Evaluation of Growth, Yield and Nutritional Characteristics of Selected Rice (*Oryza sativa* L.) Varieties under Organic Farming Conditions

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ABSTRACT

Organic rice production is an emerging sector in Sri Lankan agriculture. Therefore, it is important to identify best performing rice varieties to be grown under organic conditions. This experiment was conducted at Rice Research and Development Institute, Batalagoda with the objective of evaluating growth, yield and nutritional characteristics of selected rice varieties under organic conditions. Seven new improved rice varieties *i.e.* Bg250, Bg300, At308, Bg304, Bg352, Bw351, Ld365 and three traditional varieties *viz. madathawalu, suduheenati* and *suwandel* were cultivated in Randomized Complete Block Design with three replicates. Observations were taken on growth, yield and nutritional performances. Highest performances for growth characteristics such as leaf area and total dry weight were observed in variety Bw351. Highest root weight ratio was recorded in varieties At308 and Bw351 while highest shoot weight ratio was observed in *suduheenati* and Bg352. Highest grain yields were obtained from Ld365 (3.8 t/ha) and *suduheenati* (3.75 t/ha). Traditional varieties showed high nutritional values in seeds than new improved varieties. Among them variety *suwandel* showed highest values of seed zinc, iron and phosphorus contents. According to the results, both traditional and improved varieties grow well under organic conditions while showing different magnitudes in growth, yield, and nutritional parameters.

KEYWORDS: Growth, Nutritional properties, Organic farming, Rice varieties, Yield

INTRODUTION

Rice (*Oryza sativa* L.) is the staple food for more than half of the world population (FAO, 2004). It is dominantly produced and consumed in Asia. Meantime in Sri Lanka, rice occupies an extent of 922,151.29 ha which is 14.06 percent of total land area and accounts for approximately 4.6 million metric tons of annual production (Anon, 2014).

At the beginning of 20th century rice yields in Sri Lanka were less than 1 t/ha and exclusively traditional rice varieties were cultivated in single season using only organic fertilizers (Jayawardena *et al.*, 2010). No herbicides and pesticides were used. Even though the traditional varieties are resistant to extreme climatic conditions, soil conditions, diseases and pests, they had shown major constraints of relatively low yields, long age, lodging and large plant architecture (Pushpakumari and Geekiyanage, 2015).

However, with the increase of population in Sri Lanka, the demand for rice increased simultaneously and emphasis was given to increase the rice production. As a result, in 1950s old improved varieties (OIV) were introduced and rice production was shown a significant increase. During 1960s new improved varieties (NIV) appearing in semi dwarf plant type, good level of resistant to lodging and higher yield potentials were developed. Up to 2009 Department of Agriculture (DOA) of Sri Lanka has released sixty eight improved varieties belonging to different age groups (2 1/2, 3, 3 1/2, and 4–4 1/2 months; Jayawardena *et al.*, 2010). With the wide spread of improved varieties, the use of chemical fertilizers, pesticides and herbicides was increased significantly. Moreover, estimated fertilizer consumption for paddy in 2013 was 0.2 million metric tons (Anon, 2014). Excessive use of agrochemicals continuously could be caused health problems in human and animals; as well causing environmental pollution and decline agricultural sustainability (Weerakoon *et al.*, 2000). This led to many arguments worldwide against inorganic agriculture.

Meantime, trend for organic farming gradually increased in past two decades (Niggli, 2015). Organic farming is a productive system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth hormones and livestock additives (Anon, 1980). Today, Sri Lankan rice cultivation has given a high emphasis on

organic farming, due to the increase of consumer preference to safe, hazard free food and to avoid health hazards associated with agrochemicals (Rodrigo, 2014). Although many research work has been done on rice varieties under inorganic cultivation, relatively low attention has been given to the varieties grown under organic conditions and their performance have not been studied well.

Therefore, in this study, attempts were made to evaluate growth, yield and nutritional performances of improved and traditional rice varieties under organic conditions and to identify the best performing varieties for organic rice production. The outcome of this study will enable farmers to select rice varieties with better characteristics to grow under organic farming system.

MATERIALS AND METHODS

Experimental Site

The study was carried out from November 2015 to May 2016 at Rice Research and Development Institute, Batalagoda, Ibbagamuwa situated at low country intermediate zone (IL_{1a}). During the period of experiment, mean relative humidity and maximum temperature were 69.9% and 33 °C respectively. The experimental site contained Low Humic Glay with Red Yellow Podzolic soil. The research site has been maintained under organic conditions since 2000.

Plant Materials and Layout

Seven new improved rice varieties (Bg250, Bg300, At308, Bg304, Bg352, Bw351 and Ld365) and three traditional varieties (*madathawalu*, *suduheenati* and *suwandel*) were used as experimental materials (Table 1). They were arranged in Randomized Complete Block Design (RCBD) with three replicates.

Crop Establishment

Selected seeds of ten rice varieties were row seeded in raised beds. Seedlings (21 days old) were transplanted on 7th December 2015 as one seedling per hill and at a spacing of 20 cm between rows and 15 cm between plants.

Fertilizer Application

After first ploughing rice straw, partially burnt paddy husk and green manure were added at the rates of 5 t/ha, 625 kg/ha and 1 t/ha respectively. After second ploughing and harrowing, 2 t/ha of compost was added. Four weeks after transplanting compost was applied again at a rate of 2 t/ha.

Other Agronomic Practices

Pest control was done by using a mixture of margosa, garlic and soap extract with a regular application at two weeks interval. Weed control was done by using weeder and by hand weeding.

Data Recording

Vegetative Parameters

Plant height (cm) was measured from the base of the plant to the collar of the flag leaf, starting from six weeks after planting to harvesting, at weekly intervals. Total number effective tillers per plant was counted at harvesting stage. Leaf area (cm^2) was measured using disk and punch method, at vegetative and harvesting stages. Soil plant analysis development (SPAD) value was recorded using a SPAD meter (Konica Minolta) at vegetative and booting stages. At vegetative stage SPAD value was taken from the fully expanded immature leaf and at booting stage from the flag leaf. To evaluate biomass partitioning, roots and shoots of plants at vegetative and harvesting stages were cleaned and oven dried at 80 °C for 48 hours and weighed.

Yield and Reproductive Parameters

Total yield of 150 plants of each variety was recorded. Panicle length (cm) was measured from the base of the lowest spikelet to the tip of the latest spikelet on the panicle. To obtain hundred grain weight (g) hundred grains were counted from one plant of each replicate and weighed.

Table 1. Characteristics of selected varieties

Variety	Characteristics	Higher yield recorded (t/ha)
Bg250	2 ½ months, white pericarp, ultra short maturity, moderately resistant to BPH, BL	4.5
Bg300	3 months, white pericarp, resistant to BPH,BL	7.0
At308	3 months, white pericarp, moderately resistant to BPH, BL, BB	6.0
Bg304	3 months, good grain quality, white pericarp, resistant to BPH, GM, BL	7.4
Bg352	3 ½ months, white pericarp, intermediate bold type grains, resistant to BPH	6.0
Bw351	3 ½ months, red pericarp, moderately resistant to sheath blight	5.0
Ld365	3 ½ months, red samba, moderately resistant to BL, BPH, GM	6.0
Madathawalu	3 ½ months, red pericarp, 130 – 140cm plant height	4.0
Suduheenati	4 months, red pericarp, 130 – 135cm plant height	5.0
Suwandel	3 ½ months, white pericarp, 90 – 95cm plant height	2.5

BB– Bacterial blight, BL– Blast, BPH– Brown plant hopper, GM– Gall midge
Source- Rice congress 2010

Nutritional Properties of Seeds

Seeds were washed with distilled water, air dried and dehusked gently using a palm dehusker (*Sathake*). Dehusked seeds were ground using a mortar and pestle, weighed 0.5 g and digested by adding an acid mixture of $HClO_4$ and HNO_3 in 1:4 ratio. Digested samples were diluted with distilled water and volumed up to 50 mL. Potassium, iron and zinc concentrations were measured using Atomic Absorption Spectrophotometer (AAS–GBC). Available Phosphorus was analyzed by Olsen's method (Anon, 2007).

Statistical Analysis

The data were statistically analyzed by performing analysis of variance (ANOVA) procedure using SAS statistical package (version 9.1) and mean separation was done with use of Duncan and Least significant difference (LSD) methods.

RESULTS AND DISCUSSION

Vegetative Parameters

Plant Height

Significant differences ($p<0.05$) were observed in plant height. Highest plant height (82.3 cm) was recorded in *madathawalu* while lowest (56.8 cm) was recorded in Ld365.

Number of Effective Tillers

According to the maximum likelihood analysis of variance, no. of effective tillers per plant was not significant ($p=0.34$). Bw351 showed highest number of effective tillers (13) per plant while *madathawalu* showed the lowest (6).

Leaf Area

Leaf area depends on no. of leaves, no. of tillers and lengths of the leaves. Varieties differed significantly ($p<0.05$) in leaf area at both vegetative and harvesting stages (Table 2). At vegetative stage, Bw351 showed highest leaf area (466.0 cm^2) while Bg300 showed the lowest (160.8 cm^2). At harvesting stage, Bw351 showed the highest value (704.8 cm^2) while Bg300 showed the lowest value (210.1 cm^2). Higher leaf area was observed in harvesting stage than vegetative stage.

Specific Leaf Area

There were significant differences ($p<0.05$) in specific leaf area among tested varieties at vegetative and harvesting stages (Table 2). At vegetative stage, highest specific leaf area (294.6 cm^2/g) was recorded in Bg250 while lowest (122.8 cm^2/g) was recorded in Bg304. At harvesting stage, highest value (199.2 cm^2/g) was observed in Bg250 and lowest (118.3 cm^2/g) was recorded in Bw351. Specific leaf area of almost all varieties have decreased at harvesting stage compared to vegetative stage despite of the increase of leaf area from vegetative to harvesting stages indicating a higher dry matter accumulation in the leaves at harvesting stage.

Table 2. Leaf area and specific leaf area of different varieties

Variety	LA (cm^2)		SLA (cm^2/g)	
	Veg. stage	Harv. stage	Veg. stage	Harv. stage
Bg250	193.5^{f}	370.7^{c}	294.6^{a}	199.2^{a}
Bg300	160.8^{g}	210.1^{d}	126.8^{e}	118.3^{c}
At308	262.3^{d}	506.8^{b}	163.7^{d}	148.0^{b}
Bg304	232.0^{e}	356.0^{c}	122.8^{e}	124.6^{b}
Bg352	239.7^{c}	515.5^{b}	180.1^{d}	138.9^{b}
Bw351	466.0^{a}	764.4^{a}	243.6^{b}	118.3^{c}
Ld365	367.2^{b}	427.5^{b}	253.7^{b}	152.1^{b}
Madatawalu	307.5^{c}	508.5^{b}	134.2^{d}	145.2^{b}
Suduheenati	329.7^{c}	521.7^{b}	163.7^{d}	122.9^{b}
Suwandel	423.0^{b}	572.9^{b}	221.0^{c}	138.3^{b}

Means with the same letter are not significant at 0.05 confident levels. LA- Leaf area; SLA- Specific leaf area, Veg. stage- Vegetative stage, Harv. stage- Harvesting stage

Soil Plant Analysis Development (SPAD) Value

Value of SPAD indicates chlorophyll contents of plants. Significant differences ($p<0.05$) in SPAD value among varieties were observed at vegetative and booting stages (Table 3). At vegetative stage highest SPAD value (43.767) was recorded in Bg352, while lowest value (34.917) was in Ld365. At booting stage, At308 showed highest SPAD value (45.067) while Ld365 showed lowest (34.033). Chlorophyll content in the leaf tissue differs with age of plant, species and growing season (Tari *et al.*, 2013).

Table 3. SPAD values of selected rice varieties at vegetative and booting stages

Variety	Vegetative Stage	Booting Stage
Bg250	39.667^{c}	41.200^{b}
Bg300	36.617^{d}	40.483^{c}
At308	40.900^{b}	45.067^{a}
Bg304	39.167^{c}	41.567^{b}
Bg352	43.767^{a}	34.633^{e}
Bw351	38.683^{d}	41.783^{b}
Ld365	34.917^{d}	34.033^{e}
Madathawalu	36.833^{d}	37.383^{d}
Suduheenati	36.833^{d}	39.300^{c}
Suwandel	$36'233^{d}$	35.283^{e}

Means with the same letter are not significant at 0.05 confident levels. SPAD- Soil plant analysis development

Biomass Partitioning

Total dry weight (TDW): There were significant differences ($p<0.05$) among varieties in total dry weight at vegetative and harvesting stages (Table 4). At vegetative stage,

madathawalu variety showed highest total dry weight (7.902 g) while Bg250 showed lowest total dry weight (2.745 g). At harvesting stage Bw351 recorded the highest value (21.022 g) while Bg250 recorded lowest value (9.397 g) for total dry weight. A reason for differences in dry matter production might be crop duration. Bg250 is a variety with short duration, so it has comparatively less time for vegetative growth. Hence it has the lowest total dry weight at both stages.

Root weight ratio (RWR): Root weight ratio (g/g) was significantly deferent ($p<0.05$) among varieties at both vegetative and harvesting stages (Table 4). At vegetative stage, highest mean (0.263) was observed in At308 and lowest (0.1258) was observed in *suduheenati*. At harvesting stage, highest mean (0.188) was recorded in Bw351, while lowest (0.112) was in Bg352.

Shoot weight ratio (SWR): Significant differences ($p<0.05$) were observed among varieties in shoot weight ratio (g/g) at both stages (Table 4). At vegetative stage the highest SWR (0.874) was recorded in *suduheenati* while lowest (0.737) was observed in At308. At harvesting stage the highest value (0.888) was recorded in Bg352 while lowest (0.812) was observed in Bw351.

At308 and Bw351 varieties indicate a higher proportion of biomass partitioning towards roots and tend to produce large root systems compared to other varieties in proportionate to their total dry weight. *Suduheenati* and Bg352 varieties indicate a higher proportion of biomass partitioning towards shoots and tend to produce more above ground biomass in proportion to their total dry weight, compared to other tested varieties.

Root shoot ratio (RSR): Varieties differed significantly ($p<0.05$) in root shoot ratio (g/g) (Table 4). At vegetative stage At308 showed highest RSR (0.385) while *suduheenati* showed the lowest RSR (0.144). At harvesting stage the highest value (0.236) was recorded in Bw351 while lowest (0.127) was observed in Bg352.

Yield and Reproductive Parameters

Total Yield

Significant differences ($p<0.05$) were observed in total yield (Table 5). Highest yield (3.60 t/ha) was recorded in Bg352 while lowest (1.34 t/ha) was recorded in Bg250.

100 Grain Weight

None of the varieties showed any significant difference ($p>0.05$) for 100 grain weight (Table 5). *Suduheenati* showed the highest weight (2.75 g) while *suwandel* showed lowest (1.30 g). This value depend on the size of grain.

Panicle Length

Significant differences ($p<0.05$) were observed among varieties in panicle length (Table 5). Highest panicle length was recorded in *suduheenati* (24.188 cm) and the lowest was recorded in Bg250 (19.083 cm). The variation as assessed might be mainly due to genetic make-up of the variety.

Table 5. Reproductive parameters of selected varieties

Variety	Yield (t/ha)	100 grain weight (g)	Panicle length (cm)
Bg250	1.79^{g}	2.54	19.083^{c}
Bg300	3.25^{d}	2.40	21.155^{b}
At308	2.75^{e}	1.86	21.097^{b}
Bg304	3.48^{c}	2.24	21.518^{b}
Bg352	3.60^{b}	2.33	20.438^{c}
Bw351	3.42^{c}	2.47	23.528^{a}
Ld365	3.80^{a}	1.57	20.365^{c}
Madathwalu	3.50^{b}	1.90	21.255^{b}
Suduheenati	3.75^{a}	2.75	24.188^{a}
Suwandel	2.07^{f}	1.30	21.643^{b}

Means with the same letter are not significant at 0.05 confident levels

Table 4. Biomass partitioning of selected varieties

Variety	Vegetative stage				Harvesting stage			
	TDW(g)	RWR(g/g)	SWR(g/g)	RSR(g/g)	TDW(g)	RWR(g/g)	SWR(g/g)	RSR(g/g)
Bg250	2.745^{c}	0.153^{d}	0.847^{b}	0.183^{c}	9.397^{d}	0.164^{b}	0.836^{c}	0.197^{b}
Bg300	5.642^{b}	0.158^{d}	0.842^{c}	0.187^{c}	9.940^{d}	0.131^{c}	0.869^{b}	0.151^{c}
At308	7.695^{b}	0.263^{a}	0.737^{d}	0.385^{a}	18.982^{b}	0.153^{b}	0.847^{c}	0.181^{c}
Bg304	7.435^{b}	0.167^{d}	0.833^{c}	0.210^{c}	13.122^{c}	0.131^{c}	0.869^{b}	0.152^{c}
Bg352	5.217^{b}	0.186^{c}	0.814^{c}	0.231^{c}	16.922^{b}	0.112^{c}	0.888^{a}	0.127^{c}
Bw351	7.168^{b}	0.184^{c}	0.816^{c}	0.227^{c}	21.022^{a}	0.188^{a}	0.812^{c}	0.236^{a}
Ld365	5.830^{b}	0.208^{b}	0.792^{c}	0.264^{b}	16.342^{b}	0.140^{c}	0.860^{b}	0.163^{c}
Madathwalu	7.902^{a}	0.130^{d}	0.870^{a}	0.151^{c}	15.555^{b}	0.132^{c}	0.868^{b}	0.156^{c}
Suduheenati	6.853^{b}	0.126^{d}	0.874^{a}	0.144^{c}	18.350^{b}	0.146^{c}	0.853^{b}	0.173^{c}
Suwandel	6.922^{b}	0.163^{d}	0.837^{c}	0.197^{c}	17.735^{b}	0.130^{c}	0.870^{b}	0.152^{c}

Means with the same letter are not significant at 0.05 confident levels. TDW- Total dry weight, RWR- Root weight ratio, SWR- Shoot weight ratio, RSR- Root shoot ratio

Nutritional Properties of Seeds

Significant differences ($p<0.05$) were observed among varieties in nutritional properties (Table 6). Highest Phosphorus concentration was observed in *suwandel* (1096.4 ppm) while lowest (792.2 ppm) was observed in Bg250. Highest Potassium content (1468.6 ppm) was recorded in Bg250 while *suduheenati* recorded the lowest (1297.5 ppm) Bg304 recorded the highest Iron concentration (45.8 ppm), while Ld365 recorded the lowest (15.4 ppm). Zinc concentration was highest in *suwandel* (32.3 ppm) and lowest in Bg250 (21.0 ppm).

Table 6. Nutritional properties of brown rice of selected varieties

Variety	P (ppm)	K (ppm)	Fe (ppm)	Zn (ppm)
Bg250	792.2^{c}	1468.6^{a}	24.8^{b}	21.0^{e}
Bg300	936.8^{b}	1401.2^{c}	21.7^{b}	22.7^{e}
At308	959.7^{b}	1423.7^{d}	18.2^{b}	26.4^{c}
Bg304	985.5^{b}	1400.5^{e}	45.8^{a}	22.2^{e}
Bg352	1009.0^{b}	1429.2^{b}	23.8^{b}	25.6^{c}
Bw351	966.8^{b}	1395.0^{c}	23.7^{b}	27.2^{b}
Ld365	993.9^{b}	1408.8^{c}	15.4^{b}	24.3^{c}
Madatha.	1047.5^{b}	1426.3^{c}	17.3^{b}	27.2^{b}
Sudu.	954.0^{b}	1297.5^{f}	24.4^{b}	27.9^{b}
Suwandel	1096.4^{a}	1419.9^{c}	45.3^{a}	32.3^{a}

Means with the same letter are not significant at 0.05. Madatha.- Madathawalu, Sudu.- Suduheenati

CONCLUSIONS

Highest performances for growth characteristics such as leaf area and total dry weight were observed in variety Bw351. Varieties At308 and Bw351 showed the highest root weight ratio (RWR) in vegetative and harvesting stages respectively while showing the lowest shoot weight ratio (SWR). In contrast *suduheenati* and Bg352 showed the highest shoot weight ratio (SWR) respectively in vegetative and harvesting stages while showing the lowest root weight ratio (RWR). According to the yield results *suduheenati* and Ld365 have performed better. Traditional varieties showed high nutritional values in seeds than new improved varieties while showing highest Zn concentrations. Variety *suwandel* showed highest values of seed Zn, Fe and P contents.

According to the results, both traditional and new improved varieties grow well under organic conditions while showing different magnitudes in growth, yield and nutritional parameters. So that those varieties can be used for further research activities for screening best varieties under each separate characteristic.

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