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Effect of Days to Flowering on Plant Height and Yield of Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author ALR designed the study, wrote the protocol, managed the literature searches, analysed the data and wrote the manuscript. Authors UGSA, MJH and NGJP collected the experimental data. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: To study effect of days to flowering on the plant height and yield of rice.
Study Design: Experiment was carried out according to the complete randomized block design. Four replications were designed for the experiment and each replicate consisted of 3 lines and twenty plants were included in to each line. Data were collected in 80 plants of the each middle line of four replicates.
Place and Duration of Study: Faculty of Agriculture, University of Ruhuna, Mapalana, Sri Lanka, From 2011 November to 2013 November
Methodology: Days to flowering (DF) has been used for plant height (PH), and yield/plant (g) (YLD) were measured in 102 traditional rice cultivars. Eighty plants of each cultivar in four replicates were selected for data collection. Rice cultivars were grouped as 70, 80, 90, 100 DF. Path analysis was done using IBM SPSS AMOS statistical software. Path correlations were calculated to determine the total effect of DF on the PH and YLD.
Results: The effect of DF on the PH and YLD was greatly varied with the DF. Effect of DF on PH was highest when DF was the shortest. Effect of DF on both YLD and PH were maxima at 80 DF. The DF on the YLD was a cubic relationship of days to flowering with a minimum and a maximum value which is fitted with the equation
Conclusion: The DF on the YLD was a cubic relationship of days to flowering with a minimum and a maximum value which is fitted with the equation $y = 0.158x^3 - 1.365x^2 +$

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3.596x - 2.78, while the relationship between DF and PH was a quadratic which can be explained by the equation $y=0.127x^2 - 0.734x + 1.077$.

Keywords: Traditional rice cultivars; days to flowering; plant height; yield; path analysis.

1. INTRODUCTION

Over 30 per cent of the Sri Lanka labor force is directly or indirectly involved in rice farming. The world population is expected to reach 8 billion by 2030 and rice production must be increased by 50% in order to meet the growing demand for the world [1]. Hence, the rice breeders are interested in developing cultivars with improved yield and other desirable agronomic characters to overcome the global problem of hunger and starvation. Different morphological traits play an important role for increased rice production with new plant type characteristics associated with the yield [2]. Breeding strategy in rice mainly depends on the degree of association among different characters and its magnitude and nature of variation [3]. Rice yield is not only determined by spikelet number, grain weight, and number of grains per panicle but also affected by plant height and flowering time [4]. Further, yield, plant height, and flowering time are the three most important agronomic traits in rice [5]. Days to flowering affects on the plant height and on the yield of the rice plant is the most critical factor of a varietal selection criterion. Days to flowering recorded positive and significant correlation with plant height and negative and significant association with grain yield per plant [6]. The flowering or harvest of varieties that mature in a fixed period after seeding can coincide with natural calamities such as typhoons or droughts. In this sense also days to flowering must be considered in a rice genotype selection to finish the harvest before the bad weather comes.

Flowering refers to the events between the opening and closing of the spikelet (floret) and it lasts for 1 to 2 1/2 hours. Flowering generally begins upon panicle exertion or on the following day and is consequently considered synonymous with heading [7]. Days to flowering is controlled by both genetic and environmental factors [8,9,5]. Different factors affect on flowering in rice: Planting of younger seedlings, closer spacing, conventional irrigation and conventional weeding induce early flowering [9]. Under higher plant density, more competition among the plants induced quick growth and early flowering [8]. Under wider spacing plant growth is slower due to the less completion for moisture and nutrients and more carbohydrate assimilation per plant [10]. The temperatures higher than 34℃ at the time of flowering induce floral sterility and decrease yields [11].

The negative direct effect of days-to flowering and plant height on grain yield has been reported [12]. Qi [13] has explained that high dry matter accumulation before heading and high translocation rate after heading are the main strategy in high yielding rice cultivars. The relationship between dry matter accumulation at the heading and grain yield could be simulated by quadratic equation, and the difference in grain yield is due mainly to photosynthetic capacity from the heading stage to maturity [14].

Correlation coefficient which quantifies the degree of association between a response variable and predictor variables is a tool for selection of rice lines in breeding programs [15]. Correlation coefficient considers only the direct effect of the parameter on the yield. However the indirect effect through correlated, less complex and easily measurable traits is more efficient in decision making. Efficiency of indirect selection depends on the magnitude of correlations between yield and yield attributing traits [16]. Path analysis which reveals the

amount of direct and indirect effect of the causal components on the effect component has been used by plant breeders [17,18] to identify promising traits to be considered as criteria in selection of rice cultivars. Influence of each contributing trait to yield, which is defined by path coefficient, enables breeders to rank the genetic attributes according to their contribution. In other words, path coefficient provides an insight into the interrelationship of various characters with grain yield [19]. In the present study 100 traditional rice cultivars were used for the understanding effect of days to flowering on the plant height and yield of traditional rice cultivars using path analysis.

2. MATERIALS AND METHODS

Nearly one hundred traditional rice cultivars (Table 1) with different days to flowering were germinated and transplanted in the experimental field with 15 cm X 20 cm spacing at the Faculty of Agriculture, University of Ruhuna, Mapalana, Sri Lanka (Latitude: 6º 54′ 0″ N. Longitude: 79º 54′ 0″ E.) according to the randomized complete block design with four replications and each replication consisted of 3 lines. Twenty plants were included in to each line. Data were collected in 80 plants of four replicates. Proper weed and pest management practices were applied during the field experiment and the field was covered by a bird-nest to prevent the birds' attack. Days to flowering (DF), plant height (cm) (PH), and yield/plant (g) (YLD) were measured during the experiment in 2012-2013 Yala and Maha seasons. Rice cultivars were grouped as 70, 80, 90, 100 DF. Correlation analysis was done by IBM SPSS 20 statistical software and path analysis was done by IBM SPSS AMOS statistical software [19]. Path coefficients were calculated to determine the total effect of DF on the PH and on YLD.

Table 1. Days to flowering of studied rice genotypes

PGRC acc. No.	Name	DF	PGRC acc. No.	Name	DF
3519	Manchel Perunel	78	3669	Rajes	89
3518	H 10	79	3691	Gunaratna	89
3477	Sudu Goda wee	80	3445	Yakada wee	89
3479	Kiri Naran	80	3645	Muthumanikam	89
3562	Thunmar Hamara	80	3646	Induru Karayal	89
3639	Polayal	81	3651	Balakara	89
3506	MI 329	81	3567	Dingiri Menika	89
3416	A 6-10-37	81	3570	Madael	90
3668	Ranruwan	83	3498	Geeraga Samba	90
3395	Podi sudu wee	84	3401	Wanni Heenati	90
3463	Karayal	85	3613	Lumbini	90
3415	BG 34-8	86	3614	Sinnanayam	90
3676	Dena wee	87	3469	Sudu wee	91
3677	Herath Banda	87	3507	Suwanda Samba	91
3438	Murunga wee	87	3480	Karayal	92
3409	BG 35-2	87	3496	Bala Ma wee	92
3675	Kotathavalu	88	3423	Giress	92
3655	Rata wee	88	3571	Miti Riyan	92
3688	Handiran	88	3588	Heenpodi wee	92

PGRC acc. No.	Name	DF	PGRC acc. No.	Name	DF
3427	Naudu wee	88	3510	Sudu wee Ratnapura	92
3638	Lumbini	88	3594	Suduru Samba	92
3642	Kahata Samba	88	3486	Puwakmalata Samba	93
3674	Kirikara	89	3447	Karabewa	93
3660	Suduru	89	3451	Halabewa	93
3659	Kotathavalu	89	3650	Madabaru	93
3572	Suduru Samba	93	3671	Suduru Samba	95
3508	Madael Galle	93	3666	Podisayam	95
3511	Maha Murunga Badulla	93	3434	Kokuvellai	95
3514	Madael Kalutara	93	3607	Kiri Murunga wee	95
3686	Karayal	94	3673	Kaluhandiran	96
3487	Palasithari 601	94	3679	Kottakaram	96
3658	Ingrisi wee	94	3681	Dandumara	97
3661	Polayal	94	3670	Madoluwa	97
3664	Tissa wee	94	3440	Kaharamana	97
3665	Sudu Karayal	94	3647	Kalu gires	97
3435	Matara wee	94	3410	BG 35-7	97
3652	Buruma Thavalu	94	3417	Periamorungan	97
3517	Seeraga Samba Batticaloa	94	3482	Akuramboda	98
3497	Sinnanayan 398	94	3490	Murungakayan 101	98
3504	Dik wee 328	94	3641	Heendik wee	98
3389	Sirappu Paleusithri	94	3612	Jamis wee	98
3595	Kaharamana	94	3394	Muthu Samba	99
3598	Bala Ma wee	94	3713	Kalukanda	99
3606	Chinnapodiyan	94	3616	Jamis wee	100
3615	Yakada wee	94	3550	Bathkiri el	100
3678	Hondarawala	95	3610	Heendikki	101
3687	Dewaredderi	95	3591	Mudukiriel	102
3489	Murungakayan 3	95	3383	EAT Samba	105
3654	Pokuru Samba	95	3589	Gangala	106
3653	Kalu Karayal	95	3516	Seevalee Ratnapura	107

3. RESULTS AND DISCUSSION

Plant height and yield of individual rice cultivars were measured at the end of the experiment and data are given in Table 2.

Table 2. Plant height and yield of individual rice cultivar

Accession number	Name	Yield (g/plant)	Plant height (cm)
3463	Karayal III	36.28	96.3
3550	Bathkiri el	33.45	100.3
3616	Jamis wee II	28.39	100.9
3504	Dik wee 328	28.13	85
3713	Kalukanda	26.35	82.1
3595	Kaharamana II	25.37	79.2
3678	Hondarawala	23.72	71.1
3642	Kahata Samba	23.27	96.5
3641	Heendik wee	19.38	95.9
3482	Akuramboda	19.33	96.9
3687	Dewaredderi	19.13	90.8
3434	Kokuvellai	19.07	78.4
3645	Muthumanikam	18.90	90.4
3681	Dandumara	18.81	98.4
3612	Jamis wee I	18.77	98.9
3659	Kotathavalu II	17.98	94.2
3562	Thunmar Hamara	17.64	87.9
3416	A 6-10-37	17.52	48.3
3654	Pokuru Samba	17.25	98.3
3508	Madael Galle	16.98	79.2
3653	Kalu Karayal	16.84	94.3
3670	Madoluwa	16.19	95.8
3435	Matara wee	16.19	70.1
3570	Madael	16.13	87.7
3675	Kotathavalu I	15.53	97.6
3598	Bala Ma wee II	15.53	54.2
3567	Dingiri Menika	15.23	102.9
3477	Sudu Goda wee	15.15	93
3496	Bala Ma wee I	14.89	76.1
3394	Muthu Samba	14.16	93
3480	Karayal II	14.12	101.3
3383	EAT Samba	14.11	81
3655	Rata wee	13.73	70.1
3669	Rajes	13.64	85.1
3389	Sirappu Paleusithri	13.44	93.9
3591	Mudukiriel	13.24	73.2
3479	Kiri Naran	13.10	90
3614	Sinnanayam	13.00	101.3
3395	Podi sudu wee	12.99	98.7
3615	Yakada wee II	12.88	91.5
3415	BG 34-8	12.85	45
3665	Sudu Karayal	12.55	80.6
3664	Tissa wee	12.51	88.9
3589	Gangala	12.23	69.7
3401	Wanni Heenati	12.21	55
3487	Palasithari 601	12.16	83.8
3638	Lumbini I	12.14	89.4

Accession number	Name	Yield (g/plant)	Plant height (cm)
3447	Karabewa	12.08	66.1
3410	BG 35-7	11.90	55.8
3514	Madael Kalutara	11.90	75.5
3519	Manchel Perunel	11.76	116.9
3510	Sudu wee Ratnapura	11.72	79.9
3610	Heendikki	11.42	82.9
3427	Naudu wee	11.05	64.9
3652	Buruma Thavalu	11.03	85.3
3440	Kaharamana I	11.00	81.3
3658	Ingrisi wee	10.90	94.5
3506	MI 329	10.87	56
3571	Miti Riyan	10.87	81.8
3691	Gunaratna	10.87	90.7
3516	Seevalee Ratnapura	10.32	83.1
3423	Giress	10.23	67.8
3688	Handiran	10.14	62.4
3518	H 10	10.03	85.2
3650	Madabaru	9.93	85.4
3588	Heenpodi wee	9.82	74.3
3686	Karayal I	9.16	76.6
3607	Kiri Murunga wee	9.10	80.5
3646	Induru Karayal	9.00	93
3679	Kottakaram	8.92	91.8
3517	Seeraga Samba Batticaloa	8.85	100.4
3489	Murungakayan 3	8.83	82.2
3507	Suwanda Samba	8.78	79.5
3594	Suduru Samba III	8.37	81
3613	Lumbini II	8.26	102.1
3438	Murunga wee	8.16	77.4
3647	Kalu gires	8.13	86.7
3572	Suduru Samba II	8.07	90.7
3417	Periamorungan	8.05	92.8
3490	Murungakayan 101	8.00	76.3
3606	Chinnapodiyan	7.93	60.7
3651	Balakara	7.92	102.6
3666	Podisayam	7.76	90.8
3451	Halabewa	7.67	104.3
3676	Dena wee	7.57	102.2
3674	Kirikara	7.43	85.8
3409	BG 35-2	7.25	55.9
3668	Ranruwan	7.02	97.6
3469	Sudu wee	6.42	92.9
3677	Herath Banda	6.40	102.2
3498	Geeraga Samba	6.00	82.8
3445	Yakada wee I	5.95	60.2
3511	Maha Murunga Badulla	5.29	74.2
3497	Sinnanayan 398	5.28	60
3673	Kaluhandiran	5.01	94.6

Accession number	Name	Yield (g/plant)	Plant height (cm)
3671	Suduru Samba I	4.94	70.2
3486	Puwakmalata Samba	4.89	56.4
3661	Polayal I	4.57	68.8
3660	Suduru	3.66	90
3639	Polayal II	3.42	79.4

Rice cultivars were grouped as 70-, 80-, 90- and 100- days to flowering. Plant height, yield and biomass weight of one hundred traditional rice cultivars were averaged in different days to flowering groups of traditional rice cultivars (Table 3). Path analysis was carried out to understand the effect of DF on PH and on YLD. All parameters; plant height, yield and biomass were increased with the increasing DF. However effect of DF on plant height and YLD which is defined by path coefficient was varied with the DF (Fig. 1).

Table 3. Average value of days to flowering, plant height, yield and biomass of different age groups

DF group	Avg DF	PH (cm)	YLD (g/plant)	BM (g/plant)
70	74.2	129.773	4.59655	11.7973
80	84.6	133.468	7.56312	13.7228
90	92.3793	141.707	7.13527	18.9518
100	103.385	141.703	15.1417	31.6438

DF: Days to flowering, PH:Plant height, YLD:Yield, BM Biomass weight (g/plant)

Path coefficients of days to flowering (DF) on grain yield (YLD) were varied with the value of DF. When the DF increased from 70 to 90 the effect of DF on the PH was decreased. When the DF increased from 90 to 100 then the effect of DF on the PH was increased. Furthermore, when the DF increased from 70 to 80, effect of DF on the YLD was increased but when the DF further increased from 80 to 100, the effect of DF on the YLD was decreased (Fig.1).

It is not easy to make a simple statement on the effect of days to flowering on the yield without considering the DF of rice cultivars. It might be the reason that Akhter et al. [21] clearly reported that there is no correlation between flowering behavior and rice grain yield, contrarily to [6,12,19]. However, according to the data distribution of path coefficient and DF, from 70 DF to 100 DF the relationship between effect of DF on the YLD was a cubic relationship of DF with a minimum and a maximum value which is fitted with the equation $y = 0.158x^3 - 1.365x^2 + 3.596x - 2.78$.

When the rice cultivars exhibited a minimum period of DF, the effect of DF on the PH was positive and the effect of DF on the YLD was negative. When the rice cultivars were around 80 DF, the effects of DF on both plant height and the YLD were positive. Culm elongation of the rice plant causes the dry matter accumulation within the biomass. The relationship between dry matter accumulation and grain yield has a quadratic relationship [14]. Plant height is the main contributor to the bio mass weight. Hence, the finding of the present study: PH has a quadratic relationship with the yield, aligns with Lin et al., [14]. Further, the quadratic relationship can be explained by the equation $y = 0.127x^2 - 0.734x + 1.077$.

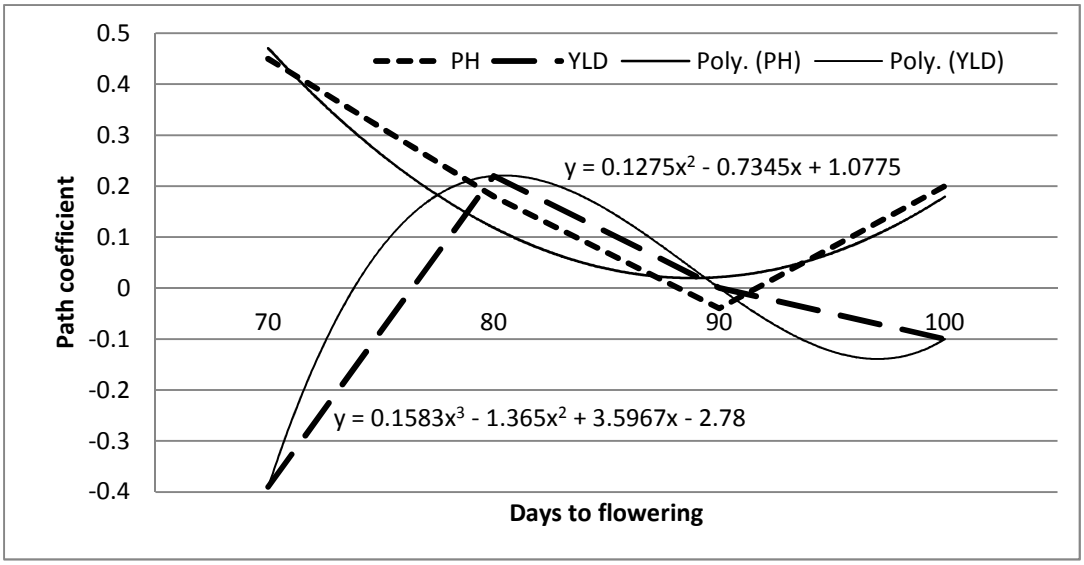

Fig. 1. Path coefficients of different days to flowering rice genotype groups on YLD and PH

4. CONCLUSION

The effect of days to flowering on the plant height and yield was varied with the days to flowering. When the days-to flowering was shorter, the effect of the days to flowering on the yield was negative and the effect of days to flowering on the yield was maximum when the days to flowering was around 80. Up to 90 days to flowering the effect of days to flowering on the yield was positive but when the days-to flowering was more than 90, the effect of days to flowering on the yield was negative. Effect of days to flowering on plant height was highest when the days to flowering was shortest. This effect decreased till the days to flowering was 90 but when the days to flowering further increased, effect of days to flowering started increasing. The relationship between effect of days to flowering on the yield is a cubic relationship of days to flowering with a minimum and a maximum value which is fitted with the equation $y = 0.158x^3 - 1.365x^2 + 3.596x - 2.78$, while the relationship between effect of days to flowering on the plant height is a quadratic relationship which can be explained by the equation $y = 0.127x^2 - 0.734x + 1.077$.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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