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Agro-morphological Variation in 71 Traditional Rice Cultivars in Sri Lanka

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This work was carried out in collaboration among all authors. Author ALR designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author ALR managed the literature searches, and authors MJH, NGJP and GWDKJ managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

Traditional rice cultivars in Sri Lanka have diverse characteristics that prove the excellent potential for utilizing them for varietal improvement. Seventy-one Sri Lankan traditional rice cultivars obtained from Plant Genetic Resources Center, Gannoruwa, Sri Lanka were used for diversity analysis. Data were collected in the middle-row-plants of each replicate and altogether 80 plants were evaluated in four replicates of each cultivar. Data were collected on 11 parameters in two consecutive *Maha* seasons in 2012-2014. According to the standard evaluation system of international rice research institute, 67% rice cultivars were tall, and 66% were low tillering. There was no any rice cultivar with high and good reproductive tillers/plant. Around 55% rice cultivars were partially sterile and 43% were fertile. The shortest days to maturity was recorded in *Gonabaru* (62 days) and the longest days to maturity was recorded in *Vellainellu* (105 days).
The variation of agro-morphological characteristics was broad in studied rice cultivars: The recorded highest yield was 22.74 g/plant while the lowest was 1.55 g/plant. The hundred-grain-

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weight ranged from 3.49-1.27 g and the plant height ranged from 95-192 cm. The recorded highest number of total tillers per plant was 10 and the lowest was 3. Panicle length and panicle weight were ranged from 13-32 cm and 0.36-4.69 g consecutively. The smallest grains were in *Herath* and the largest grains were in *Mudaliwi*. The heaviest above ground biomass was achieved by *Kallurundoivellai* and its harvest index was the least (0.09). The highest filled grain percentage (91.48%) was recorded by *Galpa Wee*.

The correlation analysis revealed that the yield per plant was significantly correlated with panicle weight, the total number of spikelets/panicle and number of fertile spikelets/panicle. There was no correlation between panicle length and the final yield of rice though panicle length was correlated with plant height and panicle weight. Total number of spikelets/panicle, the number of fertile spikelets/panicle, and plant height were significantly correlated with panicle weight. None of the parameters were correlated with hundred grain weight. Total biomass was correlated with plant height, the total number of spikelets, and fertile spikelets per panicle. There was no significant correlation between the biomass of rice with the final yield, however, a number of fertile tillers were correlated with a number of total tillers.

Eleven parameters were sorted into four principal components that explained 87.44% of total variance and cluster analysis categorized the rice cultivars into six clusters at rescaled cluster distance 10 in Ward's linkage analysis.

Keywords: Agro-morphological characteristics; cluster analysis; principal components; Sri Lanka; traditional rice.

1. INTRODUCTION

Rice is the most important staple food that provides dietary energy and nutrition for more than half of the world's population especially in Asia, North and South America, and in Africa [1]. Wheat and maize are the other most important energy supplementary crops for the world population [2].

Characterization of individuals in the germplasm is the primary goal to provide information for plant breeding programs for broadening the prevailing genetic base in Rice [3]. Many studies have been carried out for germplasm utilization in rice for breeding purposes [4,5,6,7]. Further, analyzing genetic and morphological differentiation [8] distinguishing diversity [9,10], assessing variability in agronomic characters among landraces [11], evaluating genetic relationships among landraces [12] and characterizing rice genotypes adapted to specific environment conditions [13,14,15,16], are also important aspects in the field of evolutionary, functional and ecological biology.

Li et al., [8] evaluated the correlation between *Japonica* and *Indica* sub-species using 111 accessions and reported the prevalence of variance among two sub-species. In a study that examined 5285 accessions, Yawen et al., [10] reported a broad genetic and morphological variation in Chinese traditional rice gene pool. The same has been reported in India analyzing the diversity of upland rice cultivars [9] and in Vietnam in a case study of aromatic land races [11] SSR markers have been utilized to dissect the genetic diversity of landraces in Nepal [12]. A set of salt tolerant rice genotypes originated in different locations such as India, Philippines, and Nicobar Island has been analyzed with SSR markers and characterized based on their morphological descriptors [13]. The diversity not only in *Oryza sativa* species, but also in *Oryza rufipogon* Griff. has also been dissected by Yibo et al., [14].

Traditional rice cultivars in Sri Lanka have a broad genetic variance [17,18,19] to be utilized for varietal improvement. Some traditional rice cultivars of Sri Lanka have been evaluated for salinity tolerance, submergence tolerance and drought tolerance [15,20]. Further, the response of some traditional rice cultivars for different rates of fertilizer applications [21] and their allelopathic potential [22] have been evaluated at the field conditions. Changes of yield and yield related agro-morphological characteristics of some traditional rice cultivars at *Yala* and *Maha* seasons revealed the possibility of selecting rice cultivars for the particular season based on their field performances [23]. Study on flowering time locus amplified by SSR marker RM248 and Silver stained in Polyacrylamide gel showed different allele types in RM 248 locus showing a great diversity in the particular locus among the studied traditional rice cultivars [24]. The present study dissects the diversity of a different set of traditional rice cultivars of Sri Lanka those have not been studied so far, using principal component analysis, cluster analysis, and Ward's morphological dendrogram.

2. MATERIALS AND METHODS

Seventy-one Sri Lankan traditional rice cultivars obtained from plant genetic resources center (PGRC), Gannoruwa, were used for this study [25].

The study was carried out at the Faculty of Agriculture, University of Ruhuna, Mapalana, Sri Lanka (latitude 6°54' 0" N, longitude 79°54' 0" E). Seeds of rice cultivars were germinated and maintained in the nursery beds for two weeks. Two weeks old seedlings were transplanted in the field in *Maha* season 2012/2013 and *Maha* season 2013/2014.

The experiment was carried out according to a randomized complete block design with four replications and 3 rows were included into each replicate. Each row consisted of 20 plants. Plants were established in rows with 15 cm X 20 cm spacing. The basal dressing was applied before planting and the top-dressing was applied two times at 2 weeks after planting and at 8 weeks after planting. Fertilizer application was as follows; Urea 50 kg/ha, Triple Super Phosphate (TSP) 62.5 kg/ha, Muriate of potash (MOP) 50 kg/ha as the basal dressing, at the time of sowing and urea 37.5 kg/ha was applied as a top-dressing. Data were collected on: plant height (cm), number of tillers per plant, number of fertile tillers per plant, panicle length (cm), panicle weight (g), number of spikelets per panicle, number of fertile spikelets per panicle, 100-grain weight (g) yield per plant (g) and biomass (g) in the middle line of each replicate according to the standard evaluation system (SES) for rice (IRRI, 1996). Altogether 80 plants were evaluated in four replicates of each cultivar.

Grouping traditional rice accessions were done according to SES, IRRI (IRRI, 1996). Rice plants were classified as semi-dwarf (<110 cm), intermediate (110 – 130 cm) and tall (>130 cm) varieties according to their height, and as very low (<5), low (5 – 9), medium (10 – 19), good (20 – 25), and very high tillering (>25) according to the number of tillers present in a plant. Rice accessions were grouped according to spikelet fertility: completely sterile (0%), highly sterile (50% to trace), partially sterile (50-74%), fertile (75-90%), highly fertile (>90%). Age of rice cultivars was determined as moderate maturity (60-74), late-maturity (75–89), and very late maturity (90–105) according to the time took for 80% of the grains on the panicles to be fully ripened.

Correlation analysis was carried out to understand the relationship between the trait and the yield of rice cultivars. Principal component analysis was used to identify the underlying sources of morphological variability. Cluster analysis was performed using the IBM SPSS 20 statistical software [26] to create a dendrogram to observe the clusters of rice cultivars with similar agro-morphological characteristics.

3. RESULTS AND DISCUSSION

Studied rice cultivars recorded a wide variation in evaluated characteristics (Table 1). *Thanthiri Balan* produced the highest yield (22.74 g/plant) and *Heenati 309* produced the lowest yield (1.55 g/plant). The highest 100-grain weight (3.49 g) was recorded by the cultivar *Mudaliwi* and the lowest 100-grain weight (1.27 g) was recorded by *Herath*. Among rice cultivars, the lowest plant height was recorded by *Kalu Bala wee* (95 cm) while the highest plant height was recorded by *Kallurundoi Vellai* (191 cm). *Polayla-3071, Bathkiri-el* and *Manamalaya* recorded the highest number of total tillers (10/plant) and *Yakada wee, Papaku, Rathkara, Maha Sudu wee, Masuran,* and *Thavalu* recorded the lowest number of tillers per plant (3/plant). Among them, *Yakada wee* had the lowest number of fertile tillers/plant (2 tillers/plant) and *Manamalaya* and *Bath Kiri El* had the highest number of fertile tillers/plant (8 tillers/plant). Though all the tillers in *Randhunipagal* were fertile the lowest filled grain percentage (53.33%) was also reported in the same.

Panicle length of the cultivars ranged from 13 cm (*Kalu Bala wee*) to 32 cm (*Galkatta*) while panicle weight ranged from 0.36 g (*Polayal*-3639) to 4.69 g (*Galkatta*). *Thanthiri Balan* produced both the highest total number of spikelets (326) and a total number of fertile spikelets per panicles (219) while *Kalubala Wee* produced the lowest number of total spikelets (36) and the lowest number of fertile spikelets per panicle (26). The recorded highest filled grain percentage (91.48%) was in *Galpa Wee*. Over 85% filled grain percentages were recorded by *Gonabaru* (86.19), *Kirikara* (86.28%), *Heen Wee* (88.5%), and *Dena Wee* (89.72). Based on the hundred grain weight, the smallest seeds could be seen in *Herath* (1.27 g), while the largest seeds were in *Mudali wee* (3.49 g).

Table 1. Agro-morphological characteristics of traditional rice cultivars

Accession No	Name	DF	PH	NTT	NFT	PL	PW	TNS	SPP	HGW	FGP	YLD	BM	HI
2203	*Dik Wee*	90	123.8	4	3	24.21	1.89	145	122	2.26	83.71	5.12	9.37	0.55
2340	*Weda Heenati*	81	132.67	5	4	20.4	0.91	70	54	1.93	77.43	14.46	15.18	0.95
2349	*Mas Samba*	88	154	5	5	24	3.08	146	111	2.8	75.17	8.23	16	0.51
2866	*Randhunipagal*	86	160	8	8	28	1.37	215	115	2.09	53.33	6.14	33.3	0.18
3071	*Polayal*	84	124	10	5	26	2.14	179	117	1.67	65.3	13.38	16.77	0.8
3072	*Thanthiri Balan*	101	187	6	6	28	4.6	326	219	2.37	67.18	22.74	41.06	0.55
3131	*Dahanala 2014*	87	149	5	4	21.53	1.7	91	74	2.5	81.95	4.95	14.37	0.34
3132	*Heenati 309*	81	121.5	4	3	21.08	1.38	84	63	2.22	77.61	1.55	11.25	0.14
3136	*Pachchaiperumal 2462-11*	68	119	4	3	16	1.42	85	63	2.1	73.53	2.07	6.28	0.33
3146	*Dewaredderi*	78	175	5	5	30	2.57	121	77	2.4	63.46	5.58	24.69	0.23
3158	*Kalubala Wee*	83	95	6	6	13	0.43	36	26	1.83	72.9	2.34	8.12	0.29
3160	*Valihandiram*	73	115	5	5	20	1.01	50	29	2.54	58.28	2.88	8.82	0.33
3161	*Heen Wee*	81	141	5	3	18.86	1.16	61	54	2.5	88.5	3.31	17.7	0.19
3170	*SuduBala Wee*	75	101.25	5	4	19	2.23	112	86	2.44	76.91	13.66	17.99	0.76
3191	*Heendik Wee*	90	138.67	5	4	22.25	1.33	75	58	2.78	77.19	1.62	16.18	0.1
3195	*Gallkatta*	77	142	6	5	32	4.69	179	131	3.24	73	16.08	16.35	0.98
3197	*Nanduheenati*	90	157.14	5	4	23.71	1.53	74	59	2.39	77.56	4.59	24.37	0.19
3200	*Kaluheenati*	100	153	6	5	22	1.29	102	75	2.15	73.44	5.3	15.28	0.35
3214	*Matholuwa*	79	185	6	6	27	3.79	193	130	2.49	67.53	13.79	39.34	0.35
3341	*Galpa Wee*	72	130	4	3	20.42	1.25	77	71	2.18	91.48	3.36	10.67	0.32
3387	*Kahata Wee (Long Grain)*	88	157	4	4	24.71	2.16	157	132	2.04	84.05	8.68	12.82	0.68
3388	*Moddaikaruppan*	91	147	6	6	24	2.06	121	77	2.84	63.74	7.06	21.45	0.33
3391	*SinnaKaruppan*	91	142	4	3	22.75	1.08	54	35	2.7	64.43	4.36	6.2	0.7
3397	*Suduheenati*	91	147	6	4	31	1.94	156	118	1.95	75.85	3.01	24.51	0.12
3407	*Dewaraddiri*	90	180	9	7	26	2.09	119	70	3.46	58.38	9.07	35.36	0.26
3409	*BG 35-2**	82	72	6	6	15	0.57	60	42	2.16	70.39	2.98	4.42	0.67
3445	*Yakada Wee*	82	95	3	2	22	1.53	73	58	2.23	77.44	2.31	5.62	0.41
3472	*Masuran*	91	141.33	3	3	24.5	2.05	144	106	2.51	73.99	3.64	9.4	0.39
3473	*Ratu Wee*	92	160	6	6	30	4.05	199	151	2.75	76.01	19.51	30.88	0.63

Accession No	Name	DF	PH	NTT	NFT	PL	PW	TNS	SPP	HGW	FGP	YLD	BM	HI
3487	*Palasithari 601*	95	131.5	4	3	22.4	1.49	117	82	2.27	69.79	6.41	6.95	0.92
3550	*Bathkiri el*	68	169	10	8	23	2.56	146	101	2.58	69.18	16.97	23.35	0.73
3573	*Pokkali*	90	114.5	8	4	24	1.28	96	65	1.98	67.47	5.47	7.15	0.77
3579	*KakiriataBala Wee*	87	108.33	5	5	21	2.12	124	94	2.3	75.87	16.65	23.68	0.7
3611	*BalaKaharamana*	82	151.5	8	4	31	2.71	181	118	2.89	65.5	10.13	16.67	0.61
3616	*Jamis wee*	83	172.33	5	4	25.71	1.17	69	51	2.15	78.16	2.07	13.9	0.15
3629	*Ruwan Raththaran*	93	160	5	4	24	2.9	165	122	2.25	73.94	6.87	20.79	0.33
3634	*Thavalu*	93	163.5	3	3	23.6	1.48	111	77	2.6	69.36	2.31	13.65	0.17
3639	*Polayal*	78	102	8	5	17	0.36	67	55	1.67	81.95	2.05	20.51	0.1
3644	*Herath*	81	135	8	7	21	1.11	69	50	1.27	72.82	2.89	13.6	0.21
3645	*Muthumanikam*	94	142	5	5	24	1.5	166	103	1.37	61.92	4.04	18.6	0.22
3647	*Kalugires*	98	129	6	6	24	1.78	188	133	1.39	70.57	7.03	13.05	0.54
3656	*Kuruluthudu*	87	140.89	4	3	20.34	1.43	93	70	2.29	77	3.43	10.44	0.33
3662	*Mah Sudu Wee*	88	132	3	3	20.6	1.2	69	53	2.25	75.89	3.7	6.55	0.56
3672	*Mudaliwi*	93	151	5	5	23	1.45	66	41	3.49	61.81	4.01	20.46	0.2
3676	*Dena Wee*	87	128	7	6	25	2.62	130	116	2.4	89.72	17.43	18.04	0.96
3684	*Rathkara*	88	117.67	3	3	18.63	1.02	101	77	2.51	76.04	2.51	6	0.42
3691	*Gunaratna*	91	145	7	4	23	1.09	118	99	2.69	83.62	4.05	17.64	0.23
3692	*Handiran*	91	147.43	4	3	20.54	1.31	93	77	2.17	83.31	3.89	8.64	0.45
3695	*Kahata Samba*	86	149.83	4	3	25	1.39	120	95	2.21	75.76	1.97	7.67	0.26
3698	*Surumaniyan*	90	155	5	5	25	2.83	214	150	2.03	70.2	9.99	18.85	0.53
3713	*Kalukanda*	99	150	5	5	26	3.32	173	107	2.45	61.85	8.52	14.05	0.61
3718	*Mada Thawal*	88	160	6	6	26	2.37	163	111	2.94	68.16	8.07	27.25	0.3
3720	*Kirikara*	94	158	6	5	29	4.08	192	166	2.74	86.28	18.07	27.86	0.65
3721	*Manamalaya*	93	145	10	8	25.17	2.73	129	101	2.93	78.5	15.76	28.97	0.54
3726	*Dandumara*	84	126	4	4	27.4	1.09	135	107	2.3	79.18	4.95	8.465	0.58
3734	*KanniMurunga*	89	95.5	6	5	21	2.65	116	80	3.34	69.16	16.46	17.8	0.92
3735	*Welihandiran*	70	153	7	6	26	3.84	179	137	2.94	76.21	18.21	32.3	0.56
3756		86	128	9	7	23.33	1.27	106	80	2.43	74.92	5.87	15.26	0.38
3882	*DostaraHeenati*	73	105.5	4	4	22	2.26	119	87	2.24	72.91	10.92	12.88	0.85
3982	*Kuru Wee*	78	136	4	3	19.33	0.76	86	68	2.04	79.07	2.15	17.12	0.13

Accession No	Name	DF	PH	NTT	NFT	PL	PW	TNS	SPP	HGW	FGP	YLD	BM	HI
4178	*Rathumadilla*	90	163.5	5	4	30.67	1.52	194	147	2.63	75.64	5.85	13.23	0.44
4726	*Gonabaru*	62	115.33	6	5	21	2.45	111	96	3.04	86.19	18.19	18.44	0.98
4762	*Maharajah*	103	151	4	4	26	2.48	162	116	2.74	71.25	6.89	21.45	0.32
4770	*Molligoda*	96	166	4	3	24	2.02	88	53	3.46	59.62	3.73	3.73	1
4809	*Swandal*	90	125	8	7	16	0.61	47	30	2.71	63.38	2.99	15.48	0.19
4819	*Vellainellu*	105	181	7	5	26.25	1.01	136	99	1.61	72.43	10.32	40.34	0.26
4834	*Kallurundoivellai*	103	191	6	4	26.25	1	119	91	2.13	76.97	4.57	49.46	0.09
4841	*KooponSivappu*	90	141	7	7	18.5	1.29	106	71	2.66	66.98	5.92	20.46	0.29
4858	*Potkilivan*	86	155	8	5	28	1.59	122	87	1.97	71.31	2.89	20.38	0.14
6179	*Gires*	96	170	5	4	23	2.7	216	154	2.08	71.45	9.51	38.16	0.25
6863	*Papaku*	73	106	3	3	22.25	1.1	89	63	2.84	70.15	5.69	7.5	0.76
	SD	8.79	24.49	1.77	1.43	3.89	0.97	51.93	36.48	0.47	7.79	5.45	9.84	0.26

*F: Days to flowering, PH:Plant height (cm), NTT: Number of total tillers per plant, NFT: Number of fertile tillers per plant, PL: Panicle length (cm), PW: Panicle weight (g) per plant, TNS: Total number of spikelets per plant, SPP: HGW: Hundred grain weight FGP: Filled grain percentage YLD: Yield (g) per plant, BM: Biomass (g), HI: Harvest index * Not traditional*

The heaviest above ground biomass was in *Kallurundoi vellai* (49.46 g/plant) while its average yield was 4.57 g/plant which reduced its harvest index to the least (0.09) among all others. The average yield of *Kallunrundoi vellai* was very low when compared with the highest yield recorded by *Thanthiribalan* (22.74 g/plant). Though *Molliogoda* recorded the highest harvest index (1) among studied rice cultivars, the reported yield was only 3.73 g/plant. Harvest indices of *Weda Heeneti*, *Dena Wee, Galkatta*, and *Gonabru* were comparatively higher (over 0.95) among the studied cultivars while this value is more than 0.4 in modern rice cultivars (Li et al., 2012) or varied from 0.4 to 0.6 in modern rice cultivars in Sri Lanka [27,28,29], concluded that the harvest index, days to maturity and the effective tillers/plant as the major contributors for rice yield. So the rice cultivars with a higher magnitude of these traits could be favorable for better yield in farmer field.

According to standard evaluation system (SES) of international rice research institute [30] rice cultivars were grouped as semi-dwarf, intermediate, and tall. Out of 71 rice cultivars, 67.60% rice cultivars were tall (>130 cm), 19.71% rice cultivars were intermediate (110–130 cm), and 12.67% rice cultivars were semi-dwarf (<110 cm). Semi-dwarf cultivars recorded average yield of 8.12 g/plant and this value of intermediate rice cultivars was 6.63 g/plant. The group of tall rice cultivars showed an intermediate average value of semi-dwarf and intermediate groups, which was 7.61 g/plant. The yield ranges of semi-dwarf, intermediate, and tall cultivars were 2.05-16.65,1.55-18.19, 1.62-22.74 g/plant consecutively.

Kallurundoi vellai recorded the highest average plant height (191 cm) while an improved line *BG 35-2* recorded the lowest (72 cm) plant height at maturity stage. Plant height has a great contribution to the final yield [31] but the greater plant height is unfavorable in different ways such as lodging, and disturbing mechanical harvesting [32,33], It was reported that lodging causes around 26 kg/ha loss in rice final grain yield [34].

According to the average yield of each group, semi-dwarf rice cultivars produced more yield than that of in intermediate rice cultivars or in taller rice cultivars. Similar to this, Roberts et al. [35] have reported that the semi-dwarf cultivars produce higher yields than that of in tall cultivars. This phenomenon can’t be expected in all the time hence the yield potential of rice cultivars is controlled by both genetic factors and environmental factors [36].

Considering the tillering ability, rice cultivars were grouped in accordance with the SES [30]. Around 4% of rice cultivars were medium-tillering (10-19 total tillers/plant), 66% were low-tillering (5-9 total tillers/plant) while the rest was very low tillering (>5 total tillers/plant). None of the rice cultivars recorded very high or good reproductive tillers/plant. Very low tillering rice cultivars recorded the average yield of 4.27 g/plant and low tillering rice cultivars recorded 8.41 g/plant. Medium tillering rice cultivars recorded the highest average yield/plant (15.37 g/plant).

Fifty-six percent of the studied rice cultivars were belonged to the partially sterile category; which scored average yield of 7.47 g/plant. Around 44% rice cultivars included into the fertile category and recorded the average yield of 7.63 g/plant. The lowest average yield (3.36 g/plant) was recorded by the cultivars belonged to the highly fertile category.

These rice cultivars were grouped according to the crop duration between planting and 80% maturity. The longest period for maturity (105-days) was recorded in *Vellainellu* rice cultivar. *Gonabaru* cultivar recorded the shortest period (62 days) for maturity.

Moderate- maturity (60-74) rice cultivars recorded the average yield of 7.26 g/plant while late maturity (75–89) rice cultivars recorded 7.12 g/plant . Very late maturity (90–105) rice cultivars recorded the highest average yield/plant (9.79 g/plant). Days to maturity of a rice cultivar is important to decide the planting time of a crop season [37]. Grain yield in rice has shown a significant association with days to 50% flowering [38,39,40]. However, days to maturity expressed negative direct effect on grain yield per plant [41] Elongated growth duration reduces the harvest index in rice [42], Akita, [43] calculated this reduction as 55% to 35% in elongation of maturity duration from 95 to 135 days. A significant and positive association between two traits indicates the importance of one trait in improving the other trait.

Correlation analysis shows the relationships of yield with these yield-related traits in rice (Table 2). Both positive and negative correlations for different agro-morphological traits and the yield have been reported in rice [44,45,46,47,48,49,50].

Table 2. Correlations among different agro-morphological traits of rice at field conditions

Traits	PH	NTT	NFT	PL	PW	TNS	FSP	HGW	YLD	BM
PH	1.000									
NTT	.133									
NFT	.158	.794*								
PL	.635*	.176	.118							
PW	.386	.130	.253	.606*						
TNS	.494*	.182	.273	.689*	.750*					
FSP	.450	.121	.184	.669*	.762*	.962*				
HGW	.143	-.014	.072	.182	.378	.003	-.002			
YLD	.157	.357	.434	.364	.770*	.595*	.627*	.275		
BM	.651*	.433	.476*	.445	.427	.543*	.499*	.050	.461*	1.000

*PH: Plant height, NTT: Number of tillers/plant, NFT: Number of fertile tillers/plant, PL: Panicle length, PW: Panicle weight, TNS: total number of spikelets/panicle, FSP: Number of fertile spikelets/panicle, HGW: Hundred grain weight, BM: Biomass.**

Plant yield was significantly correlated with panicle weight (r=0.77, p=0.05), total number of spikelets/panicle (r=0.595, p=0.05) and number of fertile spikelets/panicle (r=0.627, p= 0.05) (Table 2). Sanni et al., [51], Seetharam et al., [13] and Saleem et al., [47], studied the association of agro-morphological traits of rice with the final grain yield. Associations of different traits with the yield are important to the plant breeders to be considered the traits as selection criteria in plant breeding programs when utilizing germplasm for rice improvement [52,53,54].

Samonte et al., [55] have reported significant associations of yield per plant with panicle weight per plant, the number of spikelets per panicle and plant height. Further, Girish et al,[56], observed significant associations of grain yield with plant height, the number of filled spikelets per panicle, panicle length per plant, the number of tillers per plant and harvest index. Ruben and Katuli, [57] Kumar, [58] Khan et al., [46] and Bhadru et al. [59] also reported a positive correlation between plant height and the yield. However, Hairmansis et al., [49] and Bhatti et al., [60] reported a negative effect of plant height on grain yield. A quadratic relationship between plant height and yield was reported by Lin et al., [61] and Ranawake et al. [16].

A number of fertile spikelets/panicle was reported as highly correlated with the final yield in the present study (r=0.627, p=0.05). The same finding was reported by Bhatti et al., [60], Bai et al., [62] and Luzikihupi, [63]. Rice grain filling has been identified as a dynamic factor that determines the grain yield [64,65].

There was no significant correlation in between panicle length and the final yield of rice (Table 2) but Mishra, [66] and Bhagat, [67] have reported a significant association of grain yield per plant with panicle weight per plant.

According to the correlation analysis, plant height was correlated with panicle length (r=0.635, p=0.05).The same result has been reported by Venketaswarlu and Prasad, [38] Prasad et al., [45] and Ganesan et al., [68].

Yadav et al., [31] have observed that panicle length is one of the contributors to the final yield. Weber and Fehr, [32] reported that not only the panicle length; but also a number of tillers per hill and number of spikelet per panicle are the most important characters that directly contribute to the grain yield.

Total tiller number is the most important agronomic character in rice since it determines the panicle number [52,69]. However in the present study, the total tiller number was not correlated with the yield. Contrarily to this, Gunasekaran et al., [70] Osman et al., [50] and Satheeshkumar and Saravanan [71] reported positive correlation in between the yield and the total tiller number.

A number of fertile tillers was correlated with the number of total tillers (r=0.794, p=0.05) in the studied rice cultivars (Table 2). The similar findings have been reported by Sabesan et al., [72] Madhavilatha et al., [73] and Gunasekaran et al., [70].

Total number of spikelets/panicle (r=0.75, p=0.05) number of fertile spikelets/panicle (r=0.762, p= 0.05) and plant height (0.494) were significantly correlated with panicle weight (Table 2). This finding is aligned with Sharma and Choubey, [44] and Prasad et al., [45]. Number of fertile spikelets/panicle (r=0.962, p=0.05) and biomass index (r=0.543, p=0.05) were significantly correlated with number of spikelets/panicle (Table 2).

None of the parameters was correlated with hundred grain weight in the present study but significant correlation between harvest index and 1000 grain weight has been reported by Venketaswarlu and Prasad, [38], Prasad et al., [45] and Ganesan et al., [68] while hundred grain weight is said to be the trait that least influenced by environment [74].

Total biomass was correlated with plant height (r=0.651, P=0.05), total number of spikelets (r=0.543), and fertile spikelets per panicle (r=0.499, P=0.05) (Table 2). According to the correlation coefficient values, there was no significant correlation of biomass yield of rice with the final yield in studied rice cultivars (Table 2) but it has been reported that biological yield of rice is significantly correlated with the grain yield in rice [66].

According to the results of the principal component analysis, four principal components which scored more than one Eigenvalue explained more than 87.44% total variance (Table 3). This cumulative variance has been built up by individual variances of four principal components quantified as 47.81%, 17.34%, 12.099 and 10.19% (Table 3).

The first principle component (PC) was composed of plant height, panicle length, panicle weight, number of spikelets per panicle, number of fertile spikelets per panicle, yield (g/plant) and biomass while the second PC was composed of number of total tillers per plant and number of fertile tillers per plant (Table 3). Only hundred-grain-weight made a sustainable contribution to the PC3 while PC4 was composed of plant height and hundred grain weight (Table 4).

Ward's Linkage analysis created different clusters in a dendrogram. This clusters phenotypically classified all the characteristics of 71 rice genotypes into six agro-morphologically distinct clusters at the rescaled cluster distance 10 (Figure 1). In this clustering, the similar genotypes were classified into the same cluster by studying their various agro-morphological traits. Final dendrogram shows significant within cluster uniformities and inter-cluster variations (Fig. 1).

Cluster I contained a maximum number of traditional rice genotypes (Table 5). This group was consisted of intermediate plants with very low-tillering and low-grain-yield. The second cluster contained 14 rice genotypes which were having plants within intermediate, partially sterile, low-tillering and lower grain yield. Thirteen rice cultivars contained in cluster III were very tall plants with medium tillering ability, higher spikelets fertility, high yielding and potential to produce bigger panicles with a large number of grains. Cultivars in cluster IV were generally tall, good in tillering with high spikelets fertility which creates a higher number of grains per panicle. Eight rice genotypes belonged to cluster V were semi-dwarf, medium tillering and partially sterile. Nine rice genotypes included into cluster VI were semi-dwarf but high in tillering ability and low in spikelet fertility. This clustering is important to select distinct parental genotypes for the breeding programs.

Table 3. Eigenvalue and % variance of principal components

Principal component	Eigenvalues	% of variance	Cumulative	Cumulative %
1	4.781	47.810	0.4781	47.810
2	1.734	17.342	0.6515	65.152
3	1.210	12.099	0.7725	77.251
4	1.019	10.193	0.8744	87.444
5	0.488	4.882	0.9233	92.326
6	0.267	2.671	0.9500	94.997
7	0.201	2.008	0.9700	97.005
8	0.152	1.523	0.9853	98.528
9	0.118	1.185	0.9971	99.713
10	0.031	0.310	0.287	100.00

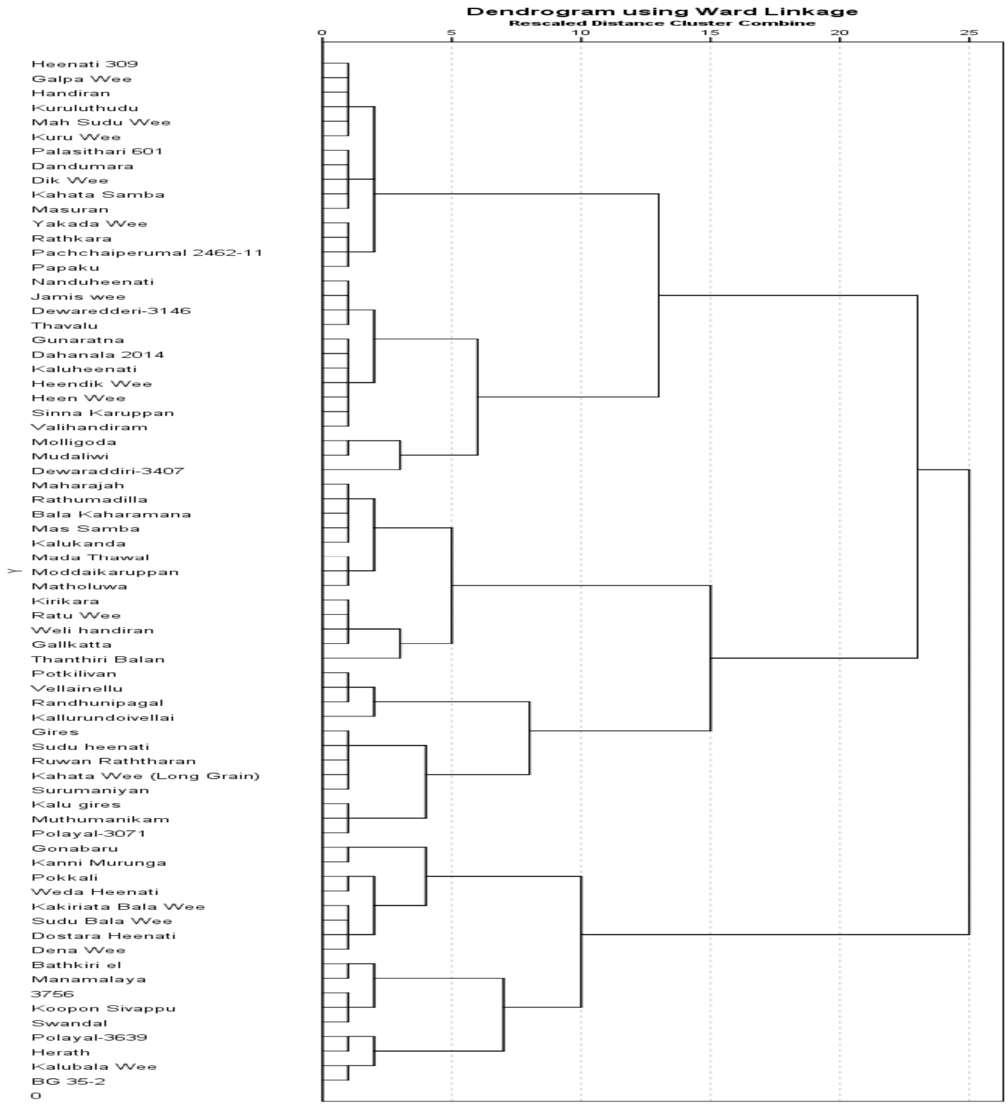

Fig. 1. Diversity among rice genotypes based on yield and yield attributing characters

Table 4. Principal components for agro-morphological traits of rice genotypes

Traits	Principal component			
	PC1	**PC2**	**PC3**	**PC4**
PH	.633	-.169	-.414	.559
NTT	.413	.830	-.057	.015
NFT	.483	.802	.054	-.007
PL	.760	-.303	-.164	.204
PW	.841	-.228	.362	-.104
TNS	.887	-.229	-.131	-.268
SPP	.864	-.298	-.090	-.323
HGW	.217	-.096	.753	.581
YLD	.754	.131	.439	-.284
BM	.737	.247	-.300	.245

PH: Plant height, NTT: Number of tillers/plant, NFT: Number of fertile tillers/plant, PL: Panicle length, PW: Panicle weight, TNS: Number of spikelets/panicle, SPP: Number of fertile spikelets/panicle, HGW: Hundred grain weight, BM: Biomass

Table 5. Clusters of seventy-one rice genotypes

Cluster number	Genotypes
Cluster I	*Heenati 309, Galpa Wee, Handiran, Kuruluthudu, Maha Sudu Wee, Kuru Wee, Palasithari 601, Dandumara, Dik Wee, Kahata Samba, Masuran, Yakada Wee, Rathkara, Pachchaperumal 2462, Papaku.*
Cluster II	*Nandu Heenati, Jamis Wee, Dewaradderi-3146, Thavalu, Gunaratna, Dahanala 2014, Kaluheenati, Heendik Wee, Heen Wee, Sinna Karuppan, Valihandiran, Molligoda, Mudaliwi, Dewaraddiri-3407*
Cluster III	*Maharajah, Rathumadilla, Bala Kaharamana Mas Samba, Kalu Kanda, , Mada Thawal, Moddaikaruppan, Matholuwa, Kirikara, Ratu Wee, Weli Handiran, Galkatta, Thanthiri Balan*
Cluster IV	*Potkilivan, Vellainellu, Randhunipagal, Kallurundoivellai, Gires, Sudu Heenati, Ruwan Raththaran, Kahata Wee(Long Grain), Surumaniyan, Kalu Gires, Muthumanikam, Polayal-3071*
Cluster V	*Gonabaru, Kanni Murunga, Pokkali, Weda Heenati, Kekiriata Bala Wee, Sudu Bala Wee, Dostara Heenati, Dena Wee*
Cluster VI	*Bathkiriel, Manamalaya, 3756, Koopan Sivappu, Swandal, Polayal-3639, Herath, Kalubala Wee, BG 35 – 2*

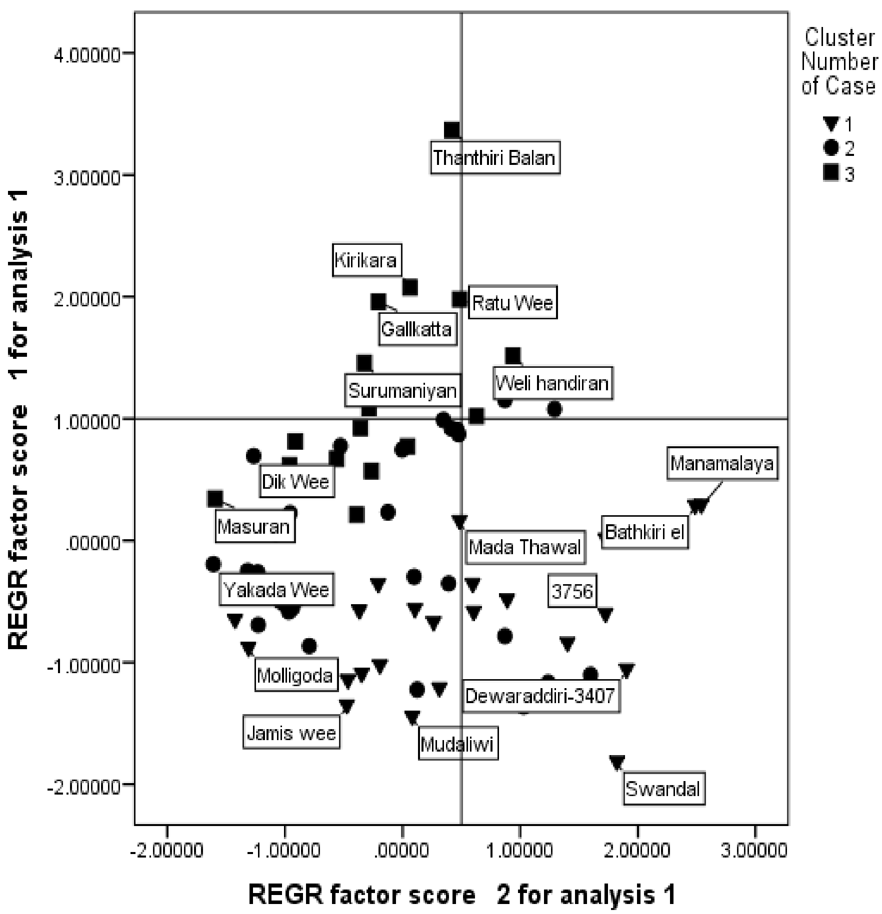

Fig. 2. Two-dimensional (2D) scatter plot diagram representing the clusters of rice genotypes on the basis of their yield and yield attributing characters

REGR factor score: Regression factor score

The 2D scatter plot diagram (Fig. 2) consisted of 4 quadrants illustrates the distribution of 71 rice genotypes according to the diversity of their agro-morphological traits. Rice cultivars distributed in all the quadrants keeping many cultivars in one quadrant. Upper two quadrants contained relatively less number of cultivars.

Though the diversity of rice cultivars can be studied in this manner, Li et al. [75] emphasized that because of environmental effect, diversity analysis based on phenotypic values may not be the perfect method for grouping diverse cultivars. Much improved genetic models or molecular markers such as SSR or AFLP must be used for a proper diversity analysis.

4. CONCLUSIONS

According to the standard evaluation system, rice cultivars were grouped as semi-dwarf, intermediate, and tall. Among tested traditional rice cultivars 67.60% rice cultivars were tall, 19.71% rice cultivars were intermediate, and 12.67% rice cultivars were semi-dwarf. *Kallurundoivellai* recorded the highest average plant height and traditional rice cultivar *Kalubala Wee* recorded the lowest plant height at maturity stage. According to the number of tillers/plant, 4.2% of rice cultivars were medium tillering, 66.2% were low tillering while the other 29.6% were very low tillering. None of the rice cultivars produced very high and good reproductive tillers per plant.

Among the tested traditional rice cultivars 54.93% were partially sterile and 43% were fertile. The lowest average yield was recorded by the highly fertile cultivars. A number of days for the maturity was ranged from 62-105 days in the studies rice cultivars. Four principal components explained 87.44% of total variance and cluster analysis categorized the rice cultivars into six distinct groups at rescaled cluster distance 10. These rice cultivars could be utilized for future breeding programs based on their agro-morphological characteristics.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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