Ratoon Rice Response to Different Fertilizer Doses in Irrigated Condition

Muhammad SHAMIUL ISLAM [1]
Mirza HASANUZZAMAN [2(✉)]
Md. ROKONUZZAMAN [3]

Summary

The response of different fertilizer doses was studied on the ratoon crop as well as main crop. The different fertilizer doses under the study were F_1 (N=90, P_2O_5 = 45, K_2O=50, S=13, Zn = 4: in kg ha^{-1}), F_2 (N=105, P_2O_5 = 55, K_2O=60, S=13, Zn = 4: in kg ha^{-1}), F_3 (N=120, P_2O_5 = 65, K_2O=70, S=13, Zn = 4: in kg ha^{-1}), F_4(N =135, P_2O_5 =75, K_2O=80, S=13, Zn=4: in kg ha^{-1}) and F_5 (N=150, P_2O_5 = 85, K_2O = 90, S=13, Zn = 4: in kg ha^{-1}). In the main crop, the highest grain and biological yields were produced by F_3 dose. The highest straw yield was produced by F_4 dose. The lowest grain yield and the lowest biological yield were produced by F_1 dose and the lowest straw yield was produced by F_2 dose. The highest crop duration was found using F_1 dose and the shortest crop duration was found using F_3 doses. In the ratoon crop, the highest grain yield, straw yield and biological yield was produced by F_5 dose whereas the lowest grain yield, straw yield and biological yield was achieved with F_1 dose. The longest crop duration was observed using F_2 dose and the shortest crop duration was recorded using F_5 dose.

Key words

rice, ratoon, fertilizer dose, yield, crop duration

[1] Department of Agronomy, Bangladesh Agricultural University, Mymensingh, Bangladesh
[2] Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh
✉ e-mail: mhzsauag@yahoo.com
[3] Department of Agricultural Extension, Chittagong Veterinary and Animal Sciences University, Chittagong, Bangladesh

Received: June 2, 2008 | Accepted: June 21, 2008

Introduction

Increasing rice grain yields per unit of area is one approach to improving total rice production (Santos et al., 2003). Ratooning is the practice of harvesting grain from tillers originating from the stubble of a previously harvested crop (main crop). It enhances rice grain yields without increasing land area (Mengel and Wilson, 1981) because it provides higher resource-use efficiency per unit of land area and per unit of time (Santos et al., 2003). Therefore, the benefit in ratooning lies in the facts of avoiding elaborate land preparation, saving of seed planting costs (Zandstra and Samson, 1979), economic use of machineries, high water use efficiency (Prashar, 1970) and considerable saving in cropping time as it has the advantages of reduced growth duration (Haque and Coffman, 1980).

On an average, ratoon rice can give a yield of roughly equivalent to 40% of that of the main crop, with 40% reduction in crop duration (Chauhan *et al.*, 1983). Ratoon yield is generally less than the main crop but cases of higher yield have also been reported in paddy (Santhi *et al.*, 1993). If grain yield of the ratoon crop alone is considered, it may be seen discouraging. However, if consideration is given to the time factor to express yield, ratoon cultures are found to be very encouraging (Quddus and Pendleton, 1990).

In Bangladesh, crop intensification through rice ratooning constitutes one of the important options for the farmers in achieving food security. In this context, ratooning can play a very significant role with its very short growth duration usually taking only 35% to 60% of the time required for the main crop (Jones and Snyder, 1987). In Bangladesh context, there is potential for rice ratooning form the stubble of *boro* rice with residual soil moisture and monsoon rainwater.

Satisfactory yield of ratoon rice depends on varieties, seasonal requirements, optimum fertilizer dose, time of fertilization, cutting height, planting dates, spacing, growth duration, date of harvest, water and pest management and so on. Among them fertilizer has an important role on the performance of ratoon rice. The ratoon crop responded to N fertilizers given in the main crop (Szokolay, 1956; Ishikawa, 1964; Balasubramanian *et al.*, 1970). It was observed that yield of ratoon crop increased with the increasing rate of nitrogen up to 125 kg ha^{-1} (Balasubramanian and Krishnasamy, 1997). Results indicated that the application of nitrogen by 140 kg ha^{-1} had better yields (increase 12.8-16.1%) and rice quality than nitrogen application at the level of 100 kg ha^{-1} (Chuang and Ding, 1992). Performance of ratoon rice is also affected by phosphorus doses (Bahar et al., 1977). Kavoosi et al. (2004) found that the highest grain yield have obtained from ratoon rice when K_2O was applied as 100 ka ha^{-1}.

Therefore, the present study was undertaken to determine the optimum fertilizer dose for ratoon of rice in Boro (winter) season under Bangladesh condition.

Materials and methods

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the period from December 2003 to August 2004. Geographically, the experimental area is located at 24^0 75′ N and 90^0 50′ E longitude at the elevation of above 18 m the sea level. The soil of the experimental pot was silty-loam having noncalcarious properties. The soil was little less then neutral (pH 6.8) in nature.

The rice variety BRRI dhan 28 was used in this experiment. The treatments comprising five different fertilizer doses viz. fertilizer doses F_1 (N=90, P_2O_5 = 45, K_2O=50, S=13, Zn = 4: in kg ha^{-1}), F_2 (N=105, P_2O_5 = 55, K_2O=60, S=13, Zn = 4: in kg ha^{-1}), F_3 (N=120, P_2O_5 = 65, K_2O=70, S=13, Zn = 4: in kg ha^{-1}), F_4 (N =135, P_2O_5 =75, K_2O=80, S=13, Zn=4: in kg ha^{-1}) and F_5 (N=150, P_2O_5 = 85, K_2O = 90, S=13, Zn = 4: in kg ha^{-1}). The experiments were laid out in a randomized complete block design with three replications for both: the main and the ratoon crops

The experiments individual plot size was 10 m^2 (4 m × 2.5 m). Land was prepared by deep plowing followed by laddering. Forty three day old seedlings were transplanted in the main field at the rate of two seedlings hill^{-1}. The main crop was fertilized according to the experimental treatments. Except urea, fertilizers were applied at the time of final land preparation. Urea was top dressed in three equal splits at 15, 30 and 45 days after transplanting (DAT). Intercultural operations such as weeding, water management and plant protection measures were done as and when required for ensuring and maintaining the normal growth of crop.

The main crop was harvested leaving a culm height 25 cm above the ground level. Ten hills (excluding border hills) were randomly selected from each unit plot prior to harvest for recording of necessary data on different crop characters. Entire plot was harvested for taking grain and straw yield data. Grain and straw yield of 10 sample plants of each plot were added to those of entire plot to calculate the yields (grain and straw) per unit plot. The data on crop characters like plant height, total number of tillers hill^{-1}, number of effective tillers hill^{-1}, number of panicles hill^{-1}, number of fertile grain panicle^{-1}, 1000-grain weight, grain yield, straw yield and crop duration were recorded from sample plants at maturity. Biological yield and harvest index were calculated from the grain and straw yields of each entire plot. Collected data were analyzed following ANOVA techniques by using MSTAT-C computer package.

The mean differences were adjudged by Duncan's Multiple Range Test (DMRT).

Results and discussion

Plant height

The plant height was significantly influenced by the fertilizer dose. Both of the main crop and ratoon crop were affected by fertilizer doses (Table 1). It was observed that the highest plant height of main crop as well as ratoon crop was produced by F_3 dose (N=120, P_2O_5 = 65, K_2O=70, S=13, Zn = 4: in kg ha^{-1}) whereas the lowest plant height was produced by F_5 dose (N=150, P_2O_5 = 85, K_2O = 90, S=13, Zn = 4: in kg ha^{-1}). The increase in plant height due to application of increased level of nitrogen might be associated with stimulating effect of nitrogen of various physiological processes including cell division and cell elongation of the plant. Zandstra and Samson (1979) stated that pant height increased significantly due to nitrogen application. The excess doses of N after F_4 did not showed increases in plant height. Mengel and Wilson (1981) reported that an N fertilizer application rate of 125 kg ha^{-1} followed by immediate flooding produced highest ratoon rice yields. In every case the plant height of the ratoon crop was lower than the main crop and it ranged from 70-73% of the main crop. It was due to less ability to use the resources in plant body which is confirmed by Jones (1993).

Total number of tillers hill^{-1}

Fertilizer dose had a significant effect on the total number of tillers hill^{-1} in this study. Only the main crop showed a significant response to N in terms of tiller production. The highest total number of tillers hill^{-1} was produced by F_3 dose. On the contrary, the lowest total number of tillers hill^{-1} was produced by F_1 which was statistically similar to that produced in the case of F_2 dose (Table 1). Total number of tillers hill^{-1} produced by F_4 was 23.43 and 21.79, respectively, which was statistically different from each other. This result corroborated with the result of Maqsood *et al.* (1999). The variation of fertilizer dose did not showed significant changes in plant height in ratoon crop. However, numerically the highest total number of tillers hill^{-1} was found in F_5 dose whereas the lowest total number of tillers hill^{-1} was found in F_1 dose (Table 2). It was due to less potentiality of the ratoon rice to tiller production (Bollich and Turner, 1988).

Number of effective tillers hill^{-1}

Fertilizer dose had significant effect on the number of effective tillers hill^{-1}. In the main crop, the highest number of effective tillers hill^{-1} was produced by F_3 dose and it was similar to that produced in F_4 dose. The lowest number of effective tillers hill^{-1} was produced by F_1 dose which was statistically similar to that of F_2 dose. The number of effective tiller hill^{-1} produced by F_5 dose was statistically dissimilar to that produced at rest of the fertilizer doses. In ratoon crop, the number of effective tillers hill^{-1} was not significantly influenced by fertilizer dose. Numerically, the highest number of effective tillers hill^{-1} was produced by F_5 dose. The lowest number of effective tillers hill^{-1} was produced by F_1 dose. It was due to the less capacity of ratoon crop to produce effective tiller with increased N, P and K. Ratoon crop also possesses less tiller producing potentiality than the main crop (Bollich and Turner, 1988).

Number of panicles hill^{-1}

Number of panicles hill^{-1} was significantly affected by different fertilizer doses both in main crop and ratoon crop in this study (Table 2). In case of main crop the highest number of panicle (42.11) was observed from F_5 which was statistically similar with F_4. In case of ratoon crop, maximum numbers of panicle was observed from F_5 which was statistically different from other doses. Although the response of fertilizer doses in rice was significant, the panicle producing capacity in ratoon crops was almost half

Table 1. Effect of fertilizer dose on plant height, total tiller and effective tillers of main and ratoon crop of *Boro* rice

Fertilizer dose	Plant height (cm)			Total number of tillers hill^{-1}			Number of effective tillers hill^{-1}		
	Main crop	Ratoon crop	% of main crop	Main crop	Ratoon crop	% of main crop	Main crop	Ratoon crop	% of main crop
F_1	113.72 c	82.81 c	72.82 (-27.18)	19.36 d	12.67	65.46 (-34.56)	11.36 c	6.82	80.04 (-19.96)
F_2	120.22 b	87.85 b	73.07 (-26.93)	20.42 d	13.18	64.54 (-35.46)	12.00 c	8.62	71.83 (-28.71)
F_3	133.18 a	97.36 a	73.11 (-26.89)	24.89 a	12.56	50.46 (-49.54)	16.58 a	7.62	45.96 (-54.04)
F_4	107.90 d	78.84 d	73.07 (-26.93)	23.43 b	14.36	52.49 (-38.79)	15.60 a	8.91	57.12 (-42.88)
F_5	98.02 e	69.03 e	70.42 (-29.58)	21.79 c	15.82	72.60 (-27.40)	13.50 b	10.31	76.37 (-23.63)
$S_{\bar{x}}$	1.54	0.66	-	0.38	0.75	-	0.44	0.75	-

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with different letters differ significantly (as per DMRT) at P≤0.05. * Figures in the parentheses indicate % increase (+) or decrease (-) in the ratoon crop as compared to the respective value in the main crop. F_1 (N=90, P_2O_5 = 45, K_2O=50, S=13, Zn = 4: in kg ha^{-1}); F_2 (N=105, P_2O_5 = 55, K_2O=60, S=13, Zn = 4: in kg ha^{-1}); F_3 (N=120, P_2O_5 = 65, K_2O=70, S=13, Zn = 4: in kg ha^{-1}); F_4 (N =135, P_2O_5 =75, K_2O=80, S=13, Zn=4: in kg ha^{-1}); F_5 (N=150, P_2O_5 = 85, K_2O = 90, S=13, Zn = 4: in kg ha^{1})

Table 2. Effect of fertilizer dose on the number of panicles, fertile grain and 1000-grain weight of main and ratoon crop of *Boro* rice

Fertilizer dose	Number of panicles hill^{-1}			Number of fertile grain panicle^{-1}			1000-grain yield (g)		
	Main crop	Ratoon crop	% of main crop	Main crop	Ratoon crop	% of main crop	Main crop	Ratoon crop	% of main crop
F_1	27.88 d	14.32 d	51.36 (-48.64)	88.43 d	40.40 d	45.69 (-54.31)	22.05 c	19.76 e	89.59 (-10.41)
F_2	34.55 c	16.22 c	46.95 (-53.05)	90.92 d	43.85 c	48.23 (-51.77)	23.85 b	22.65 b	94.96 (-5.04)
F_3	38.99 b	19.78 b	50.73 (-49.27)	99.63 c	53.43 ab	53.63 (-46.37)	28.17 a	26.92 a	95.56 (-4.44)
F_4	40.11 a	20.44 b	50.96 (-49.04)	124.74 b	54.01 a	43.30 (-56.70)	23.15 b	21.81 c	94.21 (-5.79)
F_5	42.11 a	22.76 a	54.05 (-45.95)	139.66 a	55.32 a	39.61 (-60.39)	21.77 c	20.21 d	92.82 (-7.18)
$S_{\bar{x}}$	0.89	0.76	-	2.02	1.09	-	0.28	0.14	-

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with different letters differ significantly (as per DMRT) at P≤0.05.* Figures in the parentheses indicate % increase (+) or decrease (-) in the ratoon crop as compared to the respective value in the main crop. F_1 (N=90, P_2O_5 = 45, K_2O=50, S=13, Zn = 4: in kg ha^{-1}); F_2 (N=105, P_2O_5 = 55, K_2O=60, S=13, Zn = 4: in kg ha^{-1}); F_3 (N=120, P_2O_5 = 65, K_2O=70, S=13, Zn = 4: in kg ha^{-1}); F_4 (N =135, P_2O_5 =75, K_2O=80, S=13, Zn=4: in kg ha^{-1}); F_5 (N=150, P_2O_5 = 85, K_2O = 90, S=13, Zn = 4: in kg ha^{1})

Table 3. Effect of fertilizer dose on the yields and harvest index of main and ratoon crop of *Boro* rice

Fertilizer dose	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Harvest index (%)		
	Main crop	Ratoon crop	% of main crop	Main crop	Ratoon crop	% of main crop	Main crop	Ratoon crop	% of main crop
F_1	4.92 d	1.22 b	24.75 (-75.25)	4.85 b	1.12 d	23.13 (-76.87)	50.35	52.13	103.78 (+3.78)
F_2	5.20 cd	1.24 b	23.81 (-76.19)	4.77 b	1.21 c	25.27 (-74.73)	52.15	50.61	99.77 (-0.23)
F_3	6.18 a	1.28 b	20.77 (-79.23)	5.44 ab	1.32 b	24.21 (-75.79)	53.18	49.23	95.65 (-4.35)
F_4	5.85 ab	1.42 a	24.32 (-75.68)	5.72 a	1.42 a	24.91 (-75.09)	50.56	50.00	93.96 (-6.04)
F_5	5.54 bc	1.42 a	25.58 (-74.42)	5.24 ab	1.46 a	27.77 (-72.23)	51.39	49.30	96.13 (-3.87)
$S_{\bar{x}}$	0.13	0.04	-	2.2	0.03	-	1.24	1.53	-

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with different letters differ significantly (as per DMRT) at P≤0.05.* Figures in the parentheses indicate % increase (+) or decrease (-) in the ratoon crop as compared to the respective value in the main crop. F_1 (N=90, P_2O_5 = 45, K_2O=50, S=13, Zn = 4: in kg ha^{-1}); F_2 (N=105, P_2O_5 = 55, K_2O=60, S=13, Zn = 4: in kg ha^{-1}); F_3 (N=120, P_2O_5 = 65, K_2O=70, S=13, Zn = 4: in kg ha^{-1}); F_4 (N =135, P_2O_5 =75, K_2O=80, S=13, Zn=4: in kg ha^{-1}); F_5 (N=150, P_2O_5 = 85, K_2O = 90, S=13, Zn = 4: in kg ha^{1})

the main crop. It was due to less number of effective tillers as well as less nutrient use efficiency. This result was supported by Bollich et al. (1994). In both of the cases F_1 produced lowest number of panicles hill^{-1}.

Number of fertile grain panicle^{-1}

Number of fertile grains panicle^{-1} was significantly influenced by fertilizer dose in main crop as well as in ratoon crop. In the main crop, highest number of fertile grains panicle^{-1} was found in F_5 dose, which was statistically different than other doses (Table 2). The lowest number of fertile grains panicle^{-1} was found in F_1 dose, which was statistically similar to that produced in F_2 dose. In ratoon crop the fertile grain production was 46-60% lower than in main crop but it was significantly influenced by fertilizer doses. In this case, the highest number of fertile grains panicle^{-1} was found in F_5 but it was statistically at per with F_4 and F_3 showing no extra benefit of using excess of fertilizer for production of higher fertile grain from ratoon rice crop. However, lowest number of fertile grains panicle^{-1} was found in F_1 dose that was due to improper grain filling with these doses. This result is supported by Evatt and Beachell (1969).

1000-grain weight

In this study 1000-grain weight was significantly affected by fertilizer dose both in main crop and ratoon crop. The highest 1000-grain weight was found in F_3 dose (N=120, P_2O_5 = 65, K_2O=70, S=13, Zn = 4: in kg ha^{-1}) both in main and ratoon crop (Table 2). On the contrary, the lowest 1000-grain weight was found in F_5 dose in case of main crop. But in ratoon crop it was lowest with F_1 treatments. It was revealed that the response of using fertilizers was higher in ratoon crop than in main crop in Boro rice. Probable reason for lower grain weight might be due to insufficient nutrient supply to the ratoon crop. Kasturi and Purushothaman (1992) observed that grain yield and 1000-grain weight were highest with 100 kg N + 50 P_2O_5 + 50 kg K_2O ha^{-1}. Fageria et al. (1997) also found similar results.

Grain yield

In the main crop, grain yield was significantly influenced by fertilizer dose. The highest grain yield was found in F_3 dose which was statistically similar to that produced at F_4 dose (Table 3). The lowest grain yield was found in F_1 dose which was statistically similar to that produced in

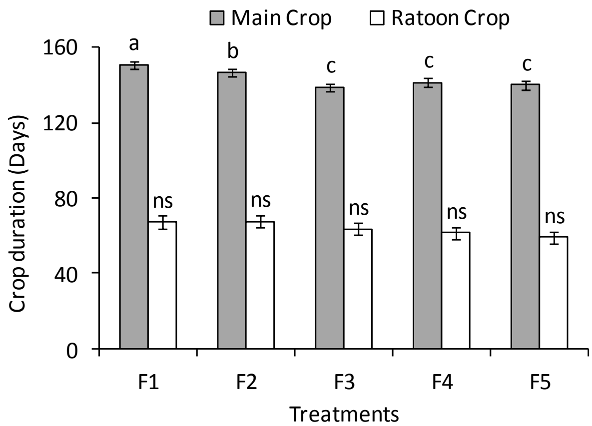

Figure 1. Crop duration of main and ratoon crop of *Boro* rice as affected by fertilizer doses. (Means separation in columns followed by the same letter(s) are not significantly different at P≤0.05; ns= non significant; F_1 (N=90, P_2O_5 = 45, K_2O=50, S=13, Zn = 4: in kg ha^{-1}); F_2 (N=105, P_2O_5 = 55, K_2O=60, S=13, Zn = 4: in kg ha^{-1}); F_3 (N=120, P_2O_5 = 65, K_2O=70, S=13, Zn = 4: in kg ha^{-1}); F_4 (N =135, P_2O_5 =75, K_2O=80, S=13, Zn=4: in kg ha^{-1}); F_5 (N=150, P_2O_5 = 85, K_2O = 90, S=13, Zn = 4: in kg ha^{-1})).

F_2 dose. Fertilizer dose also showed a significant effect on the grain yield of ratoon crop. But in this case, the highest grain yield was obtained from F_4 dose which was statistically identical with F_5 dose, which indicated that response of ratoon rice to fertilizer was stronger than that of main crop. Kasturi and Purushothaman (1992) also observed that grain yield varied with different fertilizer dose. The higher response of fertilizer doses to grain production might be due to more number of tillers, more panicles and grain weight. This result was in agreement with Choi and Kwon (1985), Hsieh and Young (1959) and Szokolay (1956).

Straw yield

Results showed that the straw yield was significantly influenced by fertilizer dose. In main crop, the highest straw yield was found in F_4 dose, which was identical to that produced in F_3 doses. The lowest straw yield was found in F_2 dose, which was statistically similar to that in rest of the fertilizer doses except F_4 dose. In case of ratoon crop, the response was little more than in main crop. In this case the highest straw yield was found in F_5 dose, which was statistically similar to that produced in F_4 dose. The lowest straw yield was found in F_1 dose. It was due to lower plant height and tiller production with these treatments. These results were supported by Setty *et al.* (1993), Kasturi and Purushothaman (1992) and Yuan *et al.* (1996).

Harvest index

There were no significant differences in harvest index due to fertilizer doses in both main crop and ratoon crop (Table 3). However, in main crop numerically the highest harvest index was found in F_3 dose. On the other hand, the lowest harvest index was found in F_1 dose. But in case of ratoon crop, the opposite results were observed.

Crop duration

Crop duration was significantly affected by fertilizer dose. In main crop, the effect was statistically significant whereas there were no significant effect of fertilizer doses on ratoon crops. In main crop, the highest crop duration was observed in F_1 dose. On the other hand, the lowest crop duration was observed in F_3 dose, which was statistically similar to that of F_4 and F_5 doses (Figure 1). In case of ratoon crop, the highest crop duration was recorded in F_2 dose and the lowest crop duration was observed in F_5 dose. In every case the duration of ratoon crop was much shorter than main crop. 43-55% lower crop duration was observed in case of ratoon cropping in Boro rice. This result is supported by Santos et al. (2003) and Haque and Coffman (1980). Jones and Snyder (1987) reported that ratoon rice needs very short growth duration usually taking only 35% to 60% of the time required for the main crop.

Conclusions

From the study it may be concluded that performance of ratoon rice as well as main crop of rice have a tremendous response to different fertilizer doses. In both of the cases yield and yield components were significantly influenced by fertilizer doses. Maximum grain yield of main crop as well as ratoon crop was produced by N=150, P_2O_5 = 85, K_2O = 90, S=13, Zn = 4: in kg ha^{-1}. Grain yield from ratoon crop was found to be lower than main crop but the crop duration was much shorter than main crop that may be a good alternative to increase total rice production.

References

Bahar F. A., De Datta S. K. (1977). Prospects of increasing tropical rice production through ratooning. Agron. J. 69:536-540

Balasubramanian B., Morachan Y. B., Kaliappa, R. (1970). Studies on ratooning in rice. Growth attributes and yields. Madras Agric. J. 57(11): 565-570.

Balasubramanian R., Krishnasamy S. (1997). Rice ratooning as influenced by varieties, nitrogen and cutting height. Madras Agric. J. 84 (8): 489-491.

Bollich C. N., Turner F. T. (1988). Commercial ratoon rice production in Texas, USA. Pages 257-264 in: Rice Ratooning. Intl. Rice Res. Inst., Manila, Philippines.

Bollich P. K., Lindau C. W., Norman R. J. (1994). Management of fertilizer nitrogen in dry-seeded, delayed-flood rice. Aust. J. Exp. Agric. 34:1007-1012.

Chauhan J.S., Virmani S.S., Aquino R.R., Vergara B.S. (1983). Evaluation of hybrid rice for ratooning ability. Intl. Rice Res. Newsl. 8(6): 6.

Choi H.C., Kwon K.W. (1985). Evaluation of varietal difference and environment variation for some characters related to source and sink in the rice plants. Korean J. Crop Sci. 30: 460-470

Chuang Y.S., Ding W.Y. (1992). Effect of nitrogen application on yield and quality of rice with different ratoon treatments. Bulletin of the Hualien District Agricultural Improvement Station No.9:83.

Evatt N.S., Beachell M.H. (1969). Ratoon cropping of short-season rice varieties in Texas. IRC Newsl. 9(3):1-4.

Fageria N.K., Santos A.B., Baligar, V.C. (1997). Phosphorus soil test calibration for lowland rice on an Inceptisol. Agron. J. 89: 737–742.

Haque M.M., Coffman W.R. (1980). Varietal variation and evaluation procedures for ratooning ability in rice. SABRAO J. 12(2): 113-120.

Hsieh C.F., Young F.P. (1959). Studies on the cultivation of ratoon. J. Taiwan Agri. Res. 8(2): 31-32.

Ishikawa T. (1964). Studies on the ratoon rice plant in early cultivation. Bull. Fac. Agric. Univ. Miyazaki, Japan. 10(2): 72-78.

Jones D. B. (1993). Rice ratoon response to main crop harvest cutting height. Agron. J. 85:1139-1142.

Jones D.B., Snyder G.H. (1987). Seeding rate and row spacing effects on yield and yield components of ratoon rice. Agron. J. 79: 627-629.

Kasturi K., Purushothaman S. (1992). Varietal and fertilizer response of ratoon rice (*Oryza sativa*). Indian J. Agron. 37(3): 565-566.

Kavoosi M., Moghadam R., Masoud A., Rahmatollah S., Yosef G., Ebrahim A., Mehrdad M., Gavad Y., Mohammad K., Abed M. (2004). Requirement of rice ratoon to macroelements (nitrogen and potassium) in Guilan paddyfields. Rice Reseach Institute of Iran. (Cited from AGRIS record No. IR2006000617).

Maqsood M., Irshad M., Hussain M.I., Rafiq K. (1999). Effect of nitrogen on growth, yield and quality of fine rice. Pakistan J. Biol. Sci. 3(11): 1831-1832.

Mengel D. B., Wilson F. E. (1981). Water management and nitrogen fertilization of ratoon crop rice. Agron. J. 73:1008-1010.

Prashar C.R.K. (1970). Some factors governing rice-ratoon yields. Plant and Soil. 32(2): 540-541.

Quddus M.A., Pendleton J.W. (1990). Management effects on main rice crop and its ratoon. Bangladesh J. Agric. 3(1&3):11-14.

Santhi P., Ponnuswamy K., Shanmugasundaram V.S. (1993). Economic evaluation of ratoon paddy in low lying old ayacut areas of Tamil Nadu .New-Botanist. 20: 1-4, 217-220.

Santos A.B., Fageria N.K., Prabhu, A. S. (2003). Rice ratooning management practices for higher yields. Commun. Soil Sci. Plant Anal. 34:881-918.

Setty T.K.P., Parameshwar N.S., Mahadevappa M. (1993). Response of Mukthi (CTH1) ratoon to nutrition in coastal Karnataka, India. Intl. Rice Res. Notes. 18(1): 42-43.

Szokolay G. (1956). Ratooning of rice on the Swaziland irrigation scheme. World Crops. 8(2): 71-73.

Yuan J., Xiaatlui S., Tianthua T., Jun M., Yuan J.C. (1996). Study on nitrogen requirement and split application of nitrogen fertilizer in ratoon rice. Acta Agron. Sinica. 22(3): 345-352.

Zandstra H.G., Samson, B.T.S. (1979). Rice ratoon management. Discussion paper presented at the International Rice Research Conference, April 1979:16-21 pp.

acs73_31