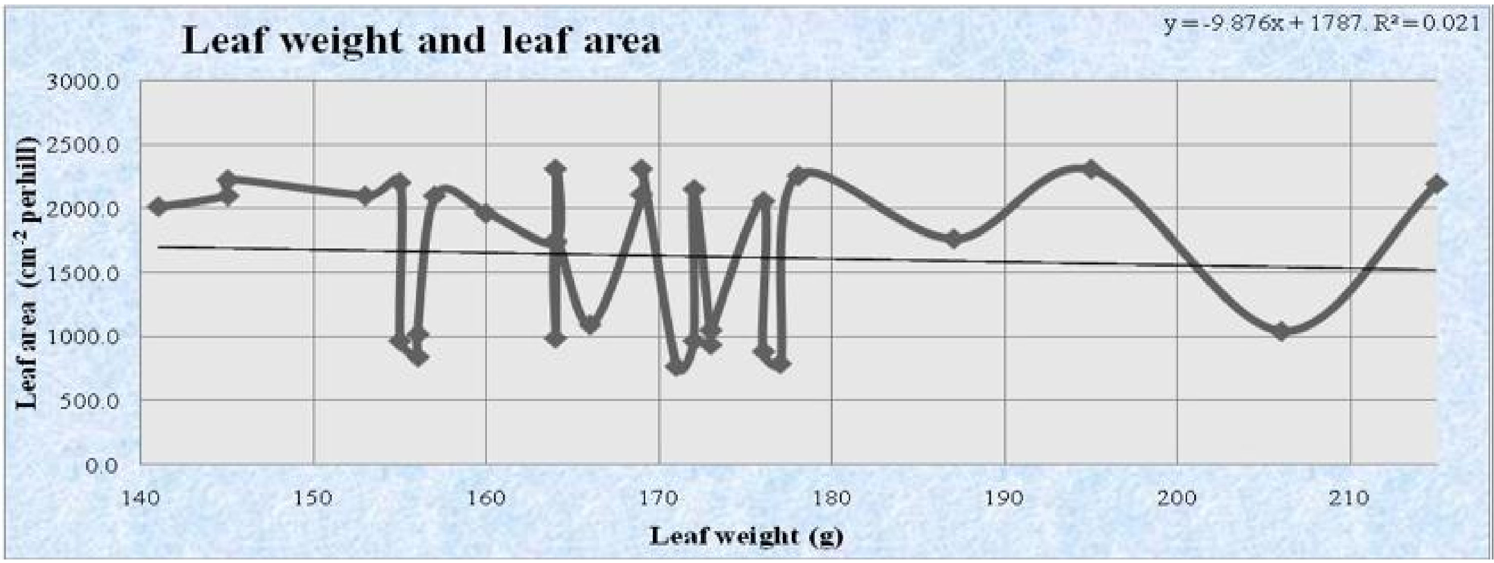

Fig. 1. Leaf dry weight and leaf area cm^{-2} per hill of advanced breeding lines of rice

Pooled data of total dry matter production at panicle initiation stage over the seasons revealed that SP-72(783 g) and SP-358 (653 g) displayed maximum total dry weight compared to the quality check BPT-5204. The minimum total dry weight was recorded by NDR-359 and Jaya (426 g and 444 g). This higher dry matter accumulation in these genotypes (SP-72, SP-358) is due to their superior leaf dry weight (Table 2).

3.1.3 Dry matter accumulation at physiological maturity stage

In the present study, significant differences were observed among the genotypes at the physiological maturity stage for dry matter and its components (Table 3). In both seasons' genotypes, SP-72and SP-358 recorded maximum leaf dry weight compared to the quality check BPT-5204. Pooled data revealed that SP-72 (215 g) and SP-358 (206 g) showed maximum leaf dry weight under control BPT-5204.

Similar to leaf dry weight, the stem dry weight was also high in genotypes in SP-72 and SP-358 in both seasons and the pooled data revealed that SP-72 (935 g) and SP-358 (780 g) displayed maximum stem dry weight compared to BPT-5204. The differences in shoot dry weight could be due to the differential performance of genotypes to a given weather condition as observed in the case of maize, pearl millet, and sugarcane [12]. The shoot and TDM was superior only in one genotype SP-72 as compared to BPT-5204. The shoot dry matter and TDM are directly related (r=0.90**) (Fig. 2).

Root dry weight was highest in genotype, SP-72 (135 g) and SP-358 (130 g) compared to the quality check BPT-5204. Pooled data revealed that SP-72(139 g) and SP-358 (134 g) displayed maximum root dry weight compared to the quality check BPT-5204. Maximum panicle dry weight of pooled data revealed the highest in SP-72 (453 g) and SP-358 (444 g) compared to BPT-5204. Genotype SP-72 (1742 g) displayed maximum total dry weight compared to the quality check BPT-5204.

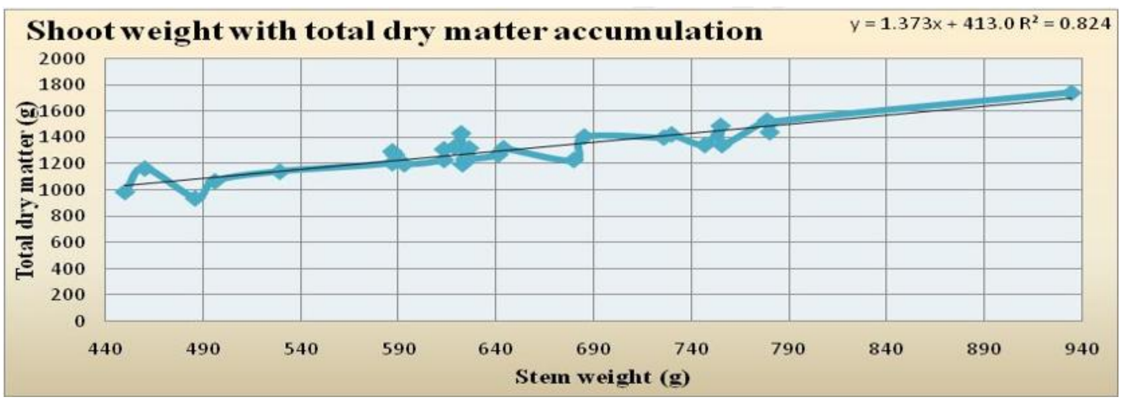

Fig. 2. Shoot dry weight with total dry matter accumulation of advanced breeding lines of rice

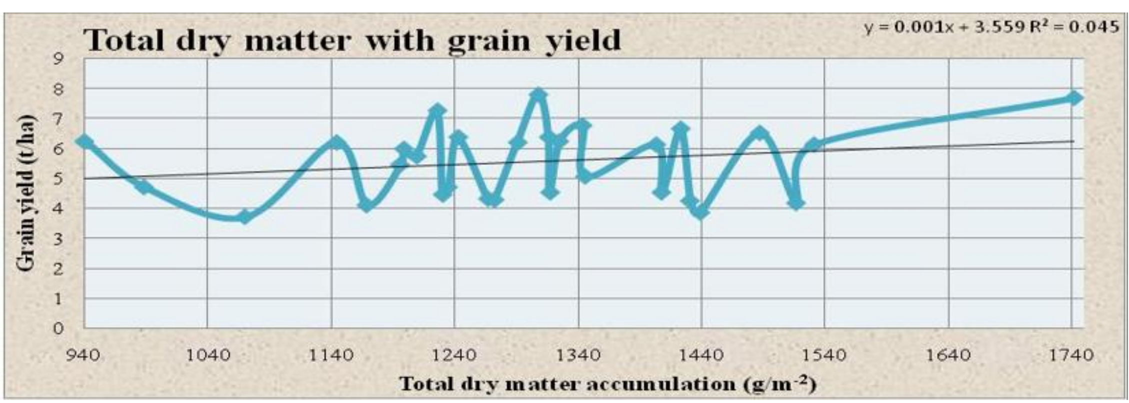

Fig. 3. Total dry weight accumulation and grain yield (t/ha) of advanced breeding lines of rice

Table 2. Dry weight of leaf, shoot, root and total dry weight (g m^{-2}) at panicle initiation in advanced breeding lines of rice

S. No	Genotypes	Panicle Initiation (g m^{-2})											
		Leaf			Shoot			Root			Total Dry Weight		
		2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
1	SP-351	96	103	100	368	385	377	72	83	77	537	571	554
2	SP-352	91	98	94	350	367	358	52	62	57	492	526	509
3	SP-353	104	110	107	433	450	441	38	48	43	574	608	591
4	SP354	115	122	118	273	290	281	53	63	58	441	475	458
5	SP-355	85	92	88	465	482	473	61	72	67	611	645	628
6	SP-356	105	111	108	450	467	459	71	81	76	626	660	643
7	SP-357	104	111	107	372	389	381	52	62	57	528	562	545
8	SP-358	121	128	125	465	482	473	78	89	83	636	670	653
9	SP-359	102	108	105	349	366	358	70	80	75	521	555	538
10	SP-360	91	98	94	353	370	361	63	73	68	506	540	523
11	SP-70	98	104	101	450	467	459	50	60	55	598	632	615
12	SP-72	127	134	130	558	575	567	81	91	86	766	800	783
13	SP-63	110	116	113	383	400	392	73	83	78	566	600	583
14	SP-61	99	106	102	365	382	373	65	76	70	529	563	546
15	SP-69	94	101	97	405	422	414	58	68	63	557	591	574
16	SP-55	92	98	95	371	388	380	55	66	61	519	553	536
17	SP-80	102	108	105	373	390	381	62	72	67	536	570	553
18	SP-25	101	108	104	370	387	379	61	71	66	532	566	549
19	SP-13	99	106	103	445	462	454	66	77	71	611	645	628
20	SP-08	96	103	100	365	382	373	65	75	70	526	560	543
21	SP-75	92	98	95	408	425	416	50	60	55	577	611	594
22	SP-57	103	110	106	381	398	390	68	79	74	553	587	570
23	SP-03	91	98	95	435	452	443	58	68	63	584	618	601
24	SP-02	96	103	100	349	366	357	62	72	67	507	541	524
25	SP-34	96	103	100	370	387	379	72	82	77	539	573	556
26	SP-37	101	107	104	464	481	473	73	83	78	638	672	655
27	NDR-359	83	89	86	289	306	297	38	48	43	409	443	426
28	BPT-5204	89	96	93	314	331	323	51	61	56	455	489	472
29	IR-64	100	107	104	267	284	276	54	65	59	422	456	439
30	Jaya	85	92	88	295	312	303	47	57	52	427	461	444

		Panicle Initiation (g m^{-2})											
S. No	Genotypes	Leaf			Shoot			Root			Total Dry Weight		
		2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
	Mean	99	106	102	384	401	393	61	71	66	544	578	561
	SE (m)	14.09	14.09	16.82	91.93	90.45	98.69	15.45	16.45	15.89	105.9	109.55	118.3
	CD at 5%	28.82	24.65	23.51	188.0	183.2	187.2	31.61	38.76	31.66	216.7	219.97	236.2
	CV (%)	10.07	9.43	8.17	16.90	16.19	15.17	18.03	15.41	16.96	13.77	12.96	14.00

Table 3. Dry weight of leaves, shoots, root, and total dry weight (g m^{-2}) at physiological maturity in advanced breeding lines of rice

		Physiological Maturity (g m^{-2})														
S. No	Genotypes	Leaf			Shoot			Root			Panicle Dry Weight			Total Dry Weight		
		2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
1	SP-351	160	168	164	613	624	619	121	128	124	414	421	418	1308	1341	1325
2	SP-352	152	159	155	583	593	588	87	94	90	435	442	438	1256	1288	1272
3	SP-353	173	180	176	721	732	726	63	71	67	429	436	433	1387	1419	1403
4	SP354	192	199	195	455	465	460	88	96	92	419	426	422	1153	1185	1169
5	SP-355	142	149	145	775	785	780	102	110	106	404	411	407	1422	1455	1439
6	SP-356	174	182	178	750	760	755	118	126	122	428	435	432	1471	1503	1487
7	SP-357	173	181	177	621	631	626	86	94	90	420	427	423	1300	1332	1316
8	SP-358	202	210	206	775	785	780	130	138	134	441	448	444	1501	1533	1517
9	SP-359	169	177	173	582	593	587	117	124	120	325	332	328	1193	1225	1209
10	SP-360	151	159	155	588	598	593	104	112	108	339	346	343	1183	1215	1199
11	SP-70	163	170	166	751	761	756	83	91	87	331	338	335	1328	1360	1344
12	SP-72	212	219	215	930	940	935	135	143	139	449	456	453	1726	1758	1742
13	SP-63	183	190	187	639	649	644	121	129	125	357	364	361	1301	1333	1317
14	SP-61	165	172	169	608	618	613	109	116	112	332	339	336	1214	1246	1230
15	SP-69	157	164	160	675	686	680	97	104	100	282	289	285	1210	1242	1226
16	SP-55	153	160	157	619	629	624	92	100	96	355	362	358	1219	1251	1235
17	SP-80	169	177	173	621	631	626	103	110	106	334	341	337	1226	1259	1243
18	SP-25	168	176	172	617	628	623	101	109	105	293	300	297	1180	1212	1196
19	SP-13	166	173	169	742	752	747	111	118	114	312	319	316	1330	1362	1346
20	SP-08	160	168	164	608	618	613	108	116	112	415	422	419	1292	1324	1308
21	SP-75	153	160	156	679	690	685	83	90	87	430	437	433	1392	1424	1408
22	SP-57	172	179	176	635	646	641	114	122	118	329	336	333	1251	1283	1267

S. No	Genotypes	Physiological Maturity (g m^{-2})														
		Leaf			Shoot			Root			Panicle Dry Weight			Total Dry Weight		
		2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
23	SP-03	152	160	156	725	735	730	97	104	100	434	441	437	1407	1439	1423
24	SP-02	160	168	164	582	592	587	103	111	107	430	437	433	1275	1307	1291
25	SP-34	161	168	164	617	627	622	120	128	124	517	524	520	1414	1447	1431
26	SP-37	168	175	172	773	784	779	121	129	125	452	459	455	1514	1547	1531
27	NDR-359	138	145	141	481	491	486	63	70	67	242	249	246	923	956	940
28	BPT-5204	149	156	153	524	534	529	85	93	89	370	377	373	1128	1160	1144
29	IR-64	167	174	171	445	455	450	90	98	94	269	276	273	972	1004	988
30	Jaya	142	149	145	491	502	496	79	86	82	342	349	346	1053	1086	1070
	Mean	165	172	169	641	651	646	101	109	105	378	385	381	1284	1317	1300
	SE (m)	23.48	23.56	29.94	153.21	159.56	156.06	25.76	22.56	27.56	92.35	90.76	93.90	232.01	243.92	220.95
	CD at 5%	48.03	46.23	49.69	313.36	318.44	312.02	52.68	50.89	54.98	188.8	180.4	187.73	474.61	493.67	441.50
	CV (%)	10.07	9.64	7.22	16.90	16.63	15.14	18.03	16.76	18.84	17.29	16.97	15.25	12.77	12.96	11.97

4. CONCLUSION

These genotypes maintained higher photosynthetic rate (SP-72) and higher grain yield (SP-08). Amanullah et al [13] reported that the increase in leaf area index (LAI) increases light interception and so more TDM production occurres at various growth stages. The relationship between CGR (Crop Growth Rate) and leaf weight, shoot weight, TDM (Total Dry Matter), and grain yield (r=0.61**) was positive and significant at physiological maturity. Genotypes, SP-08 and SP-72 showed significantly higher CGR (Crop Growth Rate) over BPT-5204 and hence, yielded higher. The higher DM partitioning to panicles at PDM indicates the more translocation of assimilates from the leaves and culms to the panicles during the grain filling period, resulting in higher grain yield [14].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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