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Influence of Fertilizer Treatments on the Milling Potentials and Total Phenolic Content of Aromatic Rice

Mary Ann Baradi[1, *], Milen Fileza Magno[1], Jessica Solero[1], Romeo Ancheta[1], Gerome Corpuz[2], Marissa Romero[2]

[1]PhilRice Batac, City of Batac, Philippines

[2]PhilRice Central Experiment Station, Science City of Muñoz, Philippines

Email address:
maubaradi@yahoo.com.ph (M. A. Baradi)

[*]Corresponding author

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Abstract: The study aimed to determine the influence of different fertilizer treatments on the milling potentials (brown rice, milled rice, and head rice recovery) and total phenolic content of aromatic rice. The two-year field experiment laid out in Split Plot Design with three replications was carried out in irrigated lowland rice soil in San Nicolas, Ilocos Norte. The fertilizer treatment served as the main plot while the variety served as the sub-plot. The different fertilizer treatments were: Control or no fertilizer, rice straw, chicken manure, LCC-based 1, and LCC-based 2; while the two aromatic rice varieties were: modern aromatic *Burdagol*-Laguna Type and traditional pigmented aromatic *Gal-ong* rice. Results showed that the brown rice recovery of *Burdag*ol*-Laguna* Type was improved with the application of organic and inorganic fertilizers. Also, the milled rice recovery of *Burdagol-Laguna* Type was higher during dry season than wet season. On the other hand, *Gal-ong* produced high brown rice and milled rice recoveries from the application of organic fertilizers (rice straw and chicken manure) and Control, which indicates that the traditional variety can be organically grown, which would be more profitable for farmers. *Gal-ong* also had higher head rice recoveries and total phenolic contents than *Burdagol-Laguna* Type regardless of fertilizer treatment and season. The higher the total phenolic content in rice, the better since this compound may provide antioxidant and radical scavenging activity.

Keywords: Aromatic Rice, Fertilizer, Milling Potential, Total Phenolic Content

1. Introduction

Rice (*Oryza sativa* L.) is the most important cereal crop in developing countries. It is the staple food and most important source of calories of over half of the world's population [1, 2], and grown in wide range of climatic zones [3].

Grain quality is one of the major objectives in rice breeding programs of many countries as they achieve rice self-sufficiency [4]. It is as important as yield because it is mainly eaten as whole cooked grains while other cereals are usually processed as food or feed (for animals) [2]. The yield of the crop is the most noticeable characteristic to farmers while it is still in the ground, but when the product (milled rice) reaches the market, quality becomes the key determinant of its saleability [5].

Grain quality parameters of rice have been classified as to physical attributes (grain size and shape), milling (% brown rice, % total milled rice, % head rice), physicochemical properties (moisture content, alkali spreading value, gel consistency, crude protein content, amylose content), cooking parameters, sensory attributes [6], and phytochemical content. Scientists have classified the grain quality of rice as milling, appearance, cooking and eating, and nutritional aspects [2].

Aromatic rice is preferred by consumers because of its distinctive pleasant scent that makes it more special than the ordinary rice. On the other hand, organically-grown rice has also become popular among consumers because of food safety and environmental issues [7]. Is is believed that organically-grown rice which is grown only with organic amendments/materials/fertilizers and bio-pesticide has more nutritional benefits [8].

Saha et al. [9] reported that organic sources can perform comparatively well in terms of chemical and physico-chemical properties, and cooking quality of rice. However, the protein content in the grain was highest in the inorganic treatment.

In 2015, Gu and co-workers [10], reported that the milling, appearance, and eating quality were significantly improved, but the nutritive value of the grain has declined due to a reduction in protein content. The application of N fertilizer decreased grain quality, especially on the eating and cooking quality (amylose content, gel consistency, peak viscosity, breakdown, and setback).

In another investigation made by Gharieb and co-workers [11], grain quality traits were significantly influenced by the organic and inorganic fertilizers, and ascobien. The percentage of hulling, milling and amylose were positively and significantly influenced by nitrogen, organic and antioxidants application.

Moreover, Kifayatullah et al. and Sangeetha et al. [7, 12] studied the effects of organic fertilizers or manures on yield and quality of rice. Sikdar et al. [13] reported the effect of nitrogen level on the quality of aromatic rice varieties and soil fertility status in Bangladesh.

It is essential, therefore, to know the amount and kind of fertilizer for a variety and its effects on the grain quality of aromatic rice. This will lead to the development of appropriate fertilizer management of high quality aromatic rice.

This study aimed to determine the influence of different fertilizers (organic and inorganic) on the milling potentials and health-promoting phytochemical (total phenolic content) of aromatic rice.

2. Methodology

The study was conducted in San Nicolas, Ilocos Norte in typical irrigated lowland soil during the dry and wet seasons of 2014 and 2015. The *Palay*Check System of rice integrated crop management [14] was followed for transplanted irrigated lowland rice.

The experiments were replicated three times and the treatments were laid out in the field following a Split Plot Design. Fertilizer treatment (Control or no fertilizer, rice straw, chicken manure, LCC-based 1, LCC-based 2) was assigned as the main plot. Variety (*Burdagol-Laguna* Type, and *Gal-ong*) was assigned as the sub-plot. Each plot size was 4 m x 5 m (20 m^2).

The following were the different fertilizer treatments used in the experiment:

1. Control or no fertilizer
2. Rice straw (4 t ha^{-1} rate)
3. Chicken manure (3 t ha^{-1} rate)
4. LCC-based 1
5. LCC-based 2

Following the *Palay*check System Handbook, basal application of 4 bags ha^{-1} of 14-14-14 in WS and 6 bags ha^{-1} 14-14-14 in DS were applied for the LCC-based. Refer to PhilRice [15] for the procedure in using the PhilRice Leaf Color Chart (LCC).

LCC-based 1: For DS, apply 35 kg Nha^{-1} or 1.5 bags ha^{-1} of urea when LCC reading is below 4 from tillering to flowering stage; and for WS, apply 23 kg N ha^{-1} or 1 $bagha^{-1}$ of urea when LCC reading is below 4 from tillering to flowering stage.

LCC-based 2: For DS, apply 53 kg N ha^{-1} or 2.3 bags ha^{-1} of urea when LCC reading is below 4 from tillering to flowering stage; and for WS, apply 35 kg N ha^{-1} or 1.5 bags ha^{-1} of urea when LCC reading is below 4 from tillering to flowering stage.

Table 1 shows the different fertilizers applied during the experiment.

Table 1. *Fertilizer applications, 2014−2015, dry and wet seasons. San Nicolas, Ilocos Norte.*

Fertilizer Management	Fertilizer Rate (kg ha^{-1})	
	DS	WS
Control	0	0
Rice straw	30-4-43 (4t ha^{-1})	4t ha^{-1}
Chicken manure	55-129-116 (3t ha^{-1})	30-240-28 (3t ha^{-1})
LCC-based 1	108-42-42	97-28-28
LCC-based 2	118-42-42	133-28-28

The milling potentials (brown rice, milled rice, and head rice recoveries) of the two aromatic rice varieties (*Burdagol-Laguna* Type and *Gal-ong*) were determined following the procedure in the National Cooperative Testing Manual for Rice [16].

The total phenolic content of the methanolic extracts was determined using the Method of Singleton et al. [17] with some modifications. Extract (0.5 mL) was mixed with 2.5 mL freshly prepared Folin-Ciocalteu reagent (1:10 dilution). After 15 min incubation, 2 mL of 7.5% sodium carbonate was added to the mixture. It was then allowed to stand for 1 h for the color formation. The absorbance of the resulting blue color was measured at 760 nm against a blank. Gallic acid (GA) was used as a standard and total phenolic content was expressed as mg GA equivalent/g sample.

The Analysis of Variance (ANOVA) for 3-way factorial in Split Plot Design was used to determine the main effects of the three factors (fertilizer, variety, season) on the milling potentials and total phenolic content of aromatic rice.

The Least Significant Difference test (LSD) was also used for treatment mean comparison at 5% level.

3. Results and Discussion

3.1. Milling Potentials

The main effect of the variety and the interaction of the season and variety on the milling potentials (% brown rice, % milled rice, % head rice) were significant (Table 2). Moreover, the main effect of the fertilizer treatment on the milled rice recovery, and its interaction effect with variety on brown rice and milled rice recoveries were also significant.

Table 2. *Results of analyses of variances of various quality parameters.*

Source of Variation	Year					
	2014			2015		
	BR	MR	HR	BR	MR	HR
Season (S)	ns	ns	ns	*	ns	*
Fertilizer (F)	*	**	ns	ns	**	***
S x F	ns	ns	ns	ns	*	***
Variety (V)	***	***	***	***	**	***
S x V	***	***	**	**	***	***
F x V	***	**	ns	***	***	***
S x F x V	**	ns	ns	ns	ns	**

BR - % brown rice; MR - % milled rice; HR - % head rice
*** highly significant at 0.1% level, ** significant at 1% level; * significant at 5% level; ns-not significant

3.1.1. Brown Rice Recovery

2014

Burdagol-Laguna Type had higher brown rice recoveries than *Gal-ong* regardless of fertilizer treatment during the dry season except when treated with rice straw (Figure 1). However, during the wet season, *Gal-ong* gave higher brown rice recoveries when treated with the control and organic fertilizers (rice straw, chicken manure) (Figure 2). This indicates that the traditional variety can be grown even at no or low N fertilizer level using organic fertilizers, still producing high brown rice recoveries.

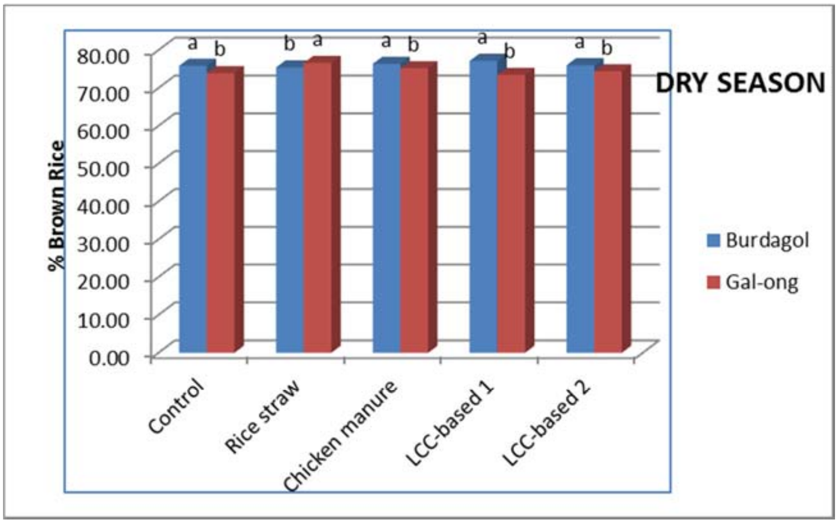

Figure 1. *Comparison of the brown rice recoveries of the two varieties at each level of fertilizer treatment during dry season in 2014.*

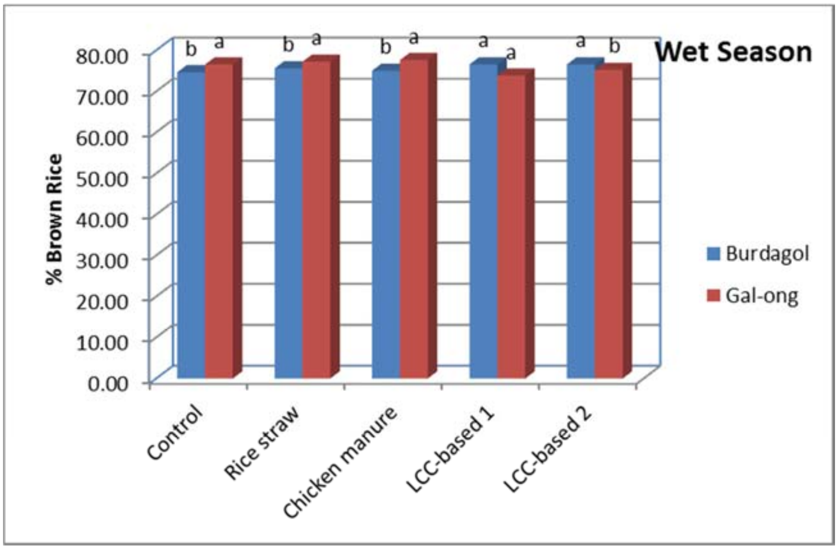

Figure 2. *Comparison of the brown rice recoveries of the two varieties at each level of fertilizer treatment during wet season in 2014.*

2015

As in 2014, Gal-ong gave higher brown rice recoveries than *Burdagol-Laguna* Type during wet season (Figure 3) and when treated with Control and organic fertilizers (Figure 4). The variation in the brown rice recoveries among the two varieties maybe due to the differences in their inherent characteristics. Kamal and his co-workers [18] that the quality attributes (milled rice rate and brown rice rate) of two rice hybrids showed variable response to various levels of NPK fertilizer.

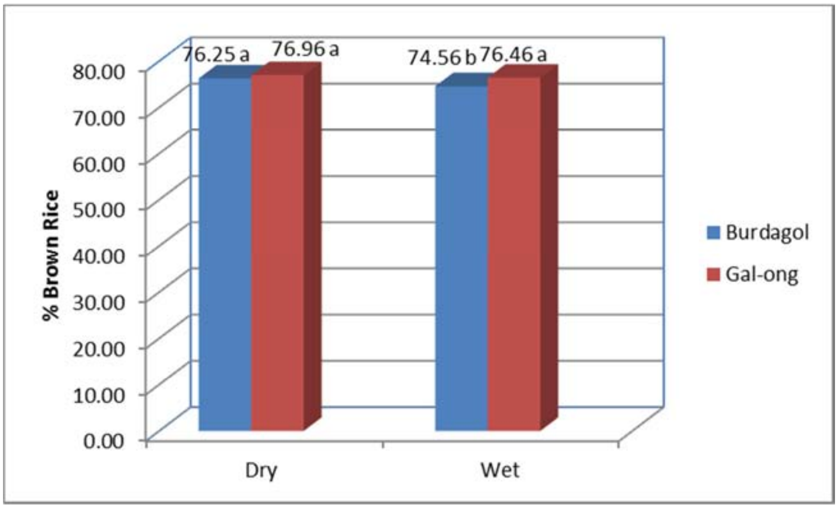

Figure 3. *Comparison of the brown rice recoveries of the two seasons at each level of variety in 2015.*

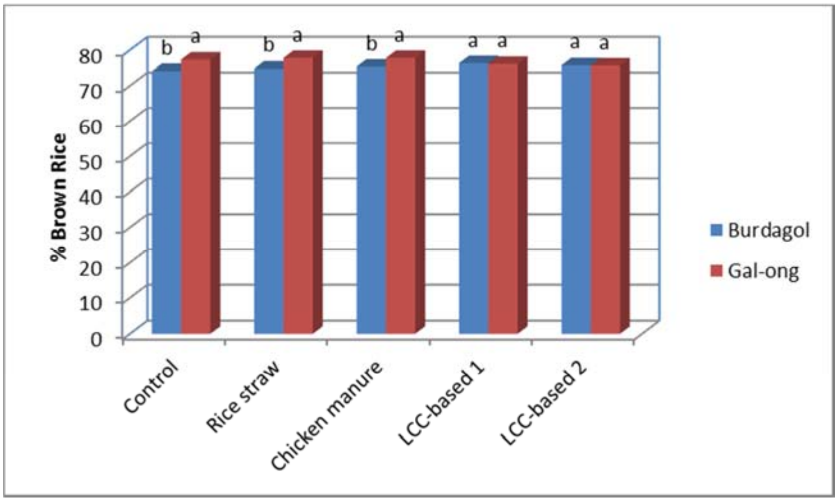

Figure 4. *Comparison of the brown rice recoveries of the two varieties at each level of season in 2015.*

Table 3. *Comparison of the brown rice recoveries of the different treatments at each level of variety in 2015.*

Fertilizer Treatment	% Brown Rice	
	***Burdagol-Laguna* Type**	***Gal-ong***
Control	74.08 b	77.32 bc
Rice straw	74.81 ab	77.79 ab
Chicken manure	75.36 ab	77.75 ab
LCC-based 1	76.32 a	76.11 bcd
LCC-based 2	75.73 ab	75.64 cd

Means in a column with the same letter are not significantly different from each other at 5% level using LSD

Table 3 shows the highest brown rice recoveries of *Burdagol-Laguna* Type were those from the LCC-based 1, followed by those treated with LCC-based 2 and organic fertilizers. The application of inorganic and organic fertilizers improved the brown rice recovery, over that of the control or no fertilizer applied. The result conformed with the reports of Gu et al. and Gharieb et al. [10–11]. It was also reported that higher value of hulling or brown rice, milling, and head rice recovery were obtained by integrating both inorganic and organic sources of nutrients [19].

3.1.2. Milled Rice Recovery

2014

The milled rice recoveries of *Burdagol-Laguna* Type were significantly higher during dry season than during wet season (Figures 5 through 6). *Gal-ong* had comparable milled rice recoveries during dry and wet seasons.

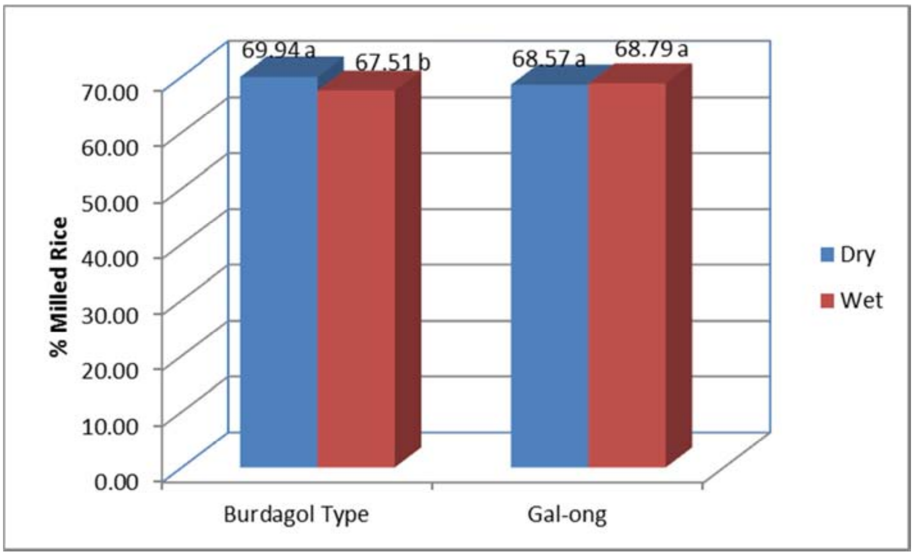

Figure 5. *Comparison of the milled rice recoveries of the two seasons at each level of variety in 2014.*

Gal-ong had higher milled rice recovery than *Burdagol-Laguna* Type during wet season (Figure 6).

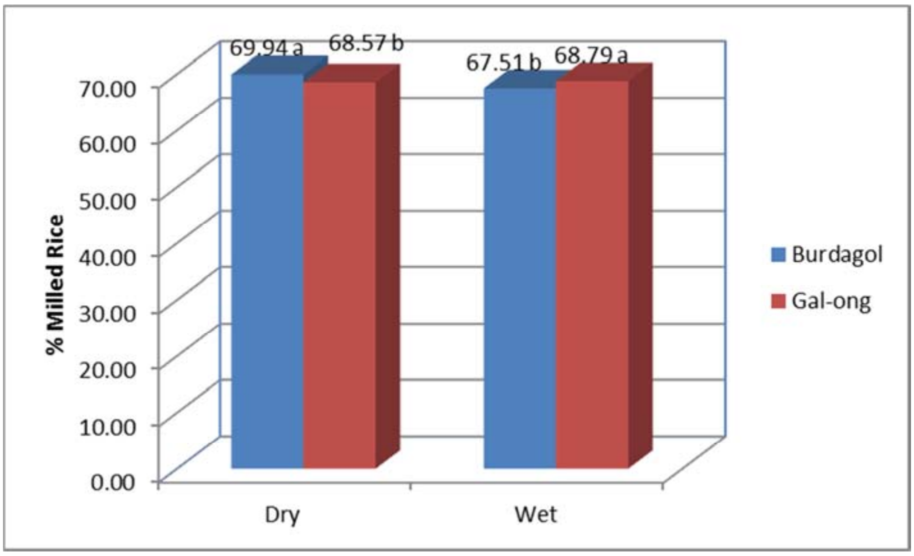

Figure 6. *Comparison of the milled rice recoveries of the two varieties at each level of season in 2014.*

Table 4 shows that the milled rice recoveries of *Burdagol-Laguna* Type treated with the different fertilizer treatments were comparable with each other. *Gal-ong* had the highest milling recoveries when treated rice straw, followed by chicken manure.

Table 4. *Comparison of the milled rice recoveries of the different treatments at each level of variety in 2014.*

Fertilizer Treatment	**% Milled Rice**	
	***Burdagol-Laguna* Type**	***Gal-ong***
Control	68.41 a	67.57 bc
Rice straw	68.61 a	69.96 a
Chicken manure	69.09 a	68.95 ab
LCC-based 1	69.21 a	66.36 c
LCC-based 2	68.45 a	67.47 bc

Means in a column with the same letter are not significantly different from each other at 5% level using LSD

Burdagol-Laguna Type consistently gave higher milling recoveries than *Gal-ong* when treated with the Control and LCC-based (Figure 7). The milling recoveries of those treated chicken manure were not significantly different among the two varieties.

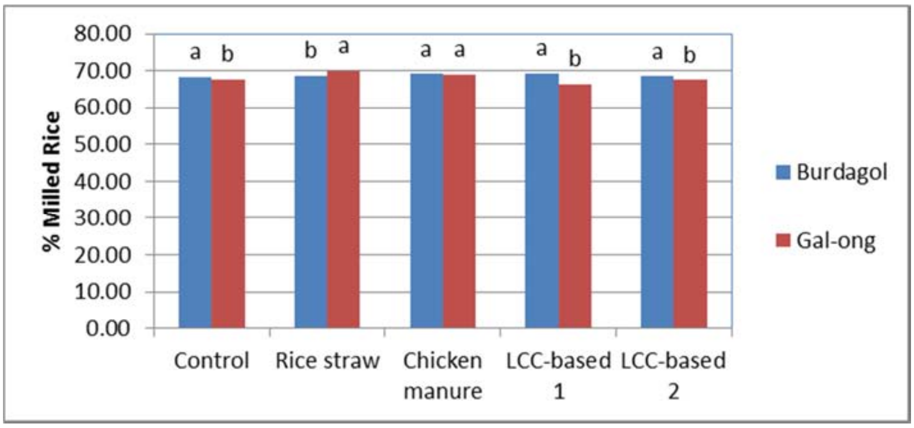

Figure 7. *Comparison of the milled rice recoveries of the two varieties at each level of fertilizer treatment in 2014.*

2015

Figure 8 shows that during wet season, *Gal-ong* had higher milled rice recovery than *Burdagol-Laguna* Type, which is the same result in 2014.

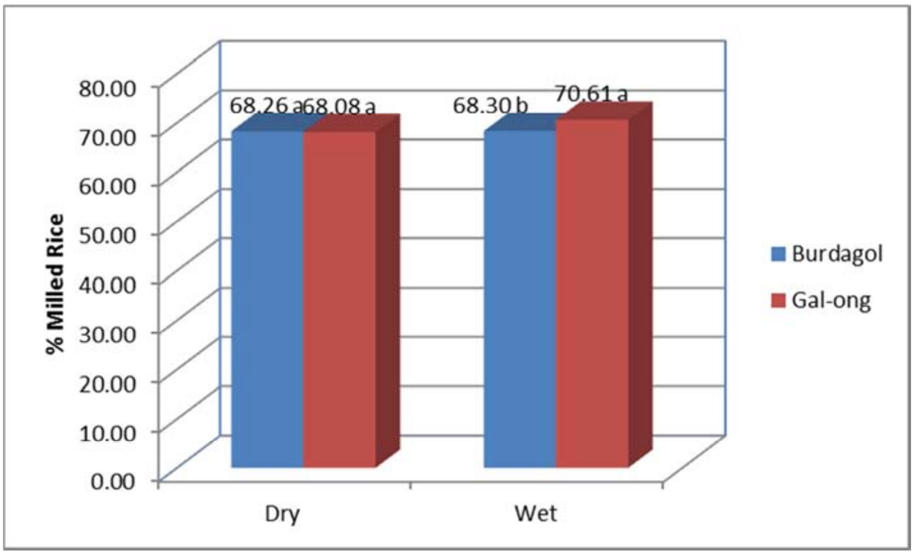

Figure 8. *Comparison of the milled rice recoveries of the two varieties at each level of season in 2015.*

The highest milling recoveries in *Burdagol-Laguna* Type were obtained from those applied with chicken manure and LCC-based 1, followed by the rice straw and LCC-based 2 (Table 5). For *Gal-ong*, the highest milling recoveries were obtained from the rice straw, followed by chicken manure and Control.

Table 5. *Comparison of the milled rice recoveries of the different treatments at each level of variety in 2015.*

Fertilizer Treatment	% Milled Rice	
	***Burdagol-Laguna* Type**	***Gal-ong***
Control	65.94 b	70.01 abc
Rice straw	68.38 ab	71.54 a
Chicken manure	68.97 a	70.79 ab
LCC-based 1	69.46 a	68.12 bcd
LCC-based 2	68.02 ab	67.69 cd

Means in a column with the same letter are not significantly different from each other at 5% level using LSD

Figure 9 shows that *Gal-ong* gave higher milled rice recoveries than *Burdagol-Laguna* Type when applied with the Control, rice straw, and chicken manure.

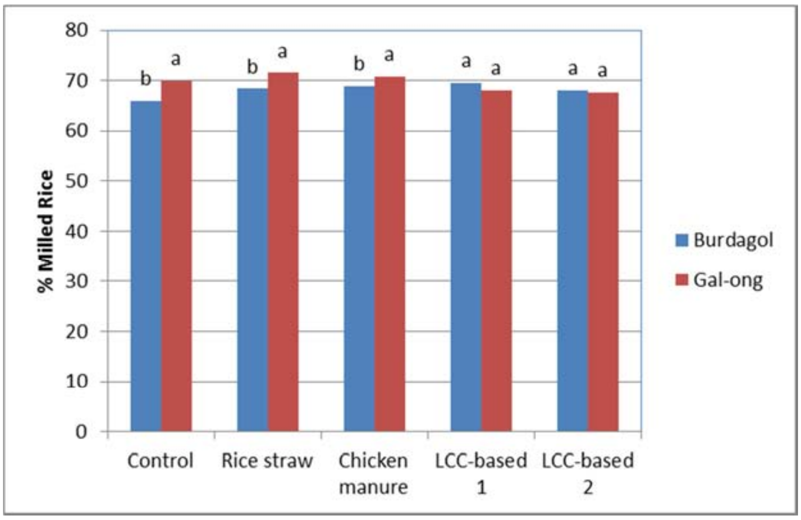

Figure 9. *Comparison of the milled rice recoveries of the two varieties at each level of fertilizer treatment in 2015.*

3.1.3. Head Rice Recovery

2014

Figure 10 shows that the head rice recovery of *Burdagol-Laguna* Type was higher during wet season than dry season. On the other hand, *Gal-ong* gave higher head rice recoveries than *Burdagol-Laguna* Type in both seasons (Figure 11).

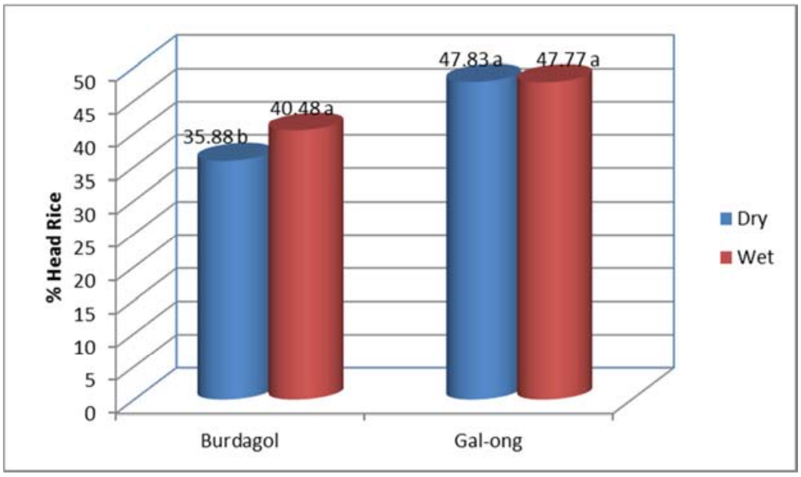

Figure 10. *Comparison of the head rice recoveries of the two seasons at each level of variety in 2014.*

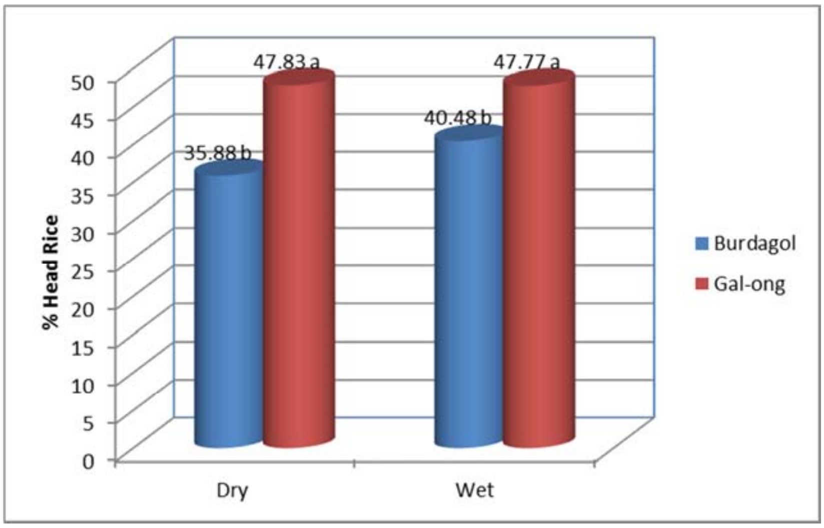

Figure 11. *Comparison of the head rice recoveries of the two varieties at each level of season in 2014.*

2015

Figure 12 shows that the head rice recoveries of *Gal-ong* during wet season were significantly higher than during dry season when applied with low N fertilizer levels (Control and rice straw).

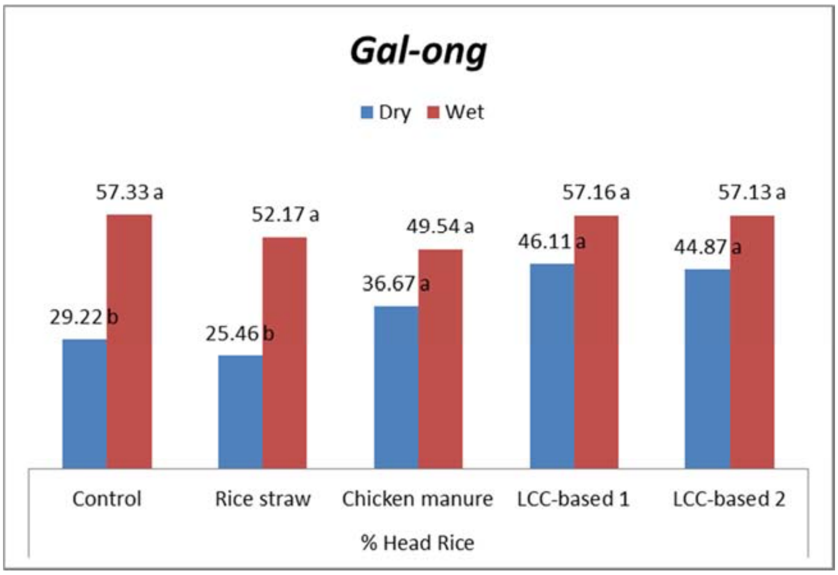

***Figure 12.** Comparison of the head rice recoveries of the two seasons at each level of fertilizer treatment in 2015.*

3.2. Total Phenolic Content

2014

In 2014, the phenolic contents of *Burdagol-Laguna* Type were higher during wet season than dry season for those treated with chicken manure and LCC-based 2 (Figure 13). Those treated with rice straw had higher phenolic contents during dry season than wet season.

Tuaño et al. [20] reported that the total phenolics of the non-aromatic NSIC Rc160 brown rice were lower in the control and organic rice than in rice treated with inorganic fertilizer and pesticide.

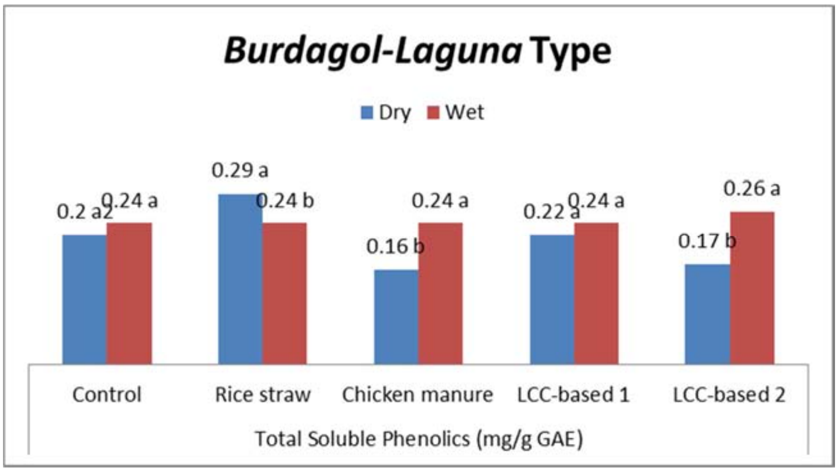

***Figure 13.** Comparison of the total phenolic contents of the two seasons at each level of fertilizer treatment in 2014.*

For *Gal-ong*, the phenolic contents during wet season were significantly higher than dry season in the various treatments except in LCC-based 1 treated samples wherein the phenolic contents were comparable during the two seasons (Figure 14).

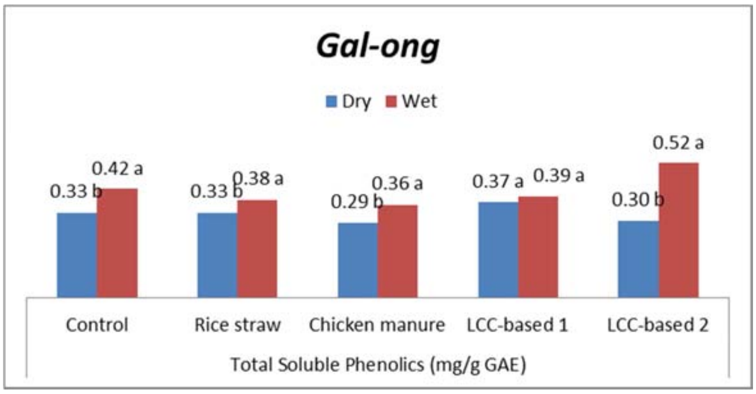

Figure 14. *Comparison of the total phenolic contents of the two seasons at each level of fertilizer treatment in 2014.*

Gal-ong had the higher total phenolic contents than *Burdagol-Laguna* Type in all fertilizer treatments during the two seasons (Figures 15 through 16, Table 6). Asaduzzaman et al. [21] reported that various aromatic rice varieties exhibit good phytochemicals characteristics such as phenolic contents.

The greater the phenolic compounds in rice, the better since these compounds may provide antioxidant and radical scavenging activities. Phenolics are able to donate hydrogen and form relatively stable resonance hybrids of delocalized unpaired electrons allowing the molecule to act as reducing agents, single oxygen quenchers, and free radical hydrogen donors. Their presumed role is the protection of cell constituents against oxidative damage [22].

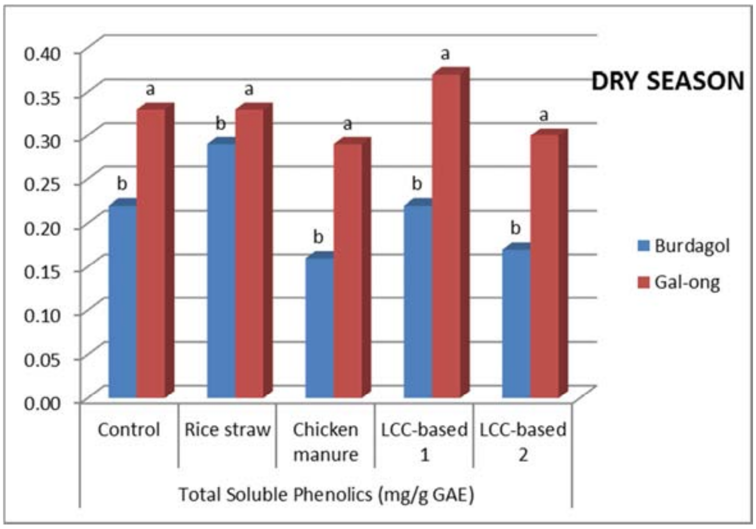

Figure 15. *Comparison of the total phenolic contents of the two varieties at each level of fertilizer treatment during dry season.*

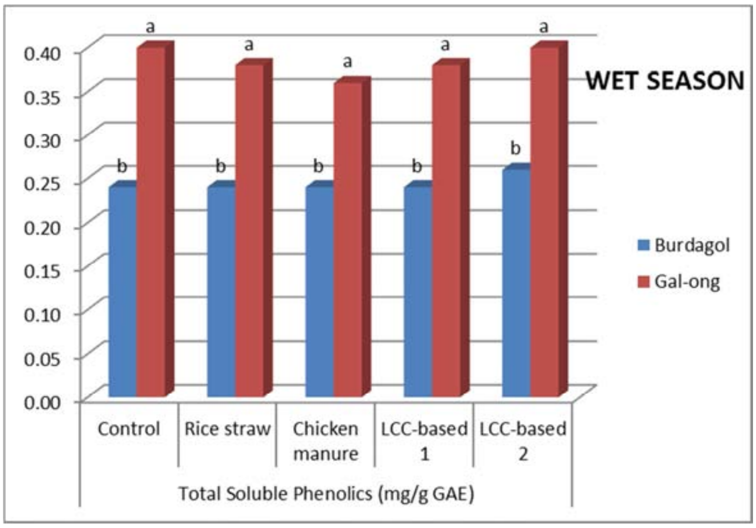

Figure 16. *Comparison of the total phenolic contents of the two varieties at each level of fertilizer treatment during wet season.*

Table 6 shows that *Gal-ong* had the highest phenolic contents when treated with LCC-based 1 during the dry season and LCC-based 2 during the wet season, respectively.

Table 6. *Comparison of the total phenolic contents of the different fertilizer treatments at each level of season and variety.*

Fertilizer Management	Total Soluble Phenolics (mg/g GAE)			
	DS		WS	
	***Burdagol-Laguna* Type**	***Gal-ong***	***Burdagol-Laguna* Type**	***Gal-ong***
Control	0.22 b	0.33 b	0.24 b	0.42 b
Rice straw	0.29 a	0.33 b	0.24 b	0.38 cd
Chicken manure	0.16 d	0.29 d	0.24 b	0.36 e
LCC-based 1	0.22 b	0.37 a	0.24 b	0.39 cd
LCC-based 2	0.17 cd	0.30 cd	0.26 a	0.52 a

Means in a column with the same letter are not significantly different from each other at 5% level using LSD

2015

The phenolic content of *Burdagol-Laguna* Type were higher during dry season than wet season regardless of fertilizer treatment applied (Figure 17).

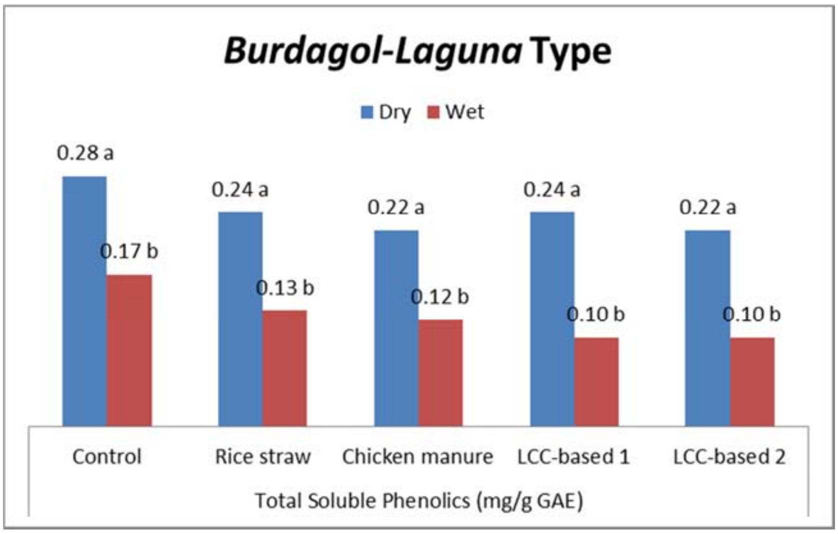

Figure 17. *Comparison of the total phenolic contents of the two seasons at each level of fertilizer treatment in 2015.*

For *Gal-ong*, higher phenolic contents were observed during dry season than wet season when treated with the control and rice straw. Those treated with chicken manure and LCC-based 1 and 2 had comparable phenolic contents during the two seasons (Figure 18).

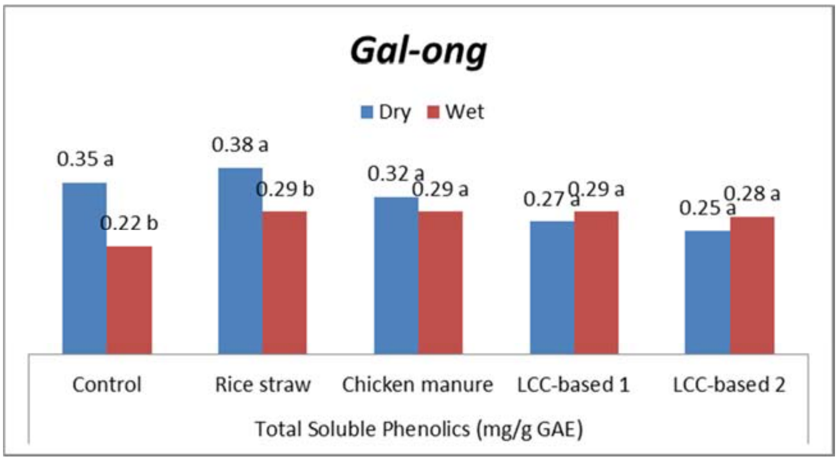

Figure 18. *Comparison of the total phenolic contents of the two seasons at each level of fertilizer treatment in 2015.*

As in 2014, *Gal-ong* had higher phenolic contents than *Burdagol-Laguna* Type regardless of fertilizer treatment in both dry and wet seasons (Figure 19 through 20). Park et al. [23] reported that contents of individual phenolic acids in different forms (free, esterified, and insoluble) varied among rice grains and suggested that the phenolic acid composition in rice grain is determined by environmental factors such as growing condition rather than by genetic factors. On the other hand, Benzon et al. [24] found that nano-fertilizer affects the total phenolic content and oxidant activity of rice.

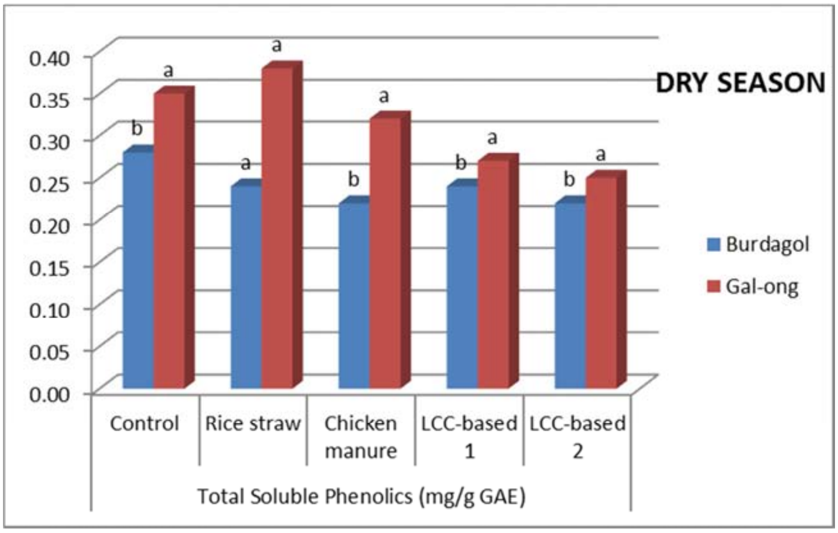

Figure 19. *Comparison of the total phenolic contents of the two varieties at each level of fertilizer treatment during dry season in 2015.*

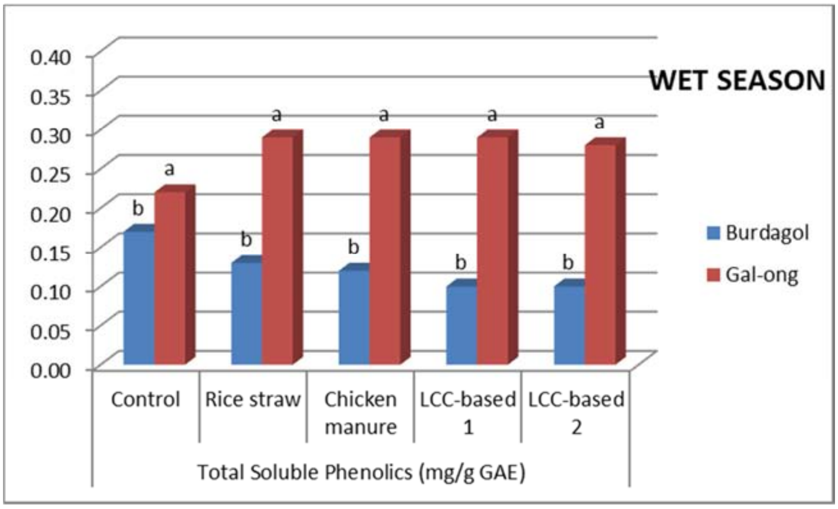

Figure 20. *Comparison of the total phenolic contents of the two varieties at each level of fertilizer treatment during wet season in 2015.*

Burdagol-Laguna Type had the highest total phenolic contents when no fertilizer applied during the two seasons (Table 7). Its phenolic contents were comparable when treated with the organic and inorganic fertilizers.

Gal-ong, on the other hand, had the highest total phenolic contents when applied with rice straw during the dry season; and highest when applied with organic and inorganic fertilizers during the wet season.

Table 7. *Comparison of the total phenolic contents of the different fertilizer treatments at each level of variety and season.*

Fertilizer Treatment	Total Soluble Phenolics (mg/g GAE)			
	Dry		Wet	
	***Burdagol-Laguna* Type**	***Gal-ong***	***Burdagol-Laguna* Type**	***Gal-ong***
Control	0.28 a	0.35 ab	0.17 a	0.22 b
Rice straw	0.24 b	0.38 a	0.13 b	0.29 a
Chicken manure	0.22 b	0.32 b	0.12 b	0.29 a
5. LCC-based 1	0.24 b	0.27 cd	0.10 b	0.29 a
6. LCC-based 2	0.22 b	0.25 d	0.10 b	0.28 a

Means in a column with the same letter are not significantly different from each other at 5% level using LSD

The variations in the total phenolic contents maybe due to the inherent characteristics of the variety, fertilizer, season, and among others.

4. Conclusion

Based on the results of the study, the milling potentials (brown rice, milled rice and head rice recoveries) and total phenolic content of the two aromatic varieties *Burdagol*-Laguna Type and *Gal-ong* were influenced by fertilizer treatment, season, and inherent characteristic of the variety.

The brown rice recovery of *Burdagol*-Laguna Type was higher when treated with organic and inorganic fertilizers than the Control which implies that this attribute was improved with the application of fertilizer.

Burdagol-Laguna Type had higher milled rice recovery during dry season than wet season which indicates that the variety performs better during dry season than wet season.

Gal-ong, a traditional variety, still produced high brown rice and milled rice recoveries even at low or no fertilizer N application (organic fertilizers) indicating that it can be organically grown which would be more profitable to the farmers. It also had higher head rice recovery and total phenolic content than *Burdagol*-Laguna Type regardless of fertilizer treatment and season. The higher the total phenolic content in rice, the better since this compound may provide antioxidant and radical scavenging activity. Variations in the head rice recoveries and phenolic contents of the two varieties maybe due to their inherent characteristics.

Understanding the influence of the different fertilizer treatments on the milling potentials and total phenolic content of aromatic rice will lead to the development of appropriate fertilizer management. This study serves as guide to farmers in their crop management to produce more and better quality rice.

Acknowledgements

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