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Growth, Physiology, Weed Abundance and Yield in Rice (*Oryza Sativa* L.) Under Three Nutrient Input Systems in the Dry Zone of Sri Lanka

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Abstract

A field experiment was conducted to compare the growth, physiology, weed abundance and yield in rice under three input systems; organic, conventional and integrated, during the 2019 *Yala* season as the second season of a long-term cropping systems trial. The design used a Randomized Complete Block Design (RCBD), with six (6) replicates for each treatment. The rice variety used in the experiment was Bg 300 and three treatments were based on three input systems such as T1 – Conventional input system (100% Department of Agriculture (DOA) inorganic fertilizer recommendation), T2 – Integrated system (50% of Department of Agriculture (DOA) inorganic fertilizer recommendation+50% of the rate of compost added to organic input system) and T3 – Organic system (No inorganic fertilizers and only compost with the rate of 10000 kg ha $^{-1}$). At the panicle initiation and harvesting stages, there was a ($p<0.05$) significant difference (in rice shoot biomass across the three input systems, with the organic system having the

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lowest values compared to the other two. At panicle initiation, 50 % heading, and harvesting phases, a significant difference ($p<0.05$) in plant height was noted among the three input systems, with the organic system showing the lowest values at all stages. The organic system had the highest weed count at all three crop stages and no significant difference between integrated and conventional systems. The three input systems had a significant difference in final grain yield at 14 percent moisture. At 14% moisture, there was no difference in final grain yield between conventional and reduced systems (4.85 and 4.67 tonnes/ha) with the organic system having the lowest value (2.74 tonnes/ha). Overall results indicate that reducing inorganic fertilizers by 50% with the combination of organic manure as in the integrated system gives similar final grain yields as the conventional system of new improved varieties like Bg 300 in high potential areas like Anuradhapura. Also, organic systems can show low crop growth and yields due to inadequate nutrient supply through organic materials and high weed density during the first year of transition.

Keywords: Crop growth; Physiological; Weed abundance; Organic; Rice

Introduction

In many parts of the world rice (*Oryza sativa* L.) is cultivated, and it is the staple food of many nations (Khairiah *et al*., 2009). Rice is known to be the single most significant crop occupying 0.9 million hectares in 2018 of the total cultivated area in Sri Lanka. In 2017/2018, an average of 560,000 and 310,000 hectares were farmed during *Maha* and *Yala*, with an average yearly extent of roughly 870,000 hectares sown. Around 1.8 million agricultural families are involved in cultivation around the island. Rice output in the country is currently 3.9 million tonnes per year, which meets around 95% of domestic demand (DOA, 2018). In Sri Lanka, rice yield is 4.30 tonnes/ha in 2018 (IRRI, 2019). After the green revolution, a challenge emerged as many farmers had to produce food for an ever-increasing world population using practices that increase crop production such as: the application of fertilizers and pesticides, intensive tillage and the use of monoculture (Benaragama *et al.,* 2016a). After the green revolution, a range of agricultural chemicals appeared in the sector all around the world. Chemical-based agriculture is rapidly becoming common also in the rice sector of Sri Lanka (Adhikari, 2011), mostly on Nitrogen, Phosphorous and Potassium.

Because of rapid response and visible benefits, most farmers tend to apply nitrogen to increase crop yield. As a result of maximising the use of inorganic fertilizers and pesticides, the use of improved high-yielding varieties that are receptive to these inputs was also increased. The government extension programs promote the use of inorganic fertilizers to increase yields and achieve self-sufficiency. Hence, inorganic inputs are a vital component of the rice sector of Sri Lanka.

Although inorganic inputs produce high yields, they cause significant environmental problem, including soil degradation, soil organic matter reduction, emission of greenhouse gases and adverse effects on natural ecosystems (Benaragama *et al*., 2016a). Problems associated with using excessive amounts of synthetic fertilizers and increasing the cost of these fertilizers are considered the major factors harmful to developing sustainable crop production systems (Adhikari, 2011). The dry zone is known as “the major rice growing area” in Sri Lanka, and rice cultivation is mostly carried out by conventional agricultural practices. In conventional agriculture practices, inorganic inputs are applied to the crop to maintain productivity. The use of excessive amounts of synthetic fertilizers, as well as the rising expense of these fertilizers, is recognized to be hazardous to agricultural production systems' sustainability (Adhikari, 2011).

Over the last 15 years, Chronic Kidney Disease (CKD) has gradually developed, impacting the low socioeconomic agricultural population in the North central province and it is thought to be attributable to the increasing usage of inorganic fertilizers. Also, farmers have to disburse a lot of money for fertilizers and other chemicals. This resulted in environmental pollution, the development of pest and disease resistance and an increase of the cost of production (Nanayakkara and Upul, 2012). Alternatively, organic crop production systems are gaining popularity. Therefore, this research was conducted to promote organic and integrated nutrient management systems to overcome problems that occurred due to conventional farming. The main goals of this study are: to compare plant growth, physiological and yield parameters in organic, integrated and conventional input systems as well as to figure out how these different input systems affect weed abundance and competition in rice during the *Yala* season in the first year of transition.

Methodology
Experimental location

A field trial was carried out during the 2019 *Yala* season at the Research Unit of the Faculty of Agriculture, Rajarata University of Sri Lanka, Puliyankulama, Anuradhapura district (located in 8° 22'14.84" N and 80° 25'13.66" E). This area belongs to the agro-ecological zone of the low country Dry Zone (DL1b) (Thenabadu, 1988). The mean annual rainfall and the average temperature of the area vary from 1250 to1750 mm and 25 to 30 respectively. The study area consists of imperfectly drained Reddish-Brown Earth soils (Soil taxonomic Order - Alfisols, Suborder - Ustalfs, Great Group - Haplustalfs) (Mapa *et al*., 2010).

Experimental design and treatments

The experimental design was RCBD and there were six (6) replicates for each treatment combination. The tested rice variety was Bg 300. Three treatments were based on three input systems as T1 – Conventional input system (100% N supplied by an inorganic fertilizer application based on the recommendation of the Department of Agriculture), T2 – Integrated system (Reducing the inorganic and organic fertilizer system by 50%) and T3 – Organic system – 50% N supplied by organic fertilizers (The Nitrogen content of organic fertilizer was previously calculated to determine the relevant rate to get the required Nitrogen content).

Plot preparation, crop establishment and management

Plots of 15 m × 6 m dimensions were made. Altogether 6 plots were prepared for one treatment and therefore, 540 m^2 were achieved as the total plot area per treatment. Land preparation of rice was carried out as per the lowland rice cultivation method. Each plot was submerged and soaked for 3 days. Then, the land was ploughed with a power tiller and impounded with water for two weeks before the establishment of the crop. After one week of the first ploughing, the second ploughing was done crosswise with the power tiller. Then bunds were reshaped. Before the establishment, the cropland was puddled and levelled. On the puddled and levelled plots, pre-germinated seeds of the Bg 300 rice variety were dispersed at a rate of 120 kg ha^{-1}.

Fertilizer application

The input systems were defined based on the elemental N supply and the sources. In organic system, the Phosphorus and Potassium rates were not standardized. The amounts of these two elements were dependent on the quality of materials used to supply N. Cow dung and compost were the organic nutrient sources used.

Table 1: Fertilizer rates added to conventional and integrated systems by mineral nutrients and alternative sources

Input system	Mineral nutrient (kg/ha)	Nutrients from alternative sources (kg/ha)
Conventional	N – 103.5 (Urea 46%) P – 3.9 (P_2O_5 43.7%) K – 30.0 (K_2O 60%)	N – 0 P – 0 K – 0
Integrated	N – 51.8 (Urea 46%) P – 1.9 (P_2O_5 43.7%) K – 15.0 (K_2O 60%)	N – 25.9 P – 0.65 K – 52.5

Weeds, insects, pest and disease management

Weed management of conventional and integrated plots was carried out by applying synthetic herbicide Sofit (Pretilachlor+safener) which is a pre-emergence herbicide. MCPA (2-methyl-4-chlorophenoxyacetic acid) was added 20 DAS. Carbosulfan 200 g L^{-1} SC was added to the field to control pests of paddy bugs, brown plant hoppers and thrips to the conventional and to the integrated system. Neemzal (neem (*Azadirecta indica* L.) based commercial organic pesticide) was applied to the organic system.

Agronomic practices and irrigation

All agronomic practices were carried out following the Department of Agriculture recommendations in Sri Lanka. Irrigation was started one week after the crop establishment and impounded with a 5 cm depth of water to keep the soil sufficient moist throughout the experimental period. The flood irrigation method was followed to keep the soil moist.

Data collection

Plant growth was measured in 20 days of intervals in seedling, panicle initiation, 50% heading and harvesting stages. Physiological parameters were taken at panicle initiation and 50% heading stage. Grain yield was measured at crop maturity after 90 days after establishment (harvesting stage). Weeds were counted at seedling, 50% heading and maturity stages. Biomass of weeds was measured at 50% heading and maturity stages.

Measurement of plant growth parameters

For measuring plant growth parameters destructive sampling techniques were practiced at seedling, panicle initiation, 50% heading and harvesting stages. The sampling was done using a quadrate of the size of 50 × 50 cm. Quadrate was placed in four places on each plot and the plant samples were collected, for most of the parameters. When it deviates from normal practice, it was highlighted in appropriate places.

Plant density

At the seedling and harvesting stages, the number of plants per unit area was measured. All the plants collected from the quadrate in four different places in a plot were counted to measure the number of plants in m^2 for each plot.

Average plant height

Randomly selected 12 seedlings per quadrate were taken to measure this parameter. At two stages (Seedling and panicle initiation), the height from the base of the plant to the tip of the fully developed leaf (in cm) was measured. At the 50 percent heading stage and maturity stage, the height from the base of the plant to the tip of the panicle was measured in cm.

Number of tillers

The number of tillers was counted by using randomly selected 12 plants that were used for the height measurements. From panicle commencement to harvesting, the number of tillers per plant was counted.

Crop biomass (shoot dry weight)

After taking measurements of plant height and tiller count, the same plants were taken to measure shoot dry weight. Plants were uprooted and thoroughly cleaned to remove any undesired contaminants, after which they were air dried. Then, all 12 plants from each plot were put separately into paper bags and then was oven dried at 60 °C until getting a constant weight and total dry weight measured per plant basis at the seedling to harvesting stage (Wijayawardhana *et al*., 2016).

Measurement of plant physiological parameters
Relative leaf chlorophyll content

At the panicle initiation and 50% flowering stages, relative leaf chlorophyll content was evaluated as a SPAD (Soil Plant Analysis Development) value using a SPAD-502- leaf chlorophyll meter. Four plants in four different places from a plot were selected to measure this parameter. Then three fully expanded leaves that arose from the top of the plant were used for readings. The SPAD values in three different places in one leaf were measured and the average of them was taken as the leaf relative chlorophyll value.

Photosynthetic rate, stomatal conductance to water vapour and leaf temperature

These parameters were measured using a portable photosynthetic meter at panicle initiation and 50% flowering stages.

Light interception

Light interceptions of the crop field were measured using Line Quantum Sensor (LI-COR LI-191R) when the field received uniform solar radiation at 50% heading stage. Here, two locations in a plot were selected considering the healthy and uniform growth of the crop in the plot. Then, the LI 250A Light meter value at the eye level of the operator was taken by levelling the instrument horizontal to the ground and recorded as the top value of the incoming, reflected, and transmitted Photosynthetically Active Radiation (PAR). Later, the instrument was placed under the crop canopy, just above the ground level in two positions by making a cross in the position. Then, PAR was measured at the position and was recorded and the average of the two values was taken as the bottom reading of the light meter. Finally, the difference between the top reading and the bottom reading was taken as the light interception value.

Electrolyte Leakage (EL)

Healthy grown two plants from a single plot were selected to measure EL. Flag leaf from each plant was detached from the rice plant at the pre-dawn stage of the day and the fresh weight of the leaf was taken (W). Then, the leaf was cut into 1 cm length pieces. The leaf pieces were washed in deionized water, blot dried on tissue papers and placed in 20 mL of deionized water containing polypropylene tubes at room temperature for 1 hour with gentle shaking. Then, the Electrical Conductivity (EC) of the bathing solution (EC1) was measured using an EC meter. The total EL was measured after freezing subsequent samples at –60 °C for 12 hours (EC2). Then EL was expressed in per gram of leaf tissue using the following equation.

Measurement of weed parameters
Weed density

The quadrate was used to count the number of weeds per unit area at the seedling stage, rather than uprooting the plants (Nkoa *et al.,* 2015). Weeds from four different locations of a single plot was selected and uprooted using the quadrate as explained in the Measurement of plant growth parameters section and counted according to categories of broad leaves, sedges and grasses at the 50% heading and harvesting stages.

Weed biomass

At 50 percent heading and harvesting, weed dry weight was measured. All of the weeds that were gathered to determine weed density per plot were rinsed thoroughly with tap water to remove any undesirable soil. The weeds were then air dried for two days before being oven dried to achieve constant weight, similar to how shoot biomass was measured in the crop biomass part.

Measurement of yield parameters

To measure the yield parameters, the first plant samples were collected using a quadrate as explained in the measurement of plant growth parameters section. Then all the panicles were separated from the plants. After that, the panicle was grouped according to the height of the panicles as high, medium and low per plot. Then 20% of the panicles were selected from each group to measure all other yield components per each plot.

Number of spikelet/panicle

Separated panicles were counted per plot. Then, the number of grains in separated panicles was counted per plot. Finally, the grain count for separated panicles was divided by separated panicle count to measure the number of spikelets/panicle per plot.

Number of filled spikelets/panicle

Grains were placed into a water basin and, grains floated were considered as unfilled grains and separated. Then the number of filled grains was counted for separated panicles and, divided by separated panicle count to measure the number of filled spikelets/panicle per plot.

Final grain yield at 14% moisture

Grain yield was corrected to 14% moisture. Final grain yield was calculated for a square meter (m^2) and then converted into tonnes/ha per each plot.

Harvest index

The percentage ratio of grain yield to grain plus straw yield of each plot was used to determine the Harvest index.

Data analysis

All the parameters were analysed using ANOVA Mixed procedure in SAS. Means were separated using LSD mean at p = 0.0

Results and Discussion

Plant growth parameters

Plant density

A significant difference was observed in plant density among the three input systems at the seedling stage. However, at the harvesting stage, no difference was observed among the three input systems (Table 2). At the seedling stage, the maximum plant density was identified in the integrated input system and the lowest was in the conventional system and the organic system showed an intermediate value. Yield does not depend solely upon the performance of the individual plants, but also on the total number of plants per plot and yield components within a plant. Wider spacing had a linear effect on boosting the performance of individual plants, according to Baloch *et al*, (2002). Increased spacing allows plants to draw more nutrients from the land around them and absorb more solar radiation for a better photosynthetic process, resulting in improved individual plant performance (Baloch *et al*., 2002). Number of tillers

There was a significant difference in tiller count among the three input systems only at 50% heading stage (Table 2). The number of tillers has been detailed to have a positive affiliation with plant biomass and financial yields in rice (Deng *et al*., 2015). At the panicle initiation stage, no differences were observed in tiller count among treatments. At the 50% heading stage, the conventional system had the maximum tiller count, and no differences were observed between integrated and organic systems. At the harvesting stage, the conventional system had the maximum tiller count and the organic system had the lowest. At all three stages, the organic system had the lowest tiller count due to P and N deficiency. As a result of Phosphorus deficiency reduced shoot growth and lesser tiller production in rice plants can be observed (Luquet *et al*., 2005).

A study by Kekulandara *et al* (2017) also reported that, there was a noteworthy delay in tillering in a Phosphorus lacking condition. The application of N fertilizer is the foremost common and viable way to enhance the tiller populace because, it increments the *cytokinin* substance inside tiller hubs and, assist improves the germination of the tiller primordium (Liu *et al.,* 2011). Similar studies that have measured morpho-physiological parameters of rice genotypes (Epstein and Bloom, 2005; Islama *et al*., 2009) also showed increase of tiller count with increase of N content.

Shoot biomass

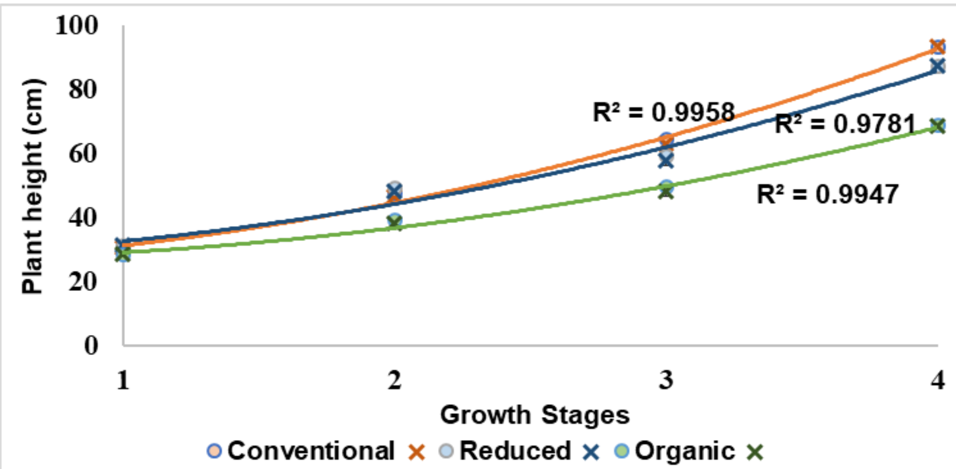
A significant difference was observed in shoot biomass among the three input systems at panicle initiation, 50% heading and harvesting stages. Mean shoot dry matters of rice in different growth stages among three input systems are presented in Table 2. At the seedling stage, no differences were observed in shoot biomass among three input systems because, at the initial stage plants do not absorb many nutrients from the soil but, depends on the nutrients in the seed. At panicle initiation, 50% heading and harvesting stages, no differences were observed among conventional and integrated systems due to the continuous application of inorganic fertilizers and their availability, and organic system had the lowest shoot biomass. Significantly low shoot biomass recorded in organic system in panicle initiation, 50% heading and harvesting stages indicate lack of soil fertility. The shoot biomass was significantly affected by major nutrients as N, P and K and also Zn (Nawaz *et al*., 2015). Also, *Fageria* and *Filho* (2001) and *Fageria* and *Baligar* (2005) have stated the increment in plant height and shoot dry weight with increasing nitrogen rate.

Table 2: Effect of three input systems on Plant growth parameters (plant density, tiller count and shoot biomass)

	Plant density (Plants/m^2)	Tiller count/plant	Shoot biomass(g)					
	Harvest stage (90DAS)	Panicle initiation stage (40DAS)	50% heading stage (60DAS)	Harvest stage (90DAS)	Seed ling Stage (20DAS)	Panicle initiation stage (40DAS)	50% heading stage (60DAS)	Harvest stage (90DAS)
Conventional	181.98[a]	1.53[a]	1.52[a]	1.3[a]	1.37[a]	9.06[a]	12.70[a]	19.55[a]
Integrated	244.69[a]	1.53[a]	1.22[b]	1.18[ab]	1.51[a]	9.60[a]	11.23[ab]	16.09[a]
Organic	240.52[a]	1.43[a]	1.19[b]	1.07[b]	1.24[a]	6.07[b]	9.70[b]	9.53[b]
Standard Error	24.78	0.07	0.12	0.07	0.09	0.69	0.67	1.35
Significant (P-value)	0.21	0.47	0.02	0.1	0.15	0.01	0.02	0.0004

Plant height

A significant difference was observed in plant height among three input systems at panicle initiation, 50% heading and harvesting stages (Figure. 1). At panicle initiation stage, no differences were observed in plant height among conventional and integrated systems and, organic system had the lowest value. Conventional and integrated systems had greater plant height compared to the organic system probably due to high level of major nutrients (N, P and K) (Iqbal *et al*., 2017). At both 50% heading and harvesting stages, the three systems showed differences in plant height, where the highest in the conventional followed by integrated and organic systems, respectively. Synthetic fertilizer provides nutrients which are readily soluble in soil solution and thereby instantly available to plant. Islam *et al*., 2017 mentioned that plant height has significant positive association with rice grain yield.



1 – Seedling stage; 2 – Panicle initiation stage; 3 – 50% heading stage; 4 – Harvesting stage

Figure 1: Differences in plant height among three input systems at seedling, panicle initiation, 50% heading and harvesting stages.

Physiological parameters
Chlorophyll content (SPAD Value)

A significant difference was observed in leaf Chlorophyll content among three input systems at panicle initiation and 50% heading stages. At both panicle initiation and 50% heading stages, the conventional system had the highest relative Chlorophyll content and organic system had the lowest (Table 3). Leaf Chlorophyll content is dependent on the Nitrogen content and the colour of the leaf; however, this correlation varies with plant growth stage and/or variety mostly because thickness of the leaf or leaf weight (Dissanayake *et al*., 2014). Chlorophyll content was significantly low in the organic input system in both growth stages when compared to conventional and integrated systems due to applying Nitrogen through inorganic fertilizer for both integrated and conventional systems and not for the organic system. Also, past research (Swain and Sandip, 2010) found that the SPAD value was linearly correlated with leaf Nitrogen content and Varvel *et al*. (1997) demonstrated N fertilizer significantly increased SPAD reading.

Electrolyte leakage

Differences in the electrolyte leakage (EL) have been known to detect stress injury of cell membrane. EL varies in relation to the ability of membrane to take up and retain solutes and, therefore, reflects stress induced changes in both membrane potentials and membrane permeability (Agarie *et al*., 1995). There was a significant difference in EL among three input systems at panicle initiation stage. Organic input system showed the highest EL, and no differences were observed among conventional and integrated systems (Table 3).

Deficiency of nutrients and environment stress conditions may be the reason for plasma membrane damage and increase of EL of organic system. Salt stressis also a reason for gradual increase of EL causing damage to the membrane (Fazal and Bano, 2016). To overcome the negative effect of salinity, the addition of different source of Nitrogen and Potassium to growth media as an ameliorative agent could be essential.

Table 3a: Effect of three input systems on Plant physiological parameters (leaf chlorophyll content (SPAD value), stomatal conductance to water vapor, leaf temperature).

	Leaf chlorophyll content (SPAD value)		**Stomatal conductance to water vapor (*u*mol/m^2/s)**		**Leaf temperature (^{o}C)**	
	Panicle initiation stage (40DAS)	**50% heading stage (60DAS)**	**Panicle initiation stage (40DAS)**	**50% heading stage (60DAS)**	**Panicle initiation stage (40DAS)**	**50% heading stage (60DAS)**
Conventional	36.29[a]	36.24[a]	-0.04[a]	0.41[a]	28.55[a]	28.29[c]
Integrated	31.21[b]	32.84[b]	0.05[a]	0.42[a]	28.46[a]	30.25[a]
Organic	25.84[c]	26.98[c]	-0.007[a]	0.24[a]	28.29[a]	29.57[b]
Standard Error	1.03	1.40	0.13	0.06	0.23	0.16
Significant (P value)	<.0001	<.0001	0.67	0.11	0.72	<.0001

Photosynthetic rate

There was a significant difference in photosynthesis among three input systems at panicle initiation and 50% heading stages. At both panicle initiation and 50% heading stages, conventional system had the highest photosynthetic rate. At both stages, no differences were observed among organic and integrated input systems (Table 3). It is fact, that P and N are contributed on regulating various photosynthetic processes and also that N: P ratio is essential for plant growth. As a result of Nitrogen and/or Phosphorus deficiency, a reduction in the photosynthetic capacity will emerge which can mainly be affect the dysfunction of the Calvin cycle and will limit nutrient supply to the chloroplasts (Conversa *et al*., 2015) and this could be the reason for low photosynthesis recorded at both panicle initiation and 50% heading stages in organic system because its wasn't treated with inorganic fertilizers containing N and P. Conventional system showed the highest photosynthetic values at both stages and integrated system showed comparatively a low value compared to conventional system because for integrated system, inorganic and organic manure were reduced by 50%, and therefore, N and P content are reduced. Amount of Chlorophyll are closely related to the photosynthetic rate. When the amount of Chlorophyll is high in the leaves, a higher photosynthetic rate can also be identified (Hidayati *et al*., 2016).

Leaf temperature

At panicle initiation stage, no significant difference was observed in leaf temperature among three input systems. A significant difference was identified in leaf temperature among the three input systems at 50% heading stage and integrated system had the highest leaf temperature and conventional system had the lowest. The low leaf temperature decreases the use of breath and helps keeping normal physiological functions of leaves (Yun-Ying *et al*., 2009). Rice varieties with lower leaf temperatures are thought to have higher photosynthetic and transpiration rates while also producing high yields (Hirayama *et al*., 2006). The above statements justify the results of this study by showing that, at 50% heading stage, conventional system had the lowest leaf temperature (28.28 ˚C) and the highest photosynthesis value was also recorded in conventional system. Idso *et al*. (1977) reported similar findings for wheat, indicating that leaf temperature during the heading stage was closely connected (Positive relationship) to grain yield and could be used to estimate yield in wheat varieties.

Light interception

There was a significant difference in Light Interception (LI) among the three input systems at 50% heading stage. LI at 50% heading stage, conventional and integrated system showed statistically similar mean values (93.02 and 97.13 µmol/ m^2/s, respectively) and organic system had a lowest value compared to conventional and integrated systems (57.14) as shown in Table 3. It is because, compared to the plants in the organic system, plant growth and tillering capacity was high in conventional and integrated systems causing greater LI. The Leaf Area Index (LAI), plant population, spatial organization, and, most importantly, canopy structures all play a role in LI by a crop canopy. Nitrogen stimulates the production and retention of leaves.

Therefore, LI would be greater in treatments receiving more applied N (Weerakoon *et al*., 2000). This supports the findings of this research as conventional and integrated systems received more applied N and therefore, high values of LI than the organic system which with low N levels. Similar observations were made by Kumar and Gangwar (1985) and Haque *et al*., (2006) by showing LI would be greater in treatments receiving more applied N.

Stomatal conductance to water vapour

There was no significant difference in stomatal conductance to water vapour among three input systems at panicle initiation and 50% heading stages. Rice grain yield was found to be highly associated with leaf photosynthetic rate and stomatal conductance in recent research (Takai *et al.,* 2009).

Table 3b: Effect of three input systems on Plant physiological parameters (photosynthetic rate, light interception and electrolyte leakage).

	Photosynthesis rate (μmol $CO_2/m^2/s$)	**Light interception (μmol/ m^2/s)**		**Electrolyte leakage**
	Panicle initiation stage (40DAS)	**50% heading stage (60DAS)**	**50% heading stage (60DAS)**	**Panicle initiation stage (40DAS)**
Conventional	24.91[a]	14.44[a]	93.02[a]	0.76[b]
Integrated	19.07[b]	11.18[b]	97.13[a]	0.97[b]
Organic	12.90[c]	7.49[c]	57.14[b]	7.34[a]
Standard Error	2.40	1.28	8.47	0.74
Significant (P value)	0.0003	0.0002	0.02	<.0001

Because H_2O and CO_2, which are involved in the photosynthetic process, must pass through the stomata before entering mesophyll cells and chloroplast stroma, stomatal conductance is important in generating photosynthesis in rice plants (Doni *et al.,* 2014). Several studies have reported a close relationship between stomatal conductance and photosynthetic rate (Lin *et al*., 2005). However, in this study such relationship was not observed

Weed abundance

Weed density

Weeds compete with rice for light, nutrients, water, and other development requirements due to their fast growth rate, ability to adapt to changing conditions, and more efficient seed production. Environmental and edaphic conditions favorable for growing rice are also favorable for growing and reproducing many terrestrial, aquatic and semiaquatic weeds (Smith, 1988; Kim and Moody, 1989). Grasses are usually the most dominating rivals in the early phases of rice production, whereas sedges and broad-leaved weeds take over in the later stages (Jiang, 1989). A significant difference in weed density was observed among the three input systems at seedling, 50% heading and harvesting stages. At all three stages, organic system had the highest weed density, and no significant difference was observed among integrated and conventional systems (Table 4). It is because there was no application of pre-emergent herbicide to the organic system, but it was applied to both integrated and conventional systems. This supports a prior study of Benaragama *et al*. (2016a) which showed greater weed density in organic systems with the exclusion of synthetic pesticide/fertilizer and genetically modified inputs, when compared to conventional systems.

Table 4: Effect of three input systems on weed density

	Weed density (Number of weeds /m^2)		
	Seedling Stage (20DAS)	**50% heading stage (60DAS)**	**Harvesting stage (90DAS)**
Conventional	160.83^b	14.67^b	6.83^b
Integrated	236.83^b	30.83^b	39.17^b
Organic	2225^a	158.33^a	536.33^a
Standard Error	136.78	6.59	45.81
Significant (P value)	<.0001	<.0001	<.0001

Weed biomass

At both 50% heading and harvesting stages, weed biomass among three input systems was significantly different (Table 5). Organic system had the largest weed biomass, integrated system had the lowest and conventional system had an intermediate value at 50 percent heading stage. However, no differences were observed in weed biomass among conventional and integrated systems at harvesting stage. However, organic system resulted the highest weed biomass probably due to the application of herbicides to conventional and integrated system and not for the organic system. At this point, the organic system had four times the weed biomass of the conventional system, which was consistent with the findings of many others (Benragama *et al*., 2016b; Davis *et al*., 2005; Ryan *et al*., 2009). However, treatments with high weed density did not necessarily have high weed biomass, indicating that there is no link between weed densities and weed biomass. When compared to conventional and integrated systems, organic systems exhibited a higher weed biomass at harvest, which could be one of the reasons for the organic system's lower crop production.

Table 5: Effect of three input systems on weed biomass

	Weed biomass (g)	
	50% Heading stage (60DAS)	**Harvesting stage (90DAS)**
Conventional	5.12[ab]	6.28[b]
Integrated	2.82[b]	5.50[b]
Organic	6.09[a]	24.14[a]
Standard Error	0.84	3.46
Significant (P value)	0.04	0.0002

Yield components

Number of spikelet/panicle

The number of spikelets/panicles varied significantly among the three input systems (Table 6). Conventional input system had the highest number of spikelet/panicle and organic system had the lowest. Three yield components, panicles per plant, grain weight, and spikelet number per panicle were used to calculate rice grain yield (Tian *et al*., 2006). As a result, the following statement can be used to validate the findings of this study because the conventional method produced the maximum number of grains per panicle, as well as the highest yield. In terms of final yield values, the integrated system had the second highest value of spikelet per panicle, while the organic system had the lowest. As can be seen, the number of spikelets per panicle is an important yield component that impacts the ultimate yield.

Number of filled spikelet/panicle

The amount of filled spikelets per panicle varied significantly between the three input systems. Conventional system had the highest value, organic system had the lowest value and integrated system had a value in between them (Table 6). Drought, low solar radiation, Nitrogen deficit, low or high temperatures and panicle blast can all increase the amount of empty spikelets and, as a result, grain output. Rice genes also control spikelet sterility and empty grains. (Fageria, 2007). Nitrogen deficiency could be the main reason for low number of filled grains in organic system (35.9) and then, higher values 70.5 and 50.6 filled grains per panicle were for conventional and integrated systems respectively, because N nutrients were adequately supplied from inorganic fertilizers to those two systems. Dissanayake *et al*., 2014 reported comparable findings for Bg 352 rice variety with identical fertilizer combination in *Maha* and *Yala* seasons.

Final grain yield at 14% moisture

The three input systems had a significant difference in final grain yield at 14 percent moisture. At 14% moisture, there was no difference in final grain yield between conventional and reduced systems, with the organic system having the lowest value (Table 6). This could be due to the contribution of chemical fertilizers in reduced and conventional systems, as well as the higher weed density in organic systems compared to reduced and conventional systems, both of which positively influenced all of the rice plant's yield contributing characters as observed in this study. The organic system's lack of soil fertility was reflected in plant growth parameters and, ultimately, crop grain production. Weed-related yield losses have been calculated in various rice-producing countries. Losses in India have been estimated at 10% of the crop. Losses in the Philippines were predicted to be 11% for the dry season and 13% for the wet season (Datta, 1981). However, according to a previous study (Benaragama *et al.*, 2016b), organic management practices and/or greater crop rotation diversification did not improve yield or minimize yield loss due to weed competition because of factors linked with poorer soil fertility. In this study, results show that reducing agrochemicals (fertilizer and herbicides) as was done in the reduced system does not affect the final grain yields, and similar results were shown in prior studies by (Benaragama *et al.,* 2016a) and (Dissanayake *et al*., 2014).

Harvest index

Harvest index is defined as the ratio of grain yield to total above-ground biomass (straw and grain) and is used to determine biological success in partitioning absorbed photosynthate to the harvestable product or simply how efficient a crop is at producing grains. (Li *et al*., 2012; Dissanayake *et al*., 2014). There is a significant difference in harvest index among the three input systems (Table 6). Conventional system had the highest harvest index and there was not any difference observed among integrated and organic systems. The number of panicles per unit area, the number of spikelets/panicle, the weight of 1,000 mature kernels and the percentage of fully ripened grains all contribute to the harvest index of rice (Li *et al*., 2012). Although the number of panicles in the integrated system is the largest of the three treatments, the number of grains per panicle and the number of filled grains per panicle are lower than in the conventional system, which is likely why the integrated system has a low harvest index. For rice, published harvest index values range from 0.35 to 0.55 (Fageria *et al*., 2003). In contrast, harvest index ranged between 0.39 to 0.46 because variety Bg 300 is a new improved rice variety. Dissanayake *et al*., 2014 found similar findings for the Bg 352 rice variety in conventional, integrated and organic systems, with harvest indexes ranging from 0.40 to 0.46.

Table 6: Effect of three input systems on yield parameters

	Number of spikelets/panicle	Number of filled spikelets/panicle	Final grain yield at 14% moisture (tonnes/ha)	Harvest index
Conventional	87.45[a]	70.47[a]	4.8519[a]	0.4666[a]
Integrated	60.63[b]	50.63[b]	4.6661[a]	0.3985[b]
Organic	42.09[c]	35.85[c]	2.7393[b]	0.4056[b]
Standard Error	0.2765	0.2752	0.3944	0.0174
Significant (P-value)	<.0001	0.0001	0.0006	0.0294

Conclusions

During the first year of transition, this study compared rice growth, physiology, weed abundance and yield using three distinct input systems (conventional, integrated and organic). Plant physiological parameters such as leaf Chlorophyll content and photosynthesis rate were nearly identical and higher in conventional and integrated systems than in organic systems at all stages, owing to adequate nutrient supply provided by inorganic fertilizers in conventional and integrated systems. At seedling stage, crop growth was not shown many differences among the input systems indicating less reliance on soil fertility but rely upon the nutrients stored inside the seeds for growth. However, after seedling stage, there was a larger rate of variances in growth metrics, with conventional and integrated systems showing more plant growth than the organic system.

When compared to conventional and integrated systems, the organic system's lack of weed control resulted in high weed density and biomass at all stages. Overall results indicate that reducing inorganic fertilizers by 50% with the combination of organic manure as in the integrated system gives similar grain yields as the conventional system for a new improved variety like Bg 300 in high potential area like Anuradhapura. Also, organic systems can show low crop growth and yields due to inadequate nutrient supply through organic materials and due to high weed density during the first year of transition. Therefore, further studies are needed for the determination of a sustainable organic material that can adequately supply the nutrient requirement and exact quantities of them. Moreover, further studies are needed to identify different problems occurred in organic rice cultivation and to ensure the sustainability of integrated (reduced) nutrient management systems.

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