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IDENTIFICATION OF PROMISSING RICE VARIETIES FOR LOW FERTILE SOILS IN THE LOW COUNTRY INTERMEDIATE ZONE

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ABSTRACT

Low productivity under short supply of plant nutrients has become a major problem for high yielding rice varieties developed by the Rice Research and Development Institute (RRDI) as the soil fertility in Sri Lankan paddy fields is in a declining trend. Therefore, experiments were conducted at the RRDI, Batalagoda to find out the most adaptable three and half months rice varieties to low fertility conditions. Eighteen high yielding three and half months rice varieties recommended by the Department of Agriculture were evaluated for plant growth and yielding ability in the fields maintained with no fertilizer addition for the last 33 years as well as in the field applied with recommended fertilizer during the same time period. According to the results, varietal differences in the performance under different fertility conditions have been proved in rice. Response of rice varieties to increasing soil fertility is different among rice varieties in term of plant height, grain yield and number of panicles. Bw 367 and Bw 363 performed well under low fertile conditions and moderate response (increasing yield proportional to increase in fertilizer level) to fertilizer. Yield reduction due to non-addition of fertilizer for Bw 367 and Bg 363 was only 23% and 35%, respectively. This study suggests that varietal response to changing soil fertility is very and Bw 363 and Bw 367 performed well under no added fertilizer conditions. Therefore, they are suitable to improve productivity of low fertility rice soils in the Low Country Intermediate Zone.

KEYWORDS: Adaptability, Rice varieties, Soil fertility.

INTRODUCTION

Rice occupies approximately 33% of the total cultivated land extent in Sri Lanka accounting to 0.78 million ha (CBSL, 2010). Two third of the cultivated rice extent is in the Dry and Intermediate Zones. Almost all the rice fields in the Dry and Intermediate Zones are extensively cultivated to high yielding rice varieties of yield potential above 10 t/ha. High yielding varieties need high rate of nutrients to give optimum yield benefits (Abeysiriwardene and Sandanayake, 2000). Most of the rice growing soils in Sri Lanka are low in organic matter, available P and exchangeable K due to continuous cultivation and adsorption to soil colloids (Bandara, 2006). Soil fertility in the Dry and Intermediate Zones declines continuously and as such, low grain production under short supply of plant nutrients has become a major problem for high yielding varieties. Therefore, farmers are encouraged liberal heavy application of all plant nutrients to sustain productivity. As nitrogen, phosphorus and potassium are the three major nutrients required by rice, a crop yielding 6 t/ha grain yields removes around 120 kg N, 120 kg K and 20 kg of P per season (Wickramasinghe *et al*., 2009). As a result, application of nitrogen, phosphorous and potassium fertilizers has been continuously increased since 1960. In the year 2001 fertilizer recommendation, N, P and K nutrients were given based on target yield levels and as such majority of the paddy fields received N, P and K levels above 100 kg N, 35 kg P_2O_5 and 30 kg K_2O per ha, respectively.

Despite heavy application of nutrients, the present cultivation system use only 20-30% of the applied N fertilizer and as a result large quantities of nitrogen fertilizer are wasted enhancing air and water pollution (Sirisena *et al*., 2001). According to Kendaragama *et al.* (2003), higher level of P application with limited supply of other nutrients in long run leads excess availability of P in paddy soils. This soil P might be transported to water bodies with irrigation water and at finally large application of P fertilizer increases eutrophication of surface water bodies. In addition, Chronic Kidney Disease of unknown etiology is a long standing health problem in the Dry Zone areas and heavy metals contained in phosphorous fertilizer have been suspected to cause this disease (Bandara *et al*., 2008). Potassium is another major nutrient with a critical role in regulating assimilates transportation; its short supply could affect the productivity of rice. To maximize the use of rice straw and to reduce the use of K fertilizer, K had been removed from the basic rice fertilizer recommendation in Sri Lanka in 1996 but re-introduced in 2001 considering the fact that the removal of K from fertilizer mixtures would lead to a greater risk in rice production (DOA, 2001). In the 2001, K fertilizer at the rate of 40 kg K_2O/ha was introduced even with the application of rice straw (DOA, 2001).

Rice production has become a marginal entity at present due to increased costs of inputs, especially labour, fertilizer and pesticides and low farm gate price. Therefore, to reduce the burden to farmers, fertilizers are given at subsidiary rates to rice farmers. With the introduction of fertilizer subsidy scheme, all the fertilizers are given merely at Rs. 7/kg. As a result of fertilizer subsidy, almost all farmers apply fertilizer to their rice fields but sometimes yield levels are below 4 t/ha. Obtaining low yields even with subsidized fertilizer use have become a burden to the government of Sri Lanka. Screening rice varieties for their performance under low fertility conditions is vital under present circumstance because fertilizer prices are increasing and environmental pollution due to fertilizer is highly concerned by the environmentalists and soil scientists. All the above reasons compelled scientists to find out ways and means to improve fertilizer use efficiency in rice in Sri Lanka. Selection of rice varieties suitable for low and high fertility conditions is one of the appropriate measures for efficient use of N, P and K fertilizers while maintaining high productivity. Seventy eight high yielding rice varieties have been developed by the Rice Research and Development Institute (RRDI) during the past 60 years but their performance under low fertility conditions has not been tested todate. Therefore, this study was conducted to identify rice varieties that are giving high yields at low fertilizer levels while showing a moderate response (increasing yield proportional to increase in fertilizer level) to fertilizer.

MATERIAL AND METHODS

Experiments were set up in *maha* 2013/2014 at the research field of the Rice Research and Development Institute (RRDI) which is situated in the Low Country Intermediate Zone (IL_3). A field maintained without fertilizer for last 33 years and a field maintained with recommended fertilizer practice for the same period was selected for the experiment. Eighteen high yielding three and half months old rice varieties developed by the RRDI were used in the study. Rice varieties selected for the study were Bg 94-1, Bw 351, Bg 352, At 353, At 354, Bg 357, Bg 358, Bg 359, Bg 360, Bw 361, At 362, Bw 363, Bw 364, Ld 365, Bg 366, Bw 367, Ld 368 and Bg 369. Twenty days old rice seedlings of the above rice varieties were transplanted at the rate of one seedling per hill in three row plots separately in both fields. Length of the three rows plot was 6 m and rice seedlings were planted at the spacing of 15 x 15 cm. Varieties were grown in RCBD design and replicated three times in both fertility conditions. Chemical fertilizers for fertilized field were applied as recommend by the Department of Agriculture (DOA, 2001). Fertilizer was not applied for no-fertilizer field. Plant height of rice varieties were recorded at 35 days after transplanting. At maturity, grains were harvested and grain yield and number of panicles per hill were recorded. Soil samples were collected at the time of planting from both fields and analyzed for pH, EC, available P, exchangeable K, total N and organic matter.

RESULTS AND DISCUSSION

Soil fertility of the field, which has been cultivated with rice for the last 33 years without fertilizer, is significantly lower than that of the field cultivated with recommended fertilizer application (Table 1). Fertility level of the low fertile soil is exceptionally lower than the values given by Bandara (2006) for high rice yields. Thus, a difference in soil fertility levels between high and low fertile fields adequate for the experiment has been achieved. Plant height is an important indicator that gives the plant's ability to response to fertilizer addition (Nahar *et al.*, 2009).

With application of fertilizer, plant height increased in all the varieties (Figure 1 and Table 2). Analysis of results shows that interaction effect between variety x fertility level was significant at 5% probability level. As such plant height of some rice varieties increase at higher rate than the others. As an example, Bg 369 is the tallest variety within the 18 recommended rice varieties while 360 is the shortest variety. The highest increase in plant height due to high fertility was recorded from Bg 360 and followed by Bg 358 and Bg 359. Bg 369, Ld 365 and Bw 367 show the least increase in plant height due to high fertility.

Table 1: Initial soil fertility status of the experimental sites.

Fertility parameter	Low fertile soil	High fertile soil
Total nitrogen (%)	0.02	0.07
Available phosphorous (mg/ kg)	1.7	5.7
Exchangeable Potassium (mg/ kg)	11	57
EC μ S/cm	54.8	57
pH	5.78	6.6
Organic matter (%)	0.61	1.8

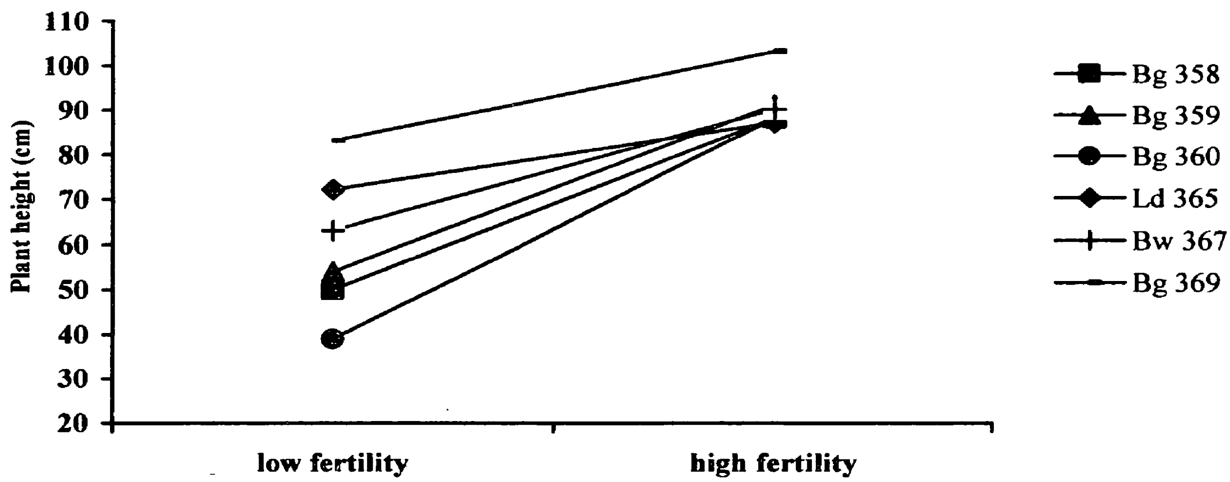

Figure 1. Changes of plant height of rice varieties.

Grain yield per hill is an important parameter which gives the indication of the yielding ability of individual rice variety. With the increasing fertility levels, grain yield increased in all varieties (Figure 2 Table 3) Analysis of results shows that interaction effect between variety x fertility level for grain yield was significant at 5% probability level. As such grain yield of some rice varieties increase at higher rate than the others. According to the yield data presented in Table 3, BW 367 which produced grain yield of 15.3 g per hill is the highest yielding variety under low fertility conditions and this was followed by Bw 363, Bw 364, Bg 366 and Bg 369 (Table 3). Bg 358 Bg 359 and Bg 352 produced the highest yield at high fertility conditions. The highest increase in grain yield due to high fertility was recorded from Bg 360 and followed by Bg 358 and Bg 359 while Bw 363, Bw 367 and Bg 366 show the least change in grain yield due to high fertility (Figure 2).

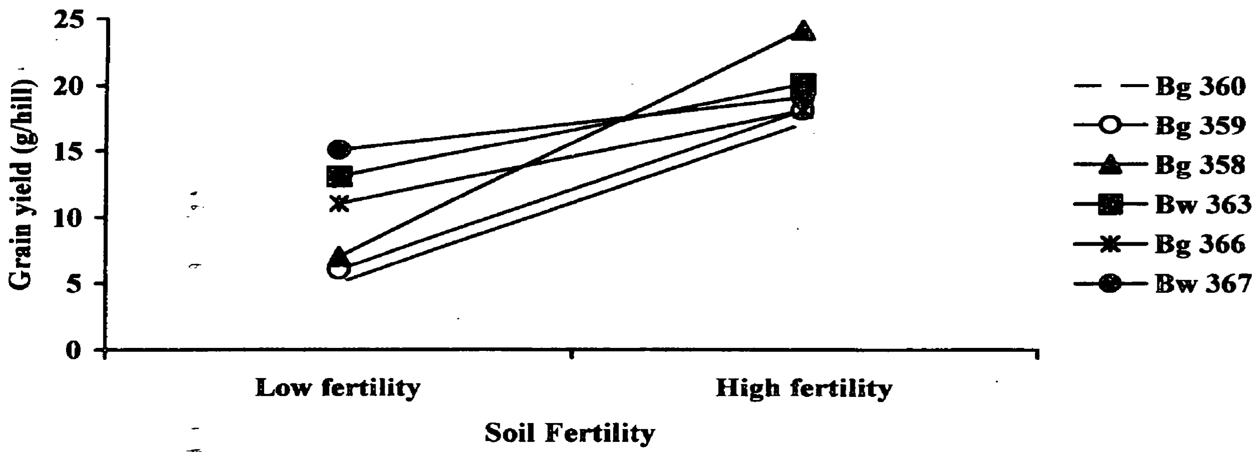

Figure 2. **Grain yield changes of rice varieties due to different fertility levels.**

Table 2. **Change of plant height of rice varieties grown in high and low fertility conditions.**

Variety	Plant height (cm)		
	No fertilizer added condition (Low Fertility)	fertilizer added condition (High fertility)	Plant height reduction due to low fertility (%)
Bg 94-1	60.2 ef	80.8 ef	32.4 cdefg
Bw 351	44.8 ih	74.5 f	28.8 efghi
Bg 352	54.5 gf	88.4 cde	25.4 fghij
At 353	46.6 ih	93.5 bcd	42.9 bcd
At 354	48.3 gh	84.4 ed	45.6 abc
Bg 357	45.3 ih	76.9 ef	37.0 bcdef
Bg 358	50.3 gh	102.2 ab	49.0 ab
Bg 359	54.4 gf	91.7 dc	47.6 ab
Bg 360	39.8 i	88.7 cde	58.2 a
Bw 361	52.1 gh	79 ef	37.0 bcdef
At 362	61.8 ef	92.8 ed	40.6 bcde
Bw 363	67.4 cde	85.6 cde	19.7 ghij
Bw 364	69.7 dc	101.4 ab	31.3 defgh
Ld 365	72.9 bc	87.5 cde	14.6 j
Bg 366	78.3 ab	92.3 dc	23.6 fghi
Bw 367	63.2 de	90 dc	19.3 ij
Ld 368	78.3 ab	96.5 abc	18.1 hij
Bg 369	83.4 a	103.1 a	12.8 j

Note: Means in each column followed by the same letter are not significantly different (P =0.05).

It is interesting to note that BW varieties, (Bw 363, Bw 367) are highly suitable for iron toxic conditions where soil P and K contents are limiting (DOA, 2011). This may be one of the reasons for Bw varieties to perform well under low fertility conditions. The highest yield increase due to high fertility was recorded by Bg 358 which is the most popular short grain rice variety in Sri Lanka and this was followed by Bg 352 and Bg 357.

Table 3. Changes of grain weight of rice varieties grown in high and low fertility conditions.

Variety	*Grain weight (g) per hill*		
	No fertilizer added condition (Low Fertility)	*fertilizer added condition (High Fertility)*	*Grain weight reduction (%)*
Bg 94-1	9.2 cdef	22.1 abc	58.4 bcde
Bw 351	6.5 fg	17.1 c	61.9 abcd
Bg 352	6.3 fg	21.6 abc	70.8 a
At 353	6.4 fg	18.9 abc	66.1 abc
At 354	7.9 defg	18.5 bc	57.3 cde
Bg 357	7.8 efg	23.1 abc	66.2 abc
Bg 358	7.6 efg	24.8 a	69.3 ab
Bg 359	6.0 fg	18.9 bc	68.2 abc
Bg 360	5 f	17.1 bc	70.7 a
Bw 361	7.0 efg	20.6 abc	66.0 abc
At 362	7.8 efg	19.8 abc	60.6 abde
Bw 363	13.5 ab	20.3 abc	35.0 g
Bw 364	11.1 bc	23.1 ab	51.9 edf
Ld 365	8.5 cdef	18.4 bc	49.1 edf
Bg 366	11.0 bcd	18.6 bc	40.8 gf
Bw 367	15.3 a	19.9 abc	23.4 h
Ld 368	9.9 ecd	19.3 abc	48.7 ef
Bg 369	10.9 bcd	22.5 abc	51.5 edf

Note: Mean in each column followed by the same letter are not significantly different (P =0.05).

All the above rice varieties are widely grown under intensive rice cultivation in Sri Lanka (RRDI, 2013). Adaptability testing of rice varieties under both high and low fertility conditions is an important criterion in the present study. Accordingly, varieties were selected for their lowest yield reduction due to non- addition of fertilizer. Results in the Table 3 and Figure 2 revealed that in term of grain yield Bw 367 and Bw 363 are the most stable varieties under both conditions and yield reduction due to changes from high fertility to low fertility is 23 % and 35%, respectively.

The productivity of rice plant is greatly dependent on the number of productive tillers. Hence we observed the panicle number which represents the number of effective tillers. Guowei *et al.* (1998) reported that rice crop functions as a population of tillers produced at different times and possessing specific growth characteristics. They showed significant contribution of cultivar tillering ability to dry matter accumulation, yield components, and grain yield. Singh *et al.* (2003) reported that crop growth rate and relative growth rate was significantly influenced by NPK.

Table 4. **Changes of number of panicles of rice varieties grown in high and low fertility conditions.**

Variety	Number of panicles		
	No added fertilizer condition (Low Fertility)	Added fertilizer condition (High Fertility)	Increase in panicle Number (%)
Bg 94-1	5.3 abc	9.4 abcd	58.4 abcde
Bw 351	4.3 bc	9.0 abcde	62.1 abcd
Bg 352	5.8 abc	9.6 abc	39.5 de
At 353	4.7 abc	8.6 bcde	45.3 abcde
At 354	5.1 abc	8.2 bcde	37.8 de
Bg 357	4.4bc	10.4 ab	57.6 abcde
Bg 358	4.4 bc	8.6 bcde	48.8 abcde
Bg 359	4.3 bc	7.6 cde	43.4 bcde
Bg 360	4.6 abc	10.6 a	56.6 abc
Bw 361	4.9 abc	11.5 a	57.3 ab
At 362	4.3 bc	6.8 de	36.7 e
Bw 363	6.3 a	9.6 abc	34.3 e
Bw 364	4.8 abc	9.4 abcd	48.9 abcde
Ld 365	4.0c	9.7 abc	58.7 abcde
Bg 366	3.7 c	6.7 de	44.7 abcde
Bw 367	5.1 abc	6.6 e	22.7 f
Ld 368	4.9 abc	8.5 bcde	42.3 de
Bg 369	4.5abc	7.0 cde	37.5 cde

Note: Means in each column followed by the same letter are not significantly different (P =0.05).

The tiller number and total dry matter production are closely correlated with yield depending on the rice cultivar (Tanaka, 1968).Tiller production can be greatly enhanced by applying proper nutrient levels (Dobermann and Fairhurst. 2000). It is shown in Figure 3 and Table 4 that response to added fertilizer is clearly indicated by the panicle number per hill. Analysis of results shows that interaction effect between variety x fertility level for panicle number was significant at 5% probability level. As such panicle number of some rice varieties increase at higher rate due to high fertility than the others. Highest number of panicles (6.3) at low fertility conditions were reported by Bw 363 and followed by Bw 367, Bw 364, Bw 361 while Bg 360, Bg 357 and Bg 352 had higher panicles under high fertility conditions. Varieties which produced highest grain yield under low fertility conditions also produced highest number of tillers per hill. As such, all Bw varieties, except Bw 351, produced significantly higher number of panicles per hill at low fertility levels. In addition, varieties which produced higher grain yield under high fertility conditions (Bg 360, Bg 357 and Bg 352) had higher panicles under high fertility conditions.

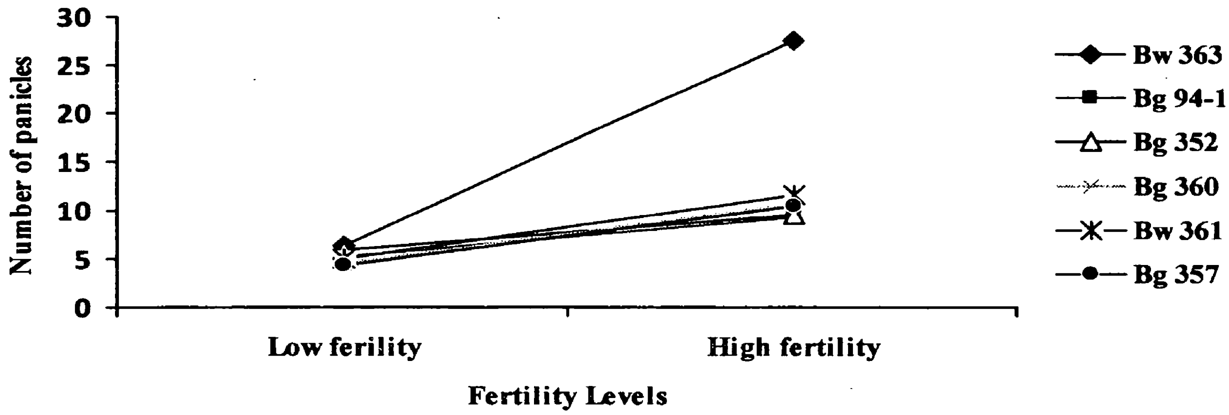

Figure 3. Change in panicle number of rice varieties due to different fertility levels

Relationship ($R^2 = 0.24$) between reduction of plant height and reduction in grain yield was not significant (Figure 4). Similar relationship is found between reduction of panicle number and reduction of grain weight (Figure 5). R^2 for both relationships are 0.24 and 0.27, respectively. Above relationship suggests that reduction in grain yield or in any other trait from high to low fertilizer level is equivalent to increase in grain yield from low to high fertilizer levels so that increasing rates cannot be related instead of decreasing rates. Therefore, both reduction of plant height and reduction of panicle number alone cannot be taken into consideration for suitability testing of rice varieties.

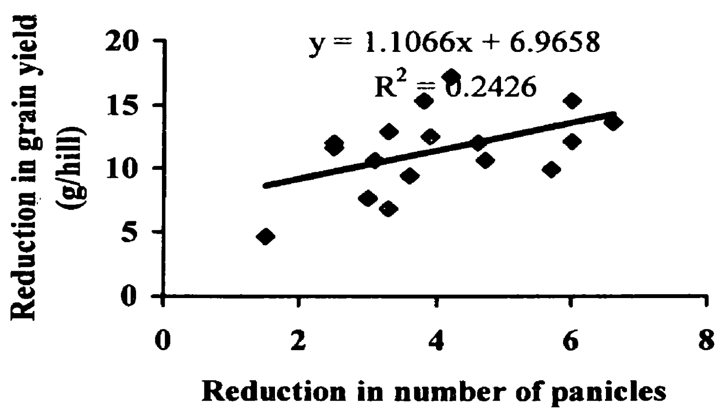

Figure 4. Relationship between reduction in number of panicles and grain yield per hill.

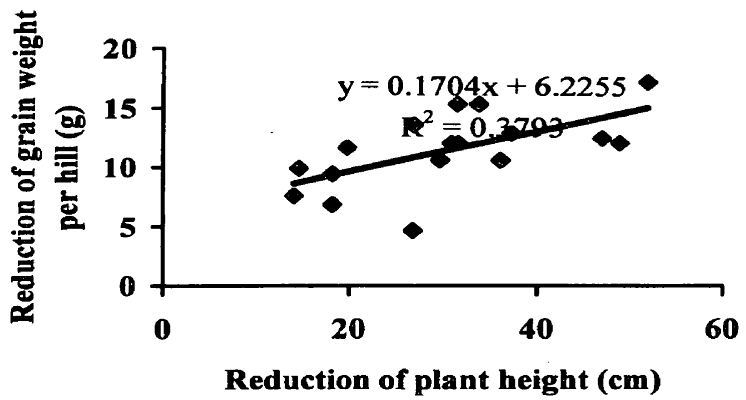

Figure 5. **Relationship between reduction in plant height and grain yield per hill.**

CONCLUSIONS

Varietal differences in the performance under different fertility conditions have been proved in rice. Grain yield of some rice varieties decrease at higher rate than the others when changing high to low fertilizer. Bw 367 and Bw 363 performed well under low fertile conditions and yield reduction due to non-addition of fertilizer for Bw 367 and Bw 363 was only 23 % and 35%, respectively. According to present study it is learned that varietal response to fertilizer addition is very much significant and Bw varieties especially Bw 367 and Bw 363 performed well under low fertility conditions in the Low Country Intermediate Zone.

REFERENCES

Abeysiriwardena, D.S.de Z. and S. Sandanayake. (2000). Future rice research as directed by trends in cultivated extent and yield of rice during the recent past. Annuals of the Sri Lanka Department of Agriculture, 2: 371-381.

Bandara, W.M.J. (2006). A site-specific fertilizer recommendation for rice (*Oryza sativa* L.) using a systematic approach to soil fertility evaluation. Unpublished thesis. PhD. Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.

Bandara, J.M.R S., D.M.A.N. Senevirathna, D. M.R.S.B. Dasanayake, V. Herath , T. Abeysekara and K.H. Rajapaksha. (2008). Chronic renal failure among farm families in cascade irrigation systems in Sri Lanka associated with elevated dietary cadmium levels in rice and freshwater fish (*Tilapia*) Environ Geochem Health.

CBSL. (2010). Annual Paddy Reports. Department of Census and Statistics, Central Bank of Sri Lanka Colombo, Sri Lanka.

DOA. (2001). Fertilizer recommendation for rice. Department of Agriculture, of Agriculture, Paradeniya, Sri Lanka.

DOA. (2011). Released and recommended new crop varieties 2011. Editor Amitha P Benthota. Published by the Department of Agriculture Paradeniya, Sri Lanka. 28 pp

Dobermann A. and T. Fairhurst. (2000). Rice. Nutrient disorders & nutrient management. Handbook series. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC) and International Rice Research Institute. 191 p.

Guowei W., L.T. Wilson and A.M. McClung. (1998). Contribution of rice tillers to dry matter accumulation and yield. Agronomy Journal, 90: 317-323.

Kendaragama, K.M.A., G.W.J. Chandrasiri and A.G.S. De. Silva. (1998). Available phosphorus status of some cultivated soils in the dry zone. Proceedings of the 54^{th} annuals session, SLASS part 1. pp. 119.

Nahar, M.H.K., M.M. Alam and M.R. Islam. (2009). Response of transplanted rice to different application methods of urea fertilizer International Journal of sustainable Agriculture, 1(1): 1-5

RRDI. (2013). Fertilizer recommendation for rice 2013. Departmnet of Agriculture Publication. Department of Agriculture, Peradeniya.

Singh V.K., B.S. Dwivedi, A.K. Shukla and R.L. Yadav. (2003). Effects of nitrogen and phosphorus fertilization on the growth and yield of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) as influenced by the inclusion of forage cowpea (*Vigna unguiculata*) in rice-wheat system. Indian Journal of Agricultural Sciences, 73 (9): 482-489.

Sirisena D.N., D.B Wickramasinghe, and L.S. Silva. (2001). Fate of nitrogen fertilizer used in rice cultivation. Annuls of the Sri Lanka Department of Agriculture, 3: 231-236.

Tanaka, A., 1968. Historical changes in plant types of rice varieties in Hokkaido. Journal of Soil Science Society. Soil manure 39: 526-534.

Wickramasinghe, W.M.A.D.B., D.N. Sirisena, W.M. J. Bandara and J.D.H.Wijewardena. (2009). Response of rice to application of phosphorus in Sri Lankan soils. Use of phosphorus and potassium fertilizers in Sri Lankan agriculture. Eds. D. Kumaragamage, T. Satyanarayana, Harmandeep-Singh and K. Majumdar. International Plant Nutrition Institute (IPNI), Gurgaon, Haryana, India.