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Changes in Yield Potential of Traditional Rice Cultivars with Variability in Plant Height, Tillers Per Plant, Fertility and Days to Maturity

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Authors' contributions

This work was carried out in collaboration between both authors. Author ALR designed the study, wrote the first draft of the manuscript. Author UGSA managed the literature searches, tabulated the data. Both authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: To understand the changes in yield potential of traditional rice cultivars with different plant height, tillers per plant, fertility and days to maturity.
Study Design: Completely randomized block design with four replicates. Twenty plants were evaluated in each replicate. Eighty plants were evaluated for each cultivar.
Place and Duration of Study: Faculty of Agriculture, University of Ruhuna, Sri Lanka in 2011-2013.
Methodology: Rice cultivars were grouped (trait groups) according to guidelines of standard evaluation system of the International Rice Research Institute. Rice cultivars were sub-divided as semi-dwarf (<110 cm), intermediate (110 – 130 cm) and tall (>130 cm) according to plant height and very low tillering (<5 tillers/plant), low tillering (5 – 9 tillers/plant), and medium tillering (10 – 19 tillers/plant) according to number of total tillers/plant. All the cultivars were grouped as completely sterile (0%), highly sterile (<50% to trace), partially sterile (50-74%), fertile (75-90%), and highly fertile (>90%) according to filled grain percentage. Two factor ANOVA without replications were

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performed to see the effect of the 3 each groups of (-plant height, -number of tillers/plant, -fertility percentage, and - days to maturity) rice cultivars on the yield.
Results: Average grain yield of each group was calculated as g/plant basis. Average yield of rice cultivars linearly increased from 7.9 g/plant, 11.13 g/plant to 13.03 g/plant from the group of semi-dwarf, intermediate, to tall. Average yield recorded as 5.39 g/plant, 10.93 g/plant, and 31.28 g/plant in very low tillering, low tillering, and medium tillering groups respectively. In maturity groups, sterile category recorded the least average yield of 4.5 g/plant and partially sterile category recorded 8.0 g/plant, while fertile category recorded the highest yield, 14.9 g/plant. According to ANOVA all these trait-groups significantly (p=0.01) increased the yield of rice cultivars.
Conclusion: Plant height, tillers per plant and days to maturity significantly increase the yield of traditional rice cultivars.

Keywords: Traditional rice; plant height; tillers per plant; fertility; days to maturity.

1. INTRODUCTION

Much of the population in Asia consumes rice in every meal and over 30% of their calorie intake comes from rice while in Sri Lanka per capita rice consumption is around 110 kg/year. Rice yield must be increased with the global growing population hence there are no avenues for expanding the cultivable lands in the world.

Grain yield is a quantitative characteristic, affected by various genetic factors and environmental fluctuations [1]. Rice yield related characters such as tiller number, grain number, grain weight and agronomic characters such as plant height and days to flowering are quantitatively inherited [2].

Breeding strategy in rice mainly depends upon the degree of association among different characters and its magnitude and nature of variation [3,4]. It has been reported that plant height, number of tillers per plant, panicle length, flag leaf area, primary branches per panicle, days to heading and days to maturity are more effective as traits in boosting yield performance of rice [5,6].

There is a considerable phenotypic variation among rice cultivars [7] which contributes to the variation of potential yield in rice. The genetic analysis of yield potential is one of the most important aspects in agriculture [8]. Rice yield is determined by two factors namely source potential and sink size [9,10,11,12]. Since source size of rice is determined by the plant architecture, this is highly important in rice breeding.

Plant height is a major contributor to the yield [13] but greater plant height susceptible to lodging reduces yield, quality of production, and mechanical harvesting efficiency [14,15]. It was estimated that lodging caused a loss of 26 kg/plant in rice production in southern India [16]. Other than plant height, number of tillers/plant directly contributes to the yield [17,13]. Number of grains per panicle is one of the most important components of yield to break the yield plateau [18]. The degree and rate of grain filling in rice spikelets differ with their positions on a panicle. Earlier-flowering superior spikelets, usually located on primary branches, are said to be filled faster and produce completely filled grains. However, later-flowering inferior spikelets, usually located on proximal secondary branches, are either sterile or fill slowly and poorly to produce unfilled grains [19,20].

Large number of tillers and large leaf area index reduces the number of surviving tillers due to mutual shading [21,22]. On the other hand smaller number of tillers per unit area results in a smaller number of panicles per unit area and ultimately leads to the lower yield [22]. This confirms that optimum tiller number per unit area, which is determined by both genetic factors of the cultivar and the cultivation practices of the field, must be maintained for an optimum yield in rice cultivation.

Maturity duration of rice cultivars are greatly variable within a germplasm. Maturity duration must be the principle factor to be considered when deciding a rice cultivar for a particular season. Further, late maturing and taller rice genotypes have high spikelet fertility contributing to higher grain yield [23]. A controversial finding has also been found; the maximum grain yield can be obtained in varieties of 110-130 days (moderate maturity) in rice [24].

In the present study, data on plant height, tiller number, filled grain percentage, maturity duration and yield were collected on 100 rice cultivars from Sri Lanka and were categorized according to guidelines of International Rice Research Institute (IRRI) using Standard Evaluation System (SES) [25]. Changes in yield potential of traditional rice cultivars with plant height, tillers per plant, fertility and days to maturity were evaluated.

2. MATERIALS AND METHODS

One hundred rice cultivars including ninety four traditional and six improved rice accessions given in Table 1 were collected in 2011 from Plant Genetic Resources Center (PGRC), Gannoruwa, Sri Lanka. Seeds of these cultivars were geminated and planted in nursery beds. Ten day old seedlings were transplanted in the experimental field at the Faculty of Agriculture, Mapalana, Kamburupitiya, Sri Lanka. The experiment was carried out according to the randomized complete block design with four replications and 3 rows per plot with 15 cm X 20 cm plant spacing. Each row contained 20 plants and the middle-raw-plants in four replicates were considered for the data collection. Plant height (cm), number of tillers per plant, number of fertile spikelets per panicle, days to maturity and yield per plant (g) were collected in 80 plants of four replicates. Days to maturity was taken when 85% of grains on panicle were matured.

Grouping of rice cultivars was performed considering plant height, tiller number/plant, fertility %, and maturity. Cultivars were grouped into the following categories:

<u>Plant height</u>: Semi-dwarf (<110 cm), intermediate (110 – 130 cm) and tall (>130 cm).
<u>Number of tillers/plant</u>: Very low tillering (<5 tillers/plant), low tillering (5 – 9 tillers/plant), medium tillering (10 – 19 tillers/plant), good tillering (20 – 25 tillers/plant), and very high tillering (>25 tillers/plant).
<u>Spikelet fertility</u>: Completely sterile (0%), highly sterile (<50% to trace), partially sterile (50-74%), fertile (75-90%), and highly fertile (>90%).
<u>Days to maturity</u>: Very early maturity (<90 days), early maturity (91-105 days), moderate maturity (105-120 days), late maturity (120-135 days) and very late maturity (> 135 days).

The significance of the average yield of trait categories (three categories were found for each trait: plant height, tiller number, filled grain percentage and maturity duration.) was examined using ANOVA two factor analysis without replications.

3. RESULTS AND DISCUSSION

3.1 Grouping Rice Cultivars According to Plant Height

Semi-dwarf cultivars recorded an average yield of 7.9 g/plant (yield range: 2.41 g/plant-18.22 g/plant). The intermediate rice cultivars recorded the average yield of 11.13 g/plant with values ranging from 1.8 g/plant to 32.05 g/plant and the tall rice cultivars recorded an average yield of 13.07 g/plant which ranged from 3.83 g/plant to 31.28 g/plant. According to average yield of each group, taller rice cultivars produced more yield than that of in semi-dwarf rice cultivars or in intermediate rice cultivars. Contrary to this, Roberts et al. [26] have reported that the semi-dwarf cultivars produce higher yields than that of in taller cultivars. However the yield potential of rice cultivars is controlled by both genetic factors and environmental factors [1].

3.1.1 Semi-dwarf cultivars (<110 cm, average yield = 7.9 g/plant)

Heendik wee, Lumbini I, Polayal II, Heendikki, Sinnanayam, Murungakayan 101, Bala Ma wee II, Buruma Thavalu, Chinnapodiyan, Suduru Samba III, Sinnanayan 398, BG 34-8, Seeraga Samba, Batticaloa, Balakara, Rajes, Kaharamana II, Madabaru, BG 35-2, H 10, BG 35-7, A 6-10-37, Madoluwa, Halabewa, Wanni Heenati, Kottakaram, Suduru Samba I, Kirikara, Ranruwan, MI 329, Muthumanikam, Kalu Karayal, Muthu Samba, Suwanda Samba, Heenpodi wee, Geeraga Samba, Karabewa, Lumbini II, Podi sudu wee, Yakada wee I,Kotathavalu II, Podisayam

Table 1. Rice accessions used for the study

	Acc. no.	Name		Name	Name
1	3673	Kaluhandiran	51	3645	Muthumanikam
2	3674	Kirikara	52	3646	Induru Karayal
3	3675	Kotathavalu	53	3647	Kalu gires
4	3676	Dena wee	54	3650	Madabaru
5	3677	Herath Banda	55	3651	Balakara
6	3678	Hondarawala	56	3652	Buruma Thavalu
7	3679	Kottakaram	57	3517	Seeraga Samba Batticaloa
8	3681	Dandumara	58	3518	H 10(Improved)
9	3686	Karayal I	59	3519	Manchel Perunel
10	3687	Dewaredderi	60	3562	Thunmar Hamara
11	3469	Sudu wee	61	3567	Dingiri Menika
12	3477	Sudu Goda wee	62	3570	Madael
13	3479	Kiri Naran	63	3571	Miti Riyan
14	3480	Karayal II	64	3572	Suduru Samba II
15	3482	Akuramboda	65	3589	Gangala
16	3486	Puwakmalata Samba	66	3588	Heenpodi wee
17	3487	Palasithari 601	67	3497	Sinnanayan 398
18	3489	Murungakayan 3	68	3498	Geeraga Samba
19	3490	Murungakayan 101	69	3504	Dik wee 328
20	3496	Bala Ma wee I	70	3506	MI 329(Improved)
21	3654	Pokuru Samba	71	3507	Suwanda Samba
22	3655	Rata wee	72	3508	Madael Galle
23	3660	Suduru	73	3510	Sudu wee Ratnapura
24	3658	Ingrisi wee	74	3511	Maha Murunga Badulla
25	3659	Kotathavalu II	75	3514	Madael Kalutara
26	3653	Kalu Karayal	76	3516	Seevalee Ratnapura
27	3668	Ranruwan	77	3383	EAT Samba
28	3669	Rajes	78	3389	Sirappu Paleusithri
29	3670	Madoluwa	79	3394	Muthu Samba
30	3671	Suduru Samba I	80	3395	Podi sudu wee
31	3688	Handiran	81	3401	Wanni Heenati
32	3691	Gunaratna	82	3409	BG 35-2(Improved)
33	3661	Polayal I	83	3410	BG 35-7(Improved)
34	3664	Tissa wee	84	3415	BG 34-8(Improved)
35	3665	Sudu Karayal	85	3416	A 6-10-37(Improved)
36	3666	Podisayam	86	3417	Periamorungan
37	3423	Giress	87	3591	Mudukiriel
38	3427	Naudu wee	88	3594	Suduru Samba III
39	3434	Kokuvellai	89	3595	Kaharamana II
40	3463	Karayal III	90	3598	Bala Ma wee II
41	3438	Murunga wee	91	3606	Chinnapodiyan
42	3435	Matara wee	92	3607	Kiri Murunga wee
43	3440	Kaharamana I	93	3610	Heendikki
44	3447	Karabewa	94	3612	Jamis wee I
45	3451	Halabewa	95	3613	Lumbini II
46	3445	Yakada wee I	96	3614	Sinnanayam
47	3638	Lumbini I	97	3615	Yakada wee II
48	3639	Polayal II	98	3616	Jamis wee II
49	3641	Heendik wee	99	3550	Bathkiri el
50	3642	Kahata Samba	100	3713	Kalukanda

Acc. No. PGRC accession number

3.1.2 Intermediate cultivars (110 cm - 130 cm, average yield = 11.13 g/plant)

Sudu wee, Periamorungan, Maha Murunga Badulla, Murunga wee, Ingrisi wee, Gangala, Miti Riyan, Madael Galle, Manchel Perunel, Giress, Karayal II, Akuramboda, Sirappu Paleusithri, Dena wee, Sudu wee Ratnapura, Kiri Murunga wee, Sudu Karayal, Jamis wee I, Suduru, EAT Samba, Madael Kalutara, Puwakmalata Samba, Sudu Goda wee, Kalu gires, Suduru Samba II, Herath Banda, Seevalee Ratnapura, Madael, Matara wee, Naudu wee, Bala Ma wee I, Murungakayan 3, Mudukiriel, Dingiri Menika, Thunmar Hamara, Kalukanda, Kaharamana I, Karayal III, Kahata Samba, Kokuvellai, Kiri Naran, Palasithari 601, Dewaredderi, Dik wee 328, Pokuru Samba, Yakada wee II, Bathkiri el, Polayal I

3.1.3 Tall (>130 cm, average yield = 13.03 g/plant)

Tissa wee, Kotathavalu I, Gunaratna, Jamis wee II, Handira, Rata wee, Karayal I, Induru Karayal, Dandumara, Kaluhandiran, Hondarawala

Considering the tillering ability, rice cultivars were grouped in accordance with the standard evaluation system of IRRI.

3.2 Grouping Rice Cultivars According to Tillers/Plant Using IRRI, SES [25]

Very low tillering rice cultivars recorded the average yield of 5.39 g/plant while low tillering rice cultivars recorded 10.93 g/plant. Medium tillering rice cultivar, Hondarawala recorded the highest average yield/plant as 31.28 g/plant. According to the average yield of each group recorded the maximum yield. Supporting this, Bahmaniar et al. [27] concluded that the tillering is the most important yield component which determines the grain yield in rice. However, number of tillers of rice plant is determined during the vegetative growth period and it is mainly governed by tillering capacity of cultivar, planting density and availability of nutrients [28].

The tiller number in unit area would be increased due to number of plants/unit area. It would cause the negative effect on the productive tillers [29]. Higher number of tillers per unit area reduces the number, size and weight of grains which reduces the final yield [30]. Hence optimum tiller number per plant or optimum tiller number per unit area must be maintained for a sustainable yield in rice. For such optimization genotype as well as environmental factors must be taken into account.

Large number of tillers and a large leaf area index caused plant mutual shading which results in shortage of photosynthates, hence reduces the number of surviving tillers [21,22]. Smaller number of tillers per unit area could also result in a smaller number of panicles per unit area and ultimately leads to lower yield [22].

3.2.1 Very low tillering cultivars (<5 tillers/plant, average yield = 5.39 g/plant)

Wanni Heenati, Polayal II, Kaluhandiran, Kirikara, Halabewa, Lumbini I, Suduru Samba I, Madabaru, Giress, Madael Galle, Karabewa, Periamorungan, Puwakmalata Samba, Murungakayan 101, Podisayam, Yakada wee I, Seeraga Samba Batticaloa, Madoluwa, A 6-10-37, Murungakayan 3, Heendik wee

3.2.2 Low tillering cultivars (5-9 tillers/plant average yield = 10.93 g/plant)

Kiri Naran, Murunga wee, Matara wee, Kaharamana I, Dik wee 328, MI 329, Sinnanayam, Ranruwan, Kottakaram, Dewaredderi, Rata wee, Rajes, Naudu wee, Lumbini II, Sudu wee, Bala Ma wee I, Pokuru Samba, Suduru, Kokuvellai, Kotathavalu I, Herath Banda, Sudu Goda wee, Karayal II, Palasithari 601, Handiran, Gunaratna, Sirappu Paleusithri, Ingrisi wee, Podi sudu wee, Kaharamana II, Heendikki, Jamis wee I, Dandumara, Sinnanayan 398, BG 35-2, Kiri Murunga wee, Dena wee, Kalu Karayal, Sudu wee Ratnapura, Madael Kalutara, Chinnapodiyan, Akuramboda, Tissa wee, Maha Murunga Badulla, Kotathavalu II, Sudu Karayal, Geeraga Samba, EAT Samba, Manchel Perunel, Suduru Samba II, BG 34-8, Mudukiriel, Kahata Samba, Dingiri Menika, Muthu Samba, Induru Karayal, Balakara, Polayal I, Karayal III, Yakada wee II, Jamis wee II, Buruma Thavalu, Suduru Samba III, H 10, Bala Ma wee II, Kalukanda, Madael, Kalu gires, Miti Riyan, Gangala, Heenpodi wee, BG 35-7, Seevalee Ratnapura, Muthumanikam, Thunmar Hamara, Karayal I, Suwanda Samba, Bathkiri el.

3.2.3 Medium tillering cultivars (10-19 tillers/plant, average yield 31.28 g/plant)

Hondarawala.

3.3 Grouping of Rice Cultivars According to Spikelet Fertility

Rice cultivars were grouped as completely sterile (0%), highly sterile (<50% to trace), partially sterile (50-74%), fertile (75-90%), highly fertile (>90%) according to IRRI [25].

The majority of the cultivars belonged to partially sterile category and recorded the average yield of 8.0 g/plant. Rice cultivars belonged to highly sterile category recorded the average yield of 4.5 g/plant. The highest average yield (14.9 g/plant) was recorded by the cultivars belonged to fertile category.

3.3.1 Highly sterile cultivars (<50%, average yield - 4.5 g/plant)

Muthu Samba, Dik wee 328, Murunga wee, Handiran, Sudu Karayal, Dewaredderi,, Balakara, Kalu gires, Polayal II, Maha Murunga Badulla, Ranruwan

3.3.2 Partially sterile cultivars (51% - 74%, average yield = 8.0 g/plant)

Suduru Samba I, Kotathavalu II, Kaharamana I, Suduru, Sinnanayan 398, Periamorungan, Madoluwa, Ingrisi wee, Kirikara, Kalu Karayal, Rajes, Dingiri Menika, Karabewa, Tissa wee, Kokuvellai, Karayal II, Puwakmalata Samba, Yakada wee I, Karayal III, Kiri Naran, Murungakayan 101, Buruma Thavalu, Kaluhandiran, Muthumanikam, Murungakayan 3, Giress, Thunmar Hamara, Rata wee, Akuramboda, Matara wee, Madabaru, Polayal I, Sudu Goda wee, Herath Banda, Lumbini II, Halabewa, Seeraga Samba Batticaloa, Sudu wee, Gunaratna, Dena wee, Pokuru Samba, Chinnapodiyan, Dandumara, H 10, Manchel Perunel, Induru Karayal, Heendik wee, Suduru Samba II, Mudukiriel, Podisayam, Heenpodi wee, Jamis wee II, BG 34-8, Bala Ma wee I.

3.3.3 Fertile cultivars (75%-90%, average yield = 14.9 g/plant)

Madael, Kottakaram, Yakada wee II, Kotathavalu I, BG 35-7, Kiri Murunga wee, Miti Riyan, MI 329, BG 35-2, Naudu wee, Sudu wee Ratnapura, Geeraga Samba, Bala Ma wee II, Kaharamana II, Lumbini I, Sirappu Paleusithri, Kahata Samba, Jamis wee I, Palasithari 601, Karayal I, Sinnanayam, Wanni Heenati, Gangala, Podi sudu wee, Suwanda Samba, Madael Galle, Seevalee Ratnapura, Heendikki, Suduru Samba III, Madael Kalutara, EAT Samba, Bathkiri el, A 6-10-37, Kalukanda, Hondarawala

3.4 Grouping of Rice Cultivars According to Days to Maturity

Moderate maturity rice cultivars recorded the average yield of 8.55 g/plant while late maturity rice cultivars recorded 10.59 g/plant. Very late maturity rice cultivars recorded the highest average yield/plant (13.71 g/plant) in general. The same has been reported by Panday et al. [23] in which late maturing and taller rice genotypes have high spikelet fertility contributing towards higher grain yield. Jennings et al. [26] found that not only the longer maturity period but also the large flag leaf contribute to higher yield capacity. Contrary to this, Akita [24] stated that the maximum grain yield can be obtained in varieties of 110-130 days (moderate maturity).

Rice cultivars were grouped according to days to maturity and average yield of each group was calculated:

3.4.1 Moderate maturity cultivars (106-120 days, average yield 8.55 g/plant)

Manchel Perunel, H 10, Sudu Goda wee, Thunmar Hamara, Polayal, MI 329, A 6-10-37, Ranruwan, Podi sudu wee, Karayal, BG 34-8, Dena wee, Herath Banda, Murunga wee, BG 35-2, Kotathavalu, Rata wee, Handiran, Lumbini, Kahata Samba, Induru Karayal, Kirikara, Suduru, Kotathavalu, Rajes, Yakada wee, Balakara, Dingiri Menika, Madael, Geeraga Samba, Wanni Heenati, Lumbini, Sinnanayam, Jamis wee

3.4.2 Late maturity cultivars (121-135 days, average yield = 10.59 g/plant)

Sudu wee, Suwanda Samba, Karayal, Bala Ma wee, Giress, Miti Riyan, Heenpodi wee, Sudu wee Ratnapura, Palasithari 601, Karabewa, Halabewa, Madabaru, Suduru Samba, Madael Galle, Maha Murunga Badulla, Madael Kalutara, Karayal, Ingrisi wee, Polayal, Tissa wee, Sudu Karayal, Matara wee, Buruma Thavalu, Seeraga Samba Batticaloa, Sinnanayan 398, Dik wee 328, Sirappu Paleusithri, Mudukiriel, Suduru Samba, Kaharamana, Bala Ma wee, Chinnapodiyan, Yakada wee, Hondarawala, Deweredderi, Murungakayan 3, Pokuru Samba, Kalu Karayal, Suduru Samba, Podisayam, Kokuvellai, Kiri Murunga wee, Kaluhandiran, Kottakaram, Dandumara, Madoluwa, Naudu wee, Kaharamana, Kalu gires, BG 35-7, Periamorungan, Akuramboda, Murungakayan 101, Heendik wee, Muthumanikam Jamis wee, Muthu Samba, Kalukanda, Bathkiri el, Heendikki, Kiri Naran, EAT Samba.

3.4.3 Very late maturity cultivars (135 days, average yield = 13.71 g/plant),

Gangala, Seevalee Ratnapura, Gunaratna, Puwakmalata Samba

Average yield of each group is given in Table 2.

ANOVA was performed to see the significance of yield in each group of rice cultivars Table 3.

According to ANOVA Table 3, there is a significant (p=0.03) difference among average yield of rice cultivars in each category of plant height, number of tillers/plant, fertility percentage, and days to maturity.

Table 2. Average yield of rice cultivars in different groups

	Group 1 yield (g/plant)	Group 2 yield (g/plant)	Group 3 yield (g/plant)
Plant height groups	7.9^{c}	11.1^{b}	13.0^{a}
Tiller groups	5.3^{c}	10.9^{b}	31.3^{a}
Fertility groups	4.5^{c}	8.0^{b}	14.9^{a}
Maturity groups	8.5^{c}	10.6^{b}	13.7^{a}

Group 1 of plant height: semi-dwarf, group 2 of plant height: Intermediate, group 3 of plant height: tall, group 1 of tiller group: very low tillering, group 2 of tiller group: low tillering, group 3 of tiller group: medium tillering, group 1 of fertility group: highly sterile, group 2 of fertility group: partially sterile group 3 of fertility group: fertile group 1 of maturity group: moderate, group 2 of maturity group: late, group 3 of maturity group: very late. Different letters in the same row indicate significant differences (p=0.01)

4. CONCLUSION

Rice cultivar-groups categorized according to the Standard Evaluation System of Rice, International Rice Research Institute, increase the average yield when the plant height, number of tillers/plant, fertility percentage, and days to maturity increase.

Table 3. ANOVA two factor without replications

Source of variation	SS	df	MS	F	P-value	F crit
Between groups	285.9617	2	142.9808	5.199986	0.031549	4.256495
Within groups	247.4675	9	27.49639			
Total	533.4292	11				

CONSENT

All authors declare that written informed consent was obtained for publication of this manuscript. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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