J.Natn.Sci.Foundation Sri Lanka 2011 **39** (1):43-52

RESEARCH ARTICLE

Minimizing the water supply duration in the field with no reduction of yield in the rice variety BG 250 of the ultra-short maturity class

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Revised: 15 September 2010 ; Accepted: 26 November 2010

Abstract: The ultra-short maturity class rice (*Oryza sativa* L.) matures in approximately 80 days from sowing and can effectively avoid droughts and floods without impairing grain yield if its field crop duration (FCD) that requires water supply is kept to a minimum. The objective of the present work was to study the influence of cultural practices, namely stand establishment, top dressing fertilization, irrigation and the growing season on the duration of the crop in the field that requires water supply and on grain yield of a newly developed rice variety (Bg 250) of the ultra-short maturity class. Bg 250 gave consistently higher yields in the dry season. Furthermore, FCD that requires water supply could be minimized to about 57-59 days depending on the season, without impairing grain yield, by transplanting 12 day old seedlings at the rate of 3 seedlings/ hill when coupled with termination of irrigation at 14 days after 50% heading. Reduction in the rate of top dressing fertilizer by half of the recommended rate did not influence FCD that requires water supply, but it reduced grain yield in the dry season which was not the case in the wet season. Therefore, in the low yielding wet season, Bg 250 can be cultivated at comparatively lower cost by reducing the rate of top dressing fertilizer to 50% of the recommended rate.

Keywords: Bg 250, drought and flood escape, field crop duration, grain yield, rice, ultra-short maturity class.

INTRODUCTION

Rain-fed lowlands are a major rice (*Oryza sativa* L.) ecosystem that covers approximately 54 million ha, representing 34% of the world's total rice land. Most of the lands in this ecosystem are either drought-prone or submergence-prone or both drought and submergence-prone (Maclean *et al*., 2002). At least 22 million ha of the global rice extent are subject to flooding (Khush, 1984). Thus, drought and flooding/submergence are the major constraints in lowland rain-fed rice ecosystems. As a result, a considerable land area in the eco-system is not cultivated, and even in the lands which are cultivated the rice yields are low. One of the successful ways to overcome the drought and flood problems in this ecosystem is to cultivate rice varieties with very short maturity duration (Wade *et al.*, 1994; Salam *et al.*, 1995). Such varieties have the ability to overcome water stress towards the tail end of the cropping season in drought-prone areas where varieties with comparatively longer maturity duration frequently fail due to severe yield losses. They can also fit into short cropping seasons after floods when the peak monsoon recedes in flood-prone areas (Wade *et al*., 1994). Successful crop establishment after the recession of flood water in flood-prone areas is very important for food security at both household and national levels (Hossain & Abedin, 2004). Switching over from medium to short-duration varieties in lands with no water harvesting facilities may avert the risk of drought in rice cultivation (Bagchi *et al.*, 1995). Use of rice varieties with short maturity duration without impairing grain yield has been proposed even under major irrigation schemes to save irrigation water in rice cultivation (Jayatillaka, 2000).

Maturity duration of rice is under genetic control (Jennings *et al.*, 1979) and in the tropics it varies from about 80 to 200 days depending on the variety (Vergara *et al*., 1966). Varieties that mature in about 80 days belong to the ultra-short maturity class and such varieties have the highest potential to avoid drought in drought-prone areas and fit into the short cropping season after

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floods recede in flood-prone areas. However, such varieties with a high yield potential were not available until recently for effective utilization in farmers' fields. The yield potential of varieties in ultra short maturity class has been reported to be not more than 2 t/ha (Bagchi *et al.*, 1995). Early flowering results in low grain yields and an optimum growth duration is necessary for achieving high grain yields (De Datta, 1970a). However, the rice variety Bg 250, which has been developed recently in Sri Lanka and released for cultivation, belongs to the ultra short maturity class and its yield potential is relatively high. This variety has the ability to avoid water stress in drought-prone areas and fit into short cropping seasons when floods recede in flood-prone areas due to its ultra short maturity duration while giving a reasonable grain yield between 3.2 - 5.7 t/ha (Abeysiriwardena *et al.*, 2004). If the field crop duration (FCD) that requires water supply of such varieties can be minimized without impairing grain yield, they may be comparatively more efficiently utilized by farmers in drought- and flood-prone areas with a minimum risk of cultivation.

The FCD that requires water supply may be minimized by reducing seed to seed maturity duration, adoption of transplanting and cutting down the water supply at the latter part of the maturity phase of the crop. Variation in seed to seed maturity duration of Bg 250 has been observed under field conditions. However the reasons for this and how it affects the grain yield are not very clear. Vergara *et al.*, (1966) studying the relationship between grain yield and growth duration of rice, reported that there was a tendency for the plant to reach optimum growth duration earlier at closer spacing. Argon and De Datta (1981) reported that there was a curvilinear decrease in the number of days to heading with increased supply of water. Low water availability during the vegetative phase increased growth duration while a water shortage during maturity phase reduced grain yield (Crusciol *et al.*, 2003). Murakami and Vignarajah (1967) reported that rice yield is severely affected when the crop is subjected to moisture stress during the period 15 days before heading to 15 days after heading. Thus there may be a possibility to terminate water supply at 15 days after heading of a rice crop to minimize the crop duration that requires water supply in the field. Manipulation of both transplanting date and seedling age caused variations in field duration of rice (Salam *et al.*, 1995). The Rice Production Manual (1970) also reported that the growing period of a rice variety varies depending on cultural practices.

If the FCD that requires water supply could be kept to a minimum in varieties with ultra short maturity duration by manipulating cultural practices enabling them to escape from drought and flood effectively without impairing grain yield, it could immensely benefit farmers in drought- and flood-prone areas around the world. In addition, studying the influence of growing season on maturity duration and grain yield of rice in the ultra short maturity class is important as drought is frequently observed in the dry season while flooding is frequently observed in the wet season. Therefore, the objective of the present study was to ascertain the influence of management practices, namely method of stand establishment, rate of top dressing fertilization and status of water supply during the latter part of the maturity phase and the growing season on FCD that requires water supply and grain yield of ultra short maturity class in rice as represented by Bg 250, the only high yielding rice variety in this maturity class in Sri Lanka.

METHODS AND MATERIALS

Experimental site and plant material: Experiments were conducted over two dry and two wet seasons (2005 to 2007) at the Rice Research and Development Institute (RRDI), Batalagoda which is situated in the Low Country Intermediate Zone (LCIZ) of Sri Lanka and receives a total annual rainfall that generally varies from 1525 to 2285 mm. The great soil group at Batalagoda is Red Yellow Podzolic with a loamy sand texture which dries in 2-3 d if not irrigated. In the wet season, the average temperature is 1 ºC lower, the solar radiation intensity as influenced by the cloud cover percentage is considerably lower and the total rainfall is 250% more than that of the dry season. The rice variety used in the experiment was Bg 250, a photoperiod insensitive 80 d variety (Abeysiriwardena *et al.*, 2004) with a yield potential of approximately 7 t/ha in the warm tropics.

Experimental design and procedure: A three factor factorial experiment, factors being irrigation regime, method of stand establishment and fertilization rate was conducted in a split-plot arrangement, laid out in a Randomized Complete Block Design (RCBD) with two replications in each of the four seasons. The gross sub plot size of the experiment was 6 × 3 m. The irrigation treatment had two regimes, namely continuous irrigation and irrigation terminated at 14 d after 50 % heading of the crop. Stand establishment had three methods, namely broadcasting with a seed rate of 100 kg/ha and transplanting with 1 seedling/ hill or 3 seedlings/ hill. Fertilization rates were recommended rate of top dressing fertilizer by the Department of Agriculture (DOA), Sri Lanka and half of the DOA recommended rate (basal fertilizer was the same for both fertilization rates). The DOA fertilizer recommendation for the region where the experiments were conducted is 25 kg of urea with 46% N, 72 kg of Triple Super Phosphate (TSP) with 45% P_2O_5 and 37 kg of Murate of Potash (MOP) with 60% K_2O as the basal and 50 kg of urea and 37 kg of MOP at each of first and second top dressings per ha. First and second top dressings were applied at 7 – 10 d and 4 wks after sowing or transplanting, respectively.

In the split-plot design, irrigation treatment was assigned to main plots and the different combinations of method of stand establishment and the rate of top dressing fertilizer were assigned to sub plots. Thus, the experiment had two main plots corresponding to two irrigation treatments and six sub plots within a main plot corresponding to six combinations of stand establishment × rate of top dressing fertilizer. Main plots were randomized within blocks and sub plots were randomized within main plots. Main plots were separated by a deep furrow having two bunds on both sides to prevent lateral water movement between main plots and the sub plots were separated by bunds only to prevent mixing up of standing water with fertilizer among plots.

In the transplanting treatments, 12 d old seedlings (Bandara, 1984) raised in a wetland nursery were transplanted at a spacing of 15 cm × 15 cm. In the broadcast sown treatment, pre-germinated seeds were broadcast sown by hand at the rate of 180 g/plot. The plant population densities between broadcast sown and transplanted plots were not comparable and broadcast sown plots always had a higher plant density than that of transplanted plots. Even the population densities between two transplanting treatments (1 and 3 seedlings /hill) were not comparable as plant density of one treatment was 3 times higher than the other. The continuous irrigation treatment had a standing water level of 2-3 cm from 4 d after seeding or transplanting till harvesting. In the terminated irrigation treatment, standing water level was drained off while irrigation was terminated at 14 d after 50% heading of the crop and plots were left to dry out. Each experimental plot had a separate inlet and outlet for irrigation and drainage, respectively. Experimental plots were maintained uniformly and the pests and diseases were controlled according to the recommendations of the DOA.

Measurements and data analysis: FCD was recorded as the number of days from seeding to maturity in the broadcast sown treatment and transplanting to maturity in the transplanting treatment. This was taken as the FCD that requires water supply in the treatment of continuous irrigation. In order to measure the FCD that requires water supply in the treatment of termination of irrigation at 14 d after 50% heading, 15 d was deducted from the total crop duration in the field. This was because the crop was in the field only for 15 d since 14 d after 50% heading as the total length of the maturity phase from 50% heading to maturity was about 29 d in Bg 250.

The crop was harvested at physiological maturity when more than 85% of grains of the crop did not have a greenish tint. In the broadcast sown plots, a 30 cm border was removed around each plot to avoid border effects and the net sub plot size became 12.96 m^2. In the transplanted plots, a single row around each plot was removed to avoid border effects and the net sub plot size became 15.39 m^2. The final grain yield was converted to t/ha for the purpose of comparison. Grain yield was adjusted to 14% moisture content before analysis.

Grain yield data were analyzed using Statistical Analysis Software (SAS). Combined analysis over seasons was performed by the method proposed by McIntosh (1983) where the season also became a factor in the analysis. As there were two experiments or tests within each of dry and wet seasons, the term test within season (Test/Season) was also included in the analysis in order to test the differences among tests within season and particularly to study whether Test/Season interacts with other treatments. As the experimental design was a split-plot treatment, main plot treatments were tested against the pooled main plot error with 4 df and sub-plot treatments were tested against the pooled sub-plot error or residual with 54 df. Whenever the interactions were found to be significant, they were presented in two-way tables with relevant pooled standard errors (SE) of difference for means.

As the FCD that requires water supply was measured in terms of number of days, the smallest unit of the measurement was a day. Error term in the analysis of the data of FCD that requires water supply was estimated to be zero because no difference in FCD that requires water supply was found between replications in all treatments. Thus, with respect to the data of FCD that requires water supply, a one day difference (the magnitude of the smallest unit of the measurement) between treatment means was considered as a true difference.

RESULTS

Climatic conditions

Weekly total rainfall and pan evaporation data during the period from two weeks before establishment to harvesting of the experiments in the dry and wet seasons at the RRDI are presented in Table 1. Only a small difference in rainfall and hardly any difference in pan evaporation between two dry seasons as well as between two wet seasons were observed. However, rainfall and pan evaporation in the wet season were much higher and a little lower respectively, than that in the dry season and pan evaporation was higher than the rainfall in the dry season while pan evaporation was much lower than the rainfall in the wet season. Thus, there was a clear difference between wet and dry seasons. Experimental plots received a higher rainfall during the period just before termination of irrigation in the wet season than that in the dry season. Rainfall received during the period after the termination of irrigation was highly variable over seasons as some seasons received a considerable rainfall while some seasons received little or no rainfall despite the season was dry or wet. However, in both dry and wet seasons soil moisture appeared adequate to maintain a rice crop without impairing grain yield as experimental plots received adequate rainfall either during the period prior to the termination of irrigation or during the period after the termination of irrigation or during both periods depending on the season.

FCD that requires water supply

FCD that requires water supply in Bg 250 was not affected by the rate of fertilizer application in all stand establishment methods and irrigation regimes in all seasons (Table 2). Transplanting significantly reduced FCD that requires water supply when compared to the broadcasting depending on the number of seedlings/ hill irrespective of the irrigation regime, rate of fertilizer and season. Transplanting with 3 seedlings/ hill reduced 7–9 days of FCD depending on the season whereas transplanting with 1 seedling/ hill reduced only about 4 days of FCD over the broadcast sown treatment irrespective of the season. Transplanting with 3 seedlings/ hill had the greatest influence on the reduction of FCD that requires water supply in the dry season as the reduction was 9 days, irrespective of the irrigation regime. Obviously, the treatment of termination of irrigation at 14 days after 50% heading reduced the FCD that requires water supply by 15 days irrespective of the method of stand establishment, rate of fertilizer application and season.

The longest FCD that requires water supply of 81 days was in broadcast sown plots with continued irrigation irrespective of the rate of fertilizer application and season. The shortest FCD that requires water supply of 57 – 58 days was recorded with transplanting (3 seedlings/ hill) when irrigation was terminated at 14 days after 50% heading of the crop in the dry season irrespective of fertilizer application. However, the corresponding FCD in the wet season was recorded as 59 days.

Table 1. Weekly total rainfall (RF) and pan evaporation (PE) data during the period from two weeks before establishing to harvesting of experiments in the dry and wet seasons at the RRDI

Weeks from two weeks before establishing experiments	Dry season				Wet season			
	Year 2005		Year 2006		Year 2005/06		Year 2006/07	
	RF (mm)	PE (mm)	RF (mm)	PE (mm)	RF (mm)	PE (mm)	RF (mm)	PE (mm)
Week 1	1.00	24.07	57.10	26.57	37.50	17.25	357.80	18.58
Week 2	0.00	30.56	0.00	33.30	94.50	18.12	64.30	17.93
Week 3[a]	0.00	28.84	19.30	28.56	84.80	14.53	125.20	17.83
Week 4[b]	26.20	24.56	50.30	17.38	26.50	18.14	1.30	22.40
Week 5	7.50	24.17	5.20	24.29	6.40	20.72	19.40	14.15
Week 6	34.90	18.42	0.00	26.53	35.90	12.90	15.50	18.85
Week 7	12.70	20.47	34.90	20.34	80.90	8.20	70.30	15.48
Week 8	0.20	23.04	56.00	26.51	31.80	21.94	0.50	23.00
Week 9	3.40	30.62	26.90	22.86	10.60	20.82	6.00	25.38
Week 10	16.20	23.60	3.30	27.43	91.40	9.19	16.70	21.68
Week 11	9.40	18.61	2.10	19.14	42.70	19.85	22.50	20.35
Week 12[c]	4.00	18.92	1.60	23.96	0.00	27.19	0.00	24.01
Week 13	31.80	17.70	5.30	27.33	0.00	25.00	26.70	22.22
Week 14[d]	0.00	28.11	0.00	29.30	27.70	24.61	0.00	27.85
Total	147.30	331.69	262.00	353.50	570.70	258.46	726.20	289.71

[a] The week when the broadcast sown plots were established

[b] The week when the transplanted plots were established

[c] The week when the irrigation was terminated in the terminated irrigation treatment

[d] The week when the experiments were harvested

Grain yield

Grain yield of Bg 250 under different irrigation regimes, methods of stand establishment and rates of top dressing fertilizer over four consecutive dry and wet seasons are presented in Table 3. In the combined analysis of variance over two dry and two wet seasons, the term Test/Season was found to be significant, indicating that there were yield differences between tests within season. These yield differences were unpredictable and the important feature was the interaction effect of Test/Season term with other factors.

All the interaction effects involving Test/Season were found to be non-significant except the interaction effect of Stand establishment x Test/Season at 1% probability level. Thus, the interaction effect of Stand establishment x Test/Season was further examined (Table 4). Irrigation and top dressing fertilizer did not interact with Test/Season and they behaved similarly in the two dry and two wet seasons indicating the possibility of generalizing the discussion on irrigation and fertilizer in dry and wet seasons, separately.

The four way interaction effect of Season x Irrigation x Fertilizer x Stand establishment and all the three way and two way interaction effects except the two way interaction effect of Fertilizer x Season were not significant (5% probability). Therefore, the two way interaction effect of Fertilizer x Season was further examined (Table 5). Reduction in rate of fertilizer application by half of the DOA recommendation caused a significant reduction in grain yield (by about 8%) in the dry season but not in the wet season.

All the interaction effects involving the irrigation treatment were non-significant (5% probability). Therefore, the irrigation main effect became important and it was also not significant (5% probability). The not significant irrigation effect was interesting as it indicated that termination of irrigation at 14 days after 50% heading did not reduce the grain yield of Bg 250. The season main effect was found to be highly significant so that comparison between seasons became interesting although some of the interaction effects involving season were found to be significant. However, the grain yield of the dry season was about 27% higher than that of the wet season (Table 4).

Table 2: Influence of irrigation regime, method of stand establishment and rate of top dressing fertilizer on field crop duration (FCD) that requires water supply of Bg 250 over two dry and two wet seasons at the RRDI

Season	Test	Continued irrigation						Terminated irrigation[a]					
		Broadcasting		Transplanting 1 seedling/hill		Transplanting 3 seedlings/hill		Broadcasting		Transplanting 1 seedling/hill		Transplanting 3 seedlings/hill	
		DOA[b] rec fer.	½ DOA rec fer.	DOA rec fer.	½ DOA rec fer.	DOA rec fer.	½ DOA rec fer.	DOA rec fer.	½ DOA rec fer.	DOA rec fer.	½ DOA rec fer.	DOA rec fer.	½ DOA rec fer.
		FCD that requires water supply (no. of days)[c]											
Dry	Year 2005	81.0	81.0	76.0	76.0	72.0	72.0	66.0	66.0	61.0	61.0	57.0	57.0
	Year 2006	81.0	81.0	77.0	77.0	73.0	73.0	66.0	66.0	62.0	62.0	58.0	58.0
	Mean over test and fertilizer	81.0		76.5		72.5		66.0		61.5		57.5	
Wet	Year 2005/06	81.0	81.0	76.0	76.0	74.0	74.0	66.0	66.0	61.0	61.0	59.0	59.0
	Year 2006/07	81.0	81.0	76.0	76.0	74.0	74.0	66.0	66.0	61.0	61.0	59.0	59.0
	Mean over test and fertilizer	81.0		76.0		74.0		66.0		61.0		59.0	

[a] Irrigation was terminated at 14 days after 50% heading

[b] Department of Agriculture recommended top dressing fertilization rate

[c] One day difference between treatment means (the smallest unit of the measurement) was considered as a true difference as the SE of mean difference was estimated to be zero due to no difference in the FCD that requires water supply was found between replications in any of the treatments

DISCUSSION

FCD that requires water supply

Transplanting is generally practiced with varieties having maturity durations longer than 3½ months as transplanting varieties with comparatively shorter maturity duration is believed to reduce grain yield. The best age of transplanting wet-bed seedlings are when they are 20 to 30 days old, and in early maturing varieties seedlings should be transplanted early (Macalinga & Obordo, 1970). However, Bandara (1984) reported that 12 -15 day old seedlings can be transplanted, irrespective of the maturity duration, without affecting grain yield. Thus adoption of transplanting with Bg 250 can be justified and it always reduced FCD that requires water

Table 3: Influence of irrigation regime, method of stand establishment and rate of top dressing fertilizer on grain yield of Bg 250 over two dry and two wet seasons at the RRDI

Season	Test	Continued irrigation						Terminated irrigation[a]					
		Broadcasting		Transplanting 1 seedling/hill		Transplanting 3 seedlings/hill		Broadcasting		Transplanting 1 seedling/hill		Transplanting 3 seedlings/hill	
		DOA[b] rec fer.	½ DOA rec fer.	DOA rec fer.	½ DOA rec fer.	DOA rec fer.	½ DOA rec fer.	DOA rec fer.	½ DOA rec fer.	DOA rec fer.	½ DOA rec fer.	DOA rec fer.	½ DOA rec fer.
		Grain yield (t/ha)[c]											
Dry	Year 2005	3.83	3.63	3.63	4.13	3.80	3.73	3.95	3.63	4.50	3.73	4.20	3.98
	Year 2006	2.63	2.08	3.15	2.48	3.73	3.03	2.98	2.85	3.40	3.25	4.13	3.55
Wet	Year 2005/06	2.58	2.73	2.88	2.55	2.93	3.40	2.38	2.08	3.18	2.98	3.33	3.10
	Year 2006/07	2.65	2.83	2.75	2.38	2.95	2.60	2.73	2.35	2.65	2.60	2.85	2.60

[a] Irrigation was terminated at 14 days after 50% heading
[b] Department of Agriculture recommended top dressing fertilization rate
[c] Pooled S.E. of difference for means (Res D.F. 54) = 0.275 t/ha

Table 4. Grain yield of Bg 250 as influenced by different methods of stand establishment under different tests over two dry and two wet seasons at the RRDI

Method of stand establishment	Dry Season			Wet Season		
	Test 1 2005	Test 2 2006	Mean	Test 3 2005/06	Test 4 206/07	Mean
	Grain yield (t /ha)					
Broadcasting	3.76[a]	2.63	3.19[b]	2.44	2.64	2.54
Transplanting 1 seedling/hill	4.00	3.07	3.53	2.90	2.59	2.74
Transplanting 3 seedlings/hill	3.93	3.61	3.77	3.19	2.75	2.97
Mean	3.90[c]	3.10	3.50[d]	2.84	2.66	2.75

[a] Pooled SE of difference for stand establishment × test/season means (Res D. F. 54) = 0.137
[b] Pooled SE of difference for stand establishment × season means (Res D. F. 54) = 0.097
[c] Pooled SE of difference for test/season means (D. F. 4) = 0.064
[d] Pooled SE of difference for season means (D.F. 4) = 0.045

Table 5. Grain yield of Bg 250 at different rates of top dressing fertilizer in the dry and wet seasons at the RRDI

Rate of top dressing Fertilizer	Season Dry	Wet
	Grain yield (t/ha) [b]	
DOA[a] recommended rate	3.66	2.82
½ of DOA recommended rate	3.34	2.68

[a] DOA – Department of Agriculture.

[b] Pooled SE of difference (Res D. F. 54) for fertilizer × season means = 0.079.

supply, the duration of reduction depending on the number of plants/ hill, when compared to broadcasting. Transplanting with 1 seedling/ hill reduced only 4-5 days of FCD irrespective of the season while transplanting with 3 seedlings/ hill reduced 9 days of FCD in the dry season and 7 days of FCD in the wet season irrespective of the rate of fertilizer and irrigation regime (Table 2).

Early maturity of the crop by 2 days resulting in a 2 day reduction in FCD that requires water supply in the dry season may be due to the higher temperature in the dry season than that in the wet season (Abeysiriwardena, 1999). Yoshida (1981) reported that variability in growth duration among locations and seasons of a given non-photoperiod rice cultivar is basically dependent upon the temperature. Abeysiriwardena (1999) also reported that growth duration of modern rice cultivars seemed to be sensitive even to minor changes in temperature over seasons. A comparatively higher reduction in FCD that requires water supply with 3 seedlings/ hill over 1 seedling/ hill by 2 – 4 days may be due to the comparatively higher plant density which made the plants mature earlier. According to Vergara *et al*. (1966) there is a tendency for the crop to reach optimum growth duration earlier at closer spacing due to higher plant density.

Reduction in the rate of top dressing fertilizer by half of the DOA recommended rate did not influence FCD that requires water supply in Bg 250. Although the influence of application of top dressing fertilizer on maturity duration of rice has not been studied, Hoan (1997) reported that application of 140 kg N/ha at panicle development stage delayed heading by 2-3 days, which resulted in a delay in maturity by the same period in rice. However, application of N fertilizer above the recommended level was studied by Hoan (1997) while the present study dealt with application of top dressing fertilizer, which included both N and K, below the recommended level across several growth stages of the rice crop. Hoan (1997) also reported that application of K in terms of K_2O had no influence on heading time in male sterile rice but application of K_2O with Gibberellic acid (7 g/ha) induced early heading in male fertile rice. However, the influence of N and K when applied together as a top dressing fertilizer on the time of heading in rice was not reported by Hoan (1997).

Although termination of irrigation at 14 days after flowering reduced FCD that requires water supply by 15 days irrespective of the season, method of stand establishment and rate of fertilizer application, it did not influence growth duration of Bg 250 in any treatment. Draining water at the latter part of the panicle development could delay heading by 2-3 days (Hoan, 1997) which in turn delays maturity by the same period while low water availability during the vegetative phase increases growth duration (Crusciol *et al.*, 2003). In contrast, early maturity expected due to draining water at the latter part of the maturity phase was not achieved in rice in the present study.

Reduction in FCD that requires water supply by 22–24 days through transplanting with 3 seedlings/ hill while cutting down the water supply at 14 days after heading can make a significant impact in reducing yield losses of rice in drought- and flood-prone areas with short cropping seasons where water is severely limited towards the end of the season. Cutting down water supply at 14 days after heading alone and transplanting 12 day old seedlings with 3 seedlings/ hill alone reduce FCD that requires water supply to 66 and 72-74 days respectively, in Bg 250. If both, transplanting 12 day old seedlings with 3 seedlings/ hill and cutting down water supply at 14 days after heading are combined, FCD that requires water supply of Bg 250 could be significantly reduced to 57-58 and 59 days in the dry and wet seasons, respectively, irrespective of the rate of fertilizer application (Table 2). Therefore, Bg 250 if managed properly can fit into short cropping seasons in areas where availability of water for rice cultivation is limited to a short period. However, the impact of management practices adopted in reducing FCD that requires water supply, on grain yield of Bg 250 needs to be studied further.

Grain yield

The dry season yields with a maximum of 4.5 t/ha were much higher than the wet season yields with a maximum of 3.4 t/ha (Table 3) indicating that Bg 250 was more adaptable to the dry season. Jayasekara (1966) also reported higher grain yields of rice in the dry season.

This is also in agreement with De Datta (1970a) who reported that if irrigation water is available in the tropics, rice grain yield obtained in the dry season will be higher. Comparatively higher rainfall and lower radiation intensity in the wet season to which Bg 250 is highly sensitive due to its short maturity duration may be the reason for lower grain yield of Bg 250 in the wet season. Bg 250 has been particularly bred for cultivation in drought-prone areas during the dry season (Abeysiriwardena *et al.*, 2004).

Transplanting did not lower grain yields when compared to broadcasting in all seasons (Table 4). There is no difference in grain yield between transplanting and broadcasting if good management practices are used (Jayasekara, 1966; Mabbayad & Obordo, 1970; Bandara, 1984). In the 2006/07 wet season, grain yield did not vary significantly between the methods of stand establishment. However, the grain yield varied between the methods of stand establishment in 2005 and 2006 dry seasons and 2005/06 wet season. In these seasons, transplanting was always better than broadcasting with the normally used seed rate of 100 kg/ha. This is in agreement with Jayasekara (1966) who reported that broadcast sowing at the normal seed rate of 100 kg/ha gave lower yields than transplanted rice. However, at lower densities broadcasting produced yields comparable to those from transplanting (Jayasekara, 1966). Transplanting with 3 seedlings/ hill recorded a higher grain yield (6 – 8%) than that with 1 seedling/ hill (Table 4). This is in agreement with Minoru *et al*. (1963) who reported a yield increase by 5-6% for every additional seedling up to the density of 3 seedlings/ hill when the number of hills/ M^2 was 16 in a fertile soil in Japan. They also reported that if the number of plants per unit area is constant, yield will increase when many number of hills with few seedlings are planted closely when compared to a situation where few hills with many seedlings are planted sparsely. Thus, for Bg 250, transplanting with 3 seedlings/ hill can be recommended.

The application of the DOA recommended rate of top dressing fertilizer produced a higher grain yield (3.66 t/ha) than that of half of recommended rate (3.34 t/ha) in the dry season while no yield difference between the same two treatments was observed in the wet season (Table 5) despite the method of stand establishment and termination of irrigation at 14 days after 50% heading. Response of rice to N fertilizer is higher during the sunny dry season than in the relatively more cloudy wet season (De Datta, 1970b). In addition, dry season yields are higher at any given level of added N fertilizer including the zero level of added N (Jayasekara, 1966; Wijesundera *et al.*, 1990). Although the benefit of K, which is included in the top dressing fertilizer, is comparatively greater in the rainy wet season, this may have been masked by the response to N as response of rice to K additions is not as prominent as those to N (De Datta, 1970b). Thus, the recommended rate of top dressing cannot be reduced by 50% without sacrificing grain yield in the dry season. However, about 0.32 t/ha in general was lost due to reduction of the rate of top dressing fertilizer by 50% and thus, the economics of this has to be calculated before taking any decision on fertilizer application in the dry season. In other words, the cost benefit ratio under reduced fertilizer is dependent on the relative prices of the rough rice and fertilizer. If the plant response to fertilizer is assumed to be constant, decrease in rough rice price and increase in fertilizer price would definitely increase the cost/ benefit ratio. An economically feasible compromise has to be adopted depending on the situation. Reduction of the DOA recommended rate of top dressing fertilizer by 50% did not reduce grain yield in the wet season where fertilizer response of Bg 250 was lower than that in the dry season. Therefore, in the wet season, Bg 250 can be cultivated at a lower cost through reduction in the recommended rate of top dressing fertilizer by 50%.

Seven to ten days before harvest, water in the rice field should gradually be drained to facilitate harvesting (Macalinga & Obordo, 1970). Minoru *et al*. (1963) reported that although the best drainage time differs according to soil conditions, water can generally be drained from the field at 20-25 days after heading of the rice crop. In contrast, the present study terminated water supply and allowed natural drying off the field as early as 14 days after 50% heading or at 15 days before harvest assuming that the length of the maturity phase of Bg 250 is 29 days. While rice yield is severely affected when the plant is subjected to moisture stress from 15 days before heading to 15 days after heading, yield loss of about 30% could be observed due to moisture stress even from 15 to 25 days after heading (Murakami & Vignarajah, 1967). Crusciol *et al*. (2003) also reported that low water availability during maturity phase of rice reduced grain yield. Termination of water supply as early as at 14 days after heading in the maturity phase, however, did not reduce grain yield of Bg 250 despite the method of stand establishment and rate of topdressing fertilizer over four consecutive growing seasons in the present study. This indicates that Bg 250 can be successfully cultivated even under the condition with on-setting of natural drying of the field at 14 days after 50 % heading, which is a very important characteristic to avoid drought through reducing FCD that requires water supply at the tail end of the crop growth.

Maturity duration vs grain yield

Maximizing grain yield while reducing the risk of cultivation has to be achieved by the farmers in drought-and flood-prone areas. Even in stress environments with less than marginal yields, farmers cultivate rice if there is no risk (Abeysiriwardena & Sandanayake, 2000). Reduction in FCD that requires water supply will help to reduce the environmental risk due to water limitations (Wade *et al.*, 1994) and also to save irrigation water in major irrigation schemes (Jayatillaka, 2000). The shortest FCD of 57-59 days that requires water supply of Bg 250 which is classified as ultra short maturity class variety, could be attained with the highest grain yield by transplanting 12 day old seedlings with 3 seedlings/hill at a spacing of 15 x 15cm between hills when coupled with termination of irrigation or allowing the onset of drying off the field at 14 days after 50 % heading in both seasons (Tables 2 and 3).

If farmers are confident that a good rice crop could be obtained by avoiding the risk of cultivation due to limited water availability through terminating water supply at 14 days after 50% heading coupled with transplanting of a variety in ultra short maturity class, they would transplant despite the labour cost for transplanting. As transplanting is labour intensive and costly, profitability may be increased by totally avoiding transplanting cost through the use of only family labour. Most of the rice cultivation in drought-and flood-prone areas is done in small holdings owned by poor farmers with family labour. Another approach to reduce the transplanting cost while retaining the advantage of transplanting would be seedling broadcasting (Yan, 1988; Gill *et al.*, 2007) of which the suitability of adoption is beyond the scope of the present study. In addition, reducing the recommended rate of top dressing fertilizer by 50% can be recommended for ultra short maturity class in rice only in the wet season characterized with low response to fertilizer as it will definitely reduce cost of cultivation without any yield reduction leading to increased profits.

CONCLUSION

Bg 250, which is an ultra short maturity duration rice variety, could produce higher grain yields in the dry season. FCD that requires water supply in ultra short maturity class of rice as represented by Bg 250 could be minimized to about 57-59 days depending on the season by transplanting with 12 day old seedlings at the rate of 3 seedlings/ hill coupled with termination of irrigation at 14 days after 50% heading, without impairing grain yield. The rate of top dressing fertilizer did not influence FCD that requires water supply, but it could be reduced by half of the recommended rate only in the wet season with no yield losses.

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