Philippine Journal of Crop Science (PJCS) issue of April 2008, 33(1): 37-58

PRODUCTIVITY AND SEED QUALITY OF RICE (*ORYZA SATIVA* L.) CULTIVARS GROWN UNDER SYNTHETIC, ORGANIC FERTILIZER AND BIODYNAMIC FARMING PRACTICES

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Portion of the MS Agronomy Thesis of the first author
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A study was conducted at PhilRice Nueva Ecija (2005 WS) to compare the performance of rice varieties under four pesticide-free production practices: 'synthetic' (or 'chemical' fertilizer), 'organic' (composted poultry manure), 'biodynamic' (biodynamic preparations, no fertilizer) and 'control' (no fertilizer). The varieties, developed and/or maintained by the Philippine Rice Research Institute (PhilRice), were PSB Rc82, PSB Rc72H and Dinorado Gold. Parameters measured included yield and other agronomic traits, eating quality, germination of artificially aged seeds, soil quality, and costs and returns. Treatments were in factorial combination, laid out in split plot in Randomized Complete Block Design in three replications. Results showed that varieties differed from each other in many parameters, but the difference was more from Dinorado than from the other varieties. Crop performance also differed with production practices. Yield of Dinorado (tallest variety) was not assessed because of uneven stand due to extensive lodging. PSB Rc72H (a hybrid) had 8% higher grain yield than PSB Rc82 (a pure line). PSB Rc72H also had higher number of productive tillers, shoot biomass, 1000-seed weight and harvest index. Grain yield of 'synthetic' was 14% higher than 'organic,' while that of 'biodynamic,' which was third in rank, was 13% higher than control. In terms of seed resistance to accelerated aging, Dinorado tended to have better vigor or storability than the PSBs. 'Organic' followed by 'biodynamic' also were better than 'synthetic.' Soil phosphorus increased after cropping but only with 'biodynamic' (20%) and 'organic' (18%). Root development was greatest for 'biodynamic' and 'organic.' 'Organic' gave greater net profit (16%) and return on investment (30%) than 'synthetic;' 'biodynamic' ranked next to 'organic.'' Tungro, which affected Dinorado, was controlled by a 'biodynamic' preparation of horsetail (Equisetum arvense). The polished 7-month grains (cooked and uncooked) of the PSBs were more favored in eating quality than the Dinorado. 'Organic' ranked highest in most sensory parameters while 'synthetic' mostly ranked last among the four practices. Except in yield, 'organic' proved the best performer in the study, while 'biodynamic' presented good potential under a low-input system.

biodynamic, Dinorado, grain quality, organic fertilizer, PhilRice varieties, rice seed quality, synthetic fertilizer

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food in around 25 countries, mostly in Asia, or around half of the world's population (>2.7 billion). This translates to approximately 132 M ha or 91% of the world's rice grown and consumed in Asia (Maclean et al 2002). Rice was the first crop that was tested in the global Green Revolution movement, which aimed to increase productivity. The program basically changed the system of farming, from a more ecological approach to continuous monoculture and use of 'chemical' or 'synthetic' inputs (inorganic fertilizers and pesticides) and use of varieties that are highly homogenous, narrow in genetic base and fertilizer-responsive. This has become the norm and persisted through decades, thus regarded as the conventional or mainstream agricultural system.

As a response to the ecological, economic and socio-cultural problems brought about by the Green Revolution (Feder 1983, Shiva 1991, Perlas 1993a & 1993b), another movement emerged. This is the sustainable agricultural movement (Perlas 1993b, Zamora 1996), within which are different time-tested approaches (Fernandez 2000 & 2001). 'Organic' agriculture is one of them, although later it has been expanded in scope to include not only input changes but also strategies and general philosophy (Fernandez 2001).

Another practice considered deeper than 'organic' is 'biodynamic' farming. It is based on the science of life forces (Steiner 2005, Perlas 1993a, Wildfeuer 2006). It is less explored in the Philippines but is showing great promise in other parts of the world. It is gaining increased attention for its emphasis on food quality and soil health (Diver 1999) while yields are not compromised (Gamela-Ruizo 2000, Fernandez 2000 & 2001).

A distinguishing feature of 'biodynamic' farming is the use of a 'biodynamic calendar' (Stella Natura 2005) and 'biodynamic' preparations (Klett 2006) for the purpose of enhancing soil quality and stimulating plant life. 'Biodynamic' preparations are intended to help moderate and regulate biological processes as well as enhance and strengthen the life (etheric) forces of the farm. The preparations are used in homeopathic quantities, and produce an effect in extremely diluted amounts (Diver 1999). To date, 'biodynamic' farming is being considered part of the larger 'organic' movement (Fernandez 2001). On the other hand, the number of studies on 'organic' farming in the Philippines is increasing (eg, Tung 2006), but only very few have been conducted under formal institutional settings.

The objective of the study was to assess the productivity, crop health, seed quality economics and effect on soil of selected rice varieties of PhilRice grown under 'synthetic,' 'organic' and 'biodynamic' farming practices in lowland culture.

MATERIALS AND METHODS

The study was conducted at the Central Experiment Station of PhilRice in Maligaya, Science City of Muñoz, Nueva Ecija from July to November 2005. The area had been planted to lowland rice for 20 years under a pure 'chemical' system. 'Organic' commercial poultry manure had been added as fertilizer to crops since five years before the study. The area was also at least four months under fallow before the experiments were conducted. The laboratory part, particularly the storage and seed quality testing, was conducted at the Analytical Service Laboratory of the Rice Chemistry and Food Science Laboratory at PhilRice, Nueva Ecija.

The field experiment was laid out in 4 x 3 factorial with treatments arranged in split-plot in randomized complete block design (RCBD) with three replications. The factors and factor levels were production practices: 'synthetic' or use of 'chemical' fertilizer, 'organic' or use of organic fertilizer, 'biodynamic' or use of selected BD preparations, and the control, which served as the main plot. Varieties, which served as subplot, included Dinorado Gold, an extract from the traditional variety Dinorado; PSB Rc82, an inbred variety which is one of the most popular varieties in Nueva Ecija where PhilRice is based, and PSB Rc72H, a hybrid.

The fertilizer rate for 'synthetic' practice was 90-30-30 NPK (supplied by 14-14-14 and 46-0-0). Application was in three splits (1/2 N and all P-K were applied basally, 1/4 N at 30 DAP and 1/4 N at panicle initiation). For 'organic' practice, commercial poultry manure was used as 'organic' fertilizer ("Plantmate" with NPK analysis of 2-3-3 and an OM of 40%) at a total rate of 400 kg/ha, all applied before planting. In 'biodynamic' farming, no fertilizer was applied; treatments were BD 500 and BD 501, obtained from Don Bosco Youth Center in Makilala, North Cotabato, and BD 508 from Los Baños.

Milk and honey (400 mL carabao fresh milk and 150 mL honey per hectare) were also applied at the vegetative stage to increase natural enemies (DBDYCI 2005). The planting time which was the same for all treatments coincided on a root day based on the Stella Natura (2005) BD Calendar.

The area of the subplot was 4 m x 5 m and the planting distance was 20 cm x 20 cm. Border between plots was 100 cm and between subplots 30-cm bunds. All rice varieties were under a lowland irrigated agroecosystem. The field was prepared thoroughly by plowing, harrowing and leveling following the usual practice for lowland rice culture (Roguel-Mina & Duldulao 2003). Seeds were soaked in water for 24 hours and incubated for another 24 hours, then germinated on a tray with soil ("dapog" style). A total of 21 day-old seedlings were transplanted at one seedling per hill. Water was maintained 2-3 cm above the soil throughout the growth period. Weeds were removed manually to avoid nutrient competition.

For 'biodynamic' treatment, BD 500 was sprayed once in the experimental plots (before transplanting) and seedlings were dipped in BD 500 before transplanting. The BD 501 was applied once to all plots during the vegetative stage (21 DAT) when radiation was low, while 508 was applied also during the vegetative stage (28 DAT) and applied twice to all plots of Dinorado, as these were infected with tungro.

The three varieties and seeds used in the study have been developed and/or maintained by PhilRice. Major characteristics of these under PhilRice management system are given in Table 1. Dinorado Gold is a pure line collection of the Germplasm Unit in PhilRice. It is one of the types of Dinorado that are being maintained by PhilRice and planted under lowland conditions under 'synthetic' production practice. The grain is white and used for breeding because of its good grain quality. PSB Rc82 is an inbred variety that was released in 2000. It has good grain quality with high percentage of public acceptability. It is one of the popular varieties because of its high milling recovery. PSB Rc72H is a hybrid variety released in 1997. It has good eating quality and high percentage of acceptability.

Table 1. **Major characteristics of Dinorado, PSB Rc82 and PSB Rc72H (National Rice Cooperative Testing Project, PhilRice, Maligaya, Science City of Muñoz)**

VARIETY	AGRONOMIC CHARACTERISTICS							
	Yield (kg/ha)		Maturity days		Plant height (cm)		Productive tillers	
	DS	WS	DS	WS	DS	WS	DS	WS
Dinorado	2500	2000	121	122	166	134	12	15
PSB Rc82	4977	4692	106	112	87	106	15	15
PSB Rc72H	5783	5048	124	120	96	101	15	14

DS – dry season *WS – wet season*

Soil samples of each replicate were collected before fertilizer application and after harvest from a depth of 15-20 cm (PCARR 1980). Samples were submitted to PhilRice laboratory for measurement of N, P, K, organic matter, pH and cation exchange capacity (CEC). Plant height (cm) at heading stage was determined by actual measurement from soil surface to the tip of the tallest panicle, with awns excluded (Inger 1996). Measurement scale was 1 for "semi-dwarf" (less than 110 cm), 5 for "intermediate" (110-130 cm) and 9 for "tall" (more than 130 cm).

At harvest, three plants from each subplot were carefully collected. The sampling area was 10 cm x 10 cm with a depth of 30 cm. Roots were separated from the shoot and washed with water. Root length was measured (cm) from the base of the root to the tip of the longest root. Root biomass from the same sample was determined after oven-drying at 50 C for at least 24 hr. Grain yield (kg/ha) was determined by harvesting 1 m^2 area from each subplot, excluding border rows, and reported at 12% moisture content. Moisture content was determined using a moisture tester (Kett-PB-1D2).

Harvest index was calculated as the ratio of grains (representing economic yield) to biological yield. Harvested grains were cleaned, weighed, their values adjusted to 12% moisture content. The biological yield was determined by weighing the dried whole plant including roots, minus the grains. The number of productive panicles per plant was counted from plants from four hills near the center of the experimental plot. Seed density expressed as weight of 1000 seeds was determined by weighing 1000 seeds from the grain harvest. Seeds were germinated (50 x 3) with a modified ISTA (1985) method, on moist filter papers laid on plastic containers kept at ambient conditions. The percentage germination was calculated based on normal seedlings.

To determine the seed storage potential (an expression of vigor), seeds were subjected to AAT (Accelerated Aging Test). Fifty seeds from each harvest were placed in a coin envelope and placed in a desiccator with 100% RH and kept at 40 C in an oven for 3 days (ISTA 1985). After aging, germination test (50 x 3) was done using rolled filter paper.

Cost and return analysis was based on the method developed by the Socio-Economics Division (SED) of PhilRice and the Sikap/Strive Foundation in 2005. All cost items were accorded monetary value (in Philippine peso). The mechanical formulas used in computing the cost and returns analysis were:

(1) ROI = NP – TPC / 100

where ROI is Return on investment, NP is Net Profit, and TPC is Total Production Cost.

(2) NP = GR – TPC

where NP is Net Profit, GR is Gross Return, TPC is Total Production Cost. GR = grain yield (kg/ha) x price of paddy rice (P/kg); TPC = cash costs + imputed costs.

No premium price was given to organic and biodynamic products. The presence of insects commonly regarded as pests, and of natural enemies was noted using the Agroecosystem Analysis (AESA) concept and procedures (Roguel-Mina & Duldulao 2003). Counting was done at the canopy level, plant interior, plant base, hill, those dislodged from the plants and those in the surrounding water. Weekly observation was done starting from 38 days after transplanting. The average of four weekly observations was then computed and used for analysis.

Grains were subjected to sensory evaluation (Sebastian et al 1997) by PhilRice's seven trained sensory panelists for rice at the Rice Chemistry and Food Science Laboratory. The grains were already seven months old when they were milled and evaluated. Raw rice evaluation was determined in terms of translucency, aroma, and whiteness.

The criteria for evaluation was for conventional grain quality of rice, which is highly polished and had come from crops that had been usually grown using 'synthetic' production practices. Freshly cooked rice and that which had been cooked six hours before were also evaluated using several criteria namely, taste, gloss, whiteness, tenderness, aroma, cohesiveness and general acceptability. The three varieties were ranked from highest (15) to lowest (0) according to the scores obtained. A higher score indicated greater preference.

Data was analyzed using the analysis of variance (ANOVA) procedure with the aid of Statistical Analysis System (SAS) Software. The Least Significant Difference (LSD) was used to make comparisons among selected treatment means for the sensory evaluation test. Group comparisons of treatment means using orthogonal contrasts were also made, also using the SAS program.

RESULTS

The study was conducted to verify how varieties of Dinorado Gold (henceforth referred to as Dinorado), PSB Rc82 and PSB Rc72H, subjected to different production practices (control, 'synthetic' which is used synonymously with 'chemical' and inorganic, 'organic' and 'biodynamic') would differ in terms of yield, seed quality, eating quality, effect on soil properties, response to pests and beneficials, and economics. The study also aimed to determine if rice performance under 'organic' production practice is comparable with or better than that under 'chemical' production practice and how 'biodynamic,' an emerging practice in the international organic agriculture international movement, will perform relative to selected 'organic' and 'chemical' practices.

Yield and Yield Components

Grain yield for Dinorado was not considered because plants lodged at the grain filling stage due to heavy rains and strong winds. Being tall, this predisposed the plants to lodging (Table 1). Significant yield differences were found between the two remaining varieties PSB Rc82 and PSB Rc72H, and among production practices (Figure 1a). 'Synthetic,' 'organic' and 'biodynamic' production practices for PSB Rc82 gave yield advantages over the control, ie, 56%, 37% and 15%, respectively. For PSB Rc72H it was 48%, 29% and 10% respectively. The yield advantages of 'synthetic' over 'organic' and 'biodynamic' were 14% and 34%, respectively.

There were significant differences among varieties for productive tillers, and seed density or 1000-seed weight (Figure 1b-1c). Variety PSB Rc72H had a slightly lower number of productive tillers than PSB Rc82, while both of them fell under the tiller rating scale of "medium to low" (Figure 1b), having a range of 9-10 tillers. On the other hand, Dinorado had the lowest number of productive tillers, falling under the tiller rating scale of "low," having a range of 6-8 tillers (Figure 1b). The control had generally the lowest number of productive tillers, but Dinorado and PSB Rc82 responded less to production practice than PSB Rc72H. The 'synthetic' treatment gave the highest number of productive tillers followed by 'organic' then 'biodynamic,' while the numbers of productive tillers from 'biodynamic' and 'organic' were not significantly different from each other.

PSB Rc72H and Dinorado had the highest and lowest 1000-seed weights, respectively (Figure 1c), while PSB Rc72H and PSB Rc82 on the other hand, differed only slightly from each other. Seed density did not differ with production practice.

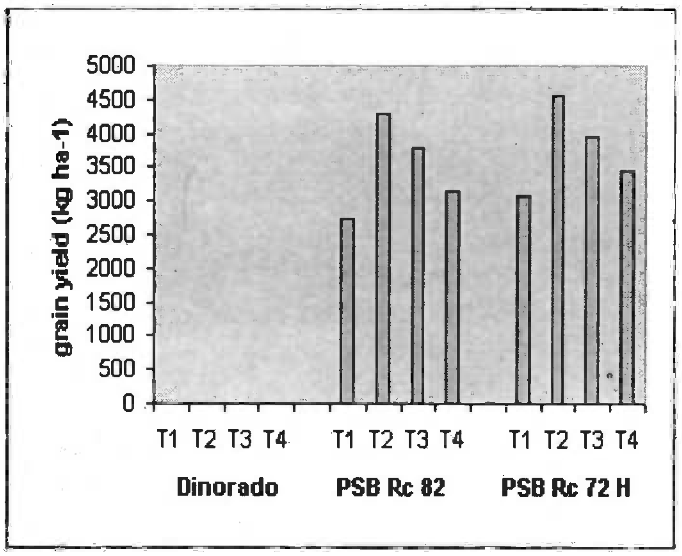
There were significant differences among varieties in terms of plant height (Figure 1d). As in past PhilRice determinations (Table 1), Dinorado was tallest followed by PSB Rc72H (Figure 1d). The difference between the two PSB varieties was only slight (7%). Production practices on the other hand did not lead to any difference in plant height.

Root length, root biomass, shoot biomass and harvest index were also significantly different among varieties and production practices, and differences were consistent across treatments (Figure 1e-1h). Dinorado had the greatest root length (Figure 1e). Variety PSB Rc82 came second but its difference from PSB Rc72H was only slight (4%). Regardless of variety, 'organic' and 'biodynamic' together gave higher root lengths than the 'synthetic' and control taken together. For root biomass, the same trend as root length was observed (Figure 1f). Dinorado had the greatest root biomass, and the difference was coming from 'organic' and especially 'biodynamic' treatments.

PSB Rc72H had slightly higher shoot biomass than PSB Rc82 (Figure 1g). Shoot biomass of Dinorado was not assessed as explained above. From the highest to the lowest, the ranking in shoot biomass was 'synthetic,' followed by 'organic,' then 'biodynamic,' and finally the control. Variety PSB Rc72H had 10% higher shoot biomass than PSB Rc82.

PSB Rc72H also had a higher harvest index than PSB Rc82 (Figure 1h). The harvest index for Dinorado was not obtained for lack of data as already explained. The 'synthetic' production practice gave the highest harvest index regardless of variety. This indicates that PSB Rc72H invested more in shoot and grain production than in root development. Such trend can be commonly found in modern hybrid varieties.

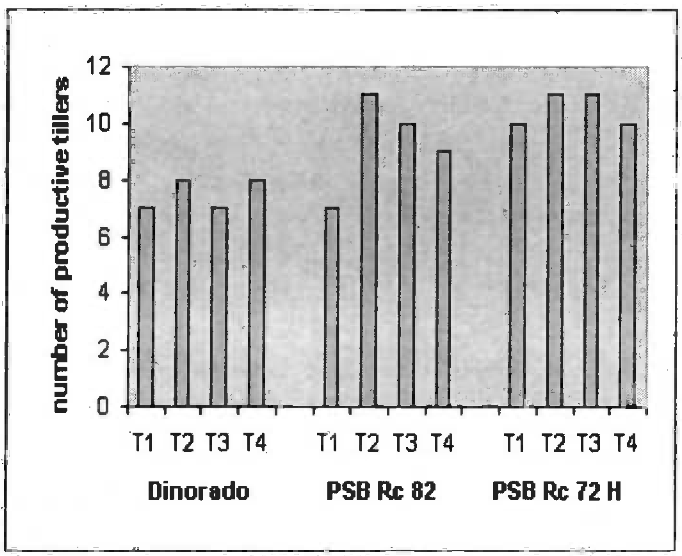
Figure 1. **Yield and other agronomic parameters from varieties grown under different production practices. (T1 = control/ctrl, T2 = synthetic/syn, T3 = organic/org, T4 = biodynamic/bio)**



1a. Grain yield

T vs V : Pr > F = 0.0001
V : Pr > F = 0.0001
T vs V : Pr > F = 0.38
Ctrl vs Others: Pr > F = 0.0001
Bio & Org vs Syn: Pr > F = 0.0001 Bio vs Org: Pr > F = 0.0001

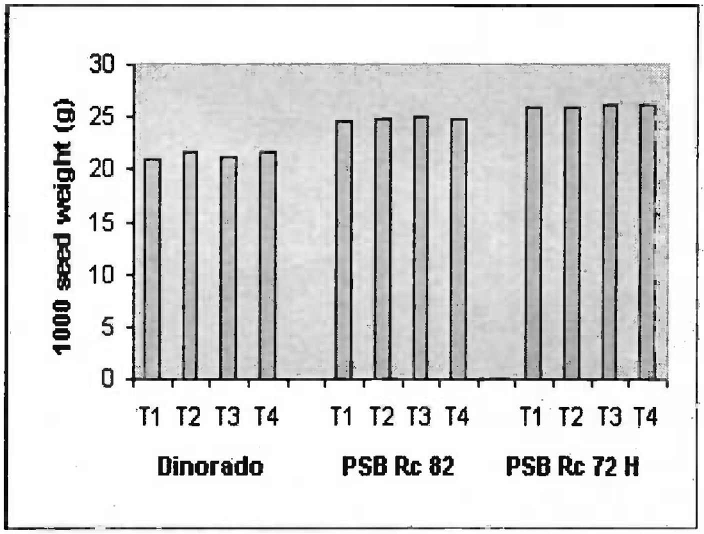
Note: No yield taken from Dinorado



1b. Productive tillers

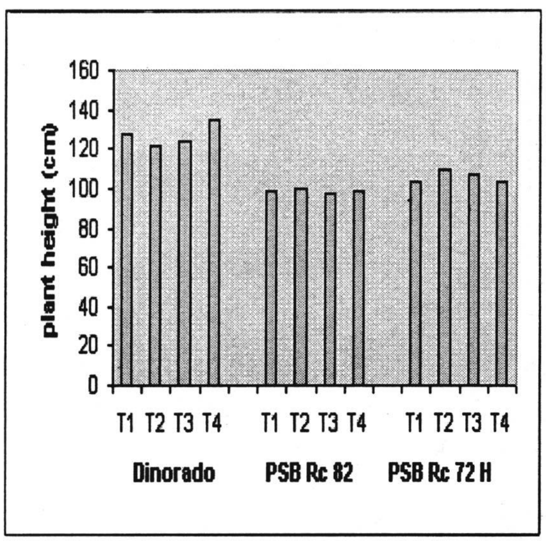
T: Pr > F = 0.018
V : Pr > F = 0.0001
V x T : Pr > F = 0.28
Ctrl vs Others: Pr > F = 0.02
Bio and Org vs Syn: Pr> F =0.017

Figure 1. **Yield and other agronomic parameters from varieties grown under different production practices. (T1 = control/ctrl, T2 = synthetic/syn, T3 = organic/org, T4 = biodynamic/bio)**



1c. 1000-Seed weight

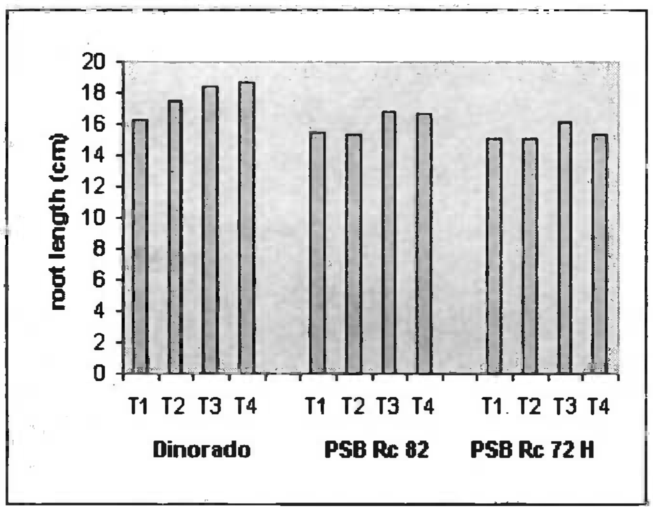
T: Pr > F = 0.68
V: Pr > F = 0.0001
VxT : Pr > F = 0.98
Ctrl vs Others: Pr > F = 0.24
Bio & Org vs Syn: Pr > F = 0.97
Bio vs Org: Pr > F = 0.81



1d. plant height

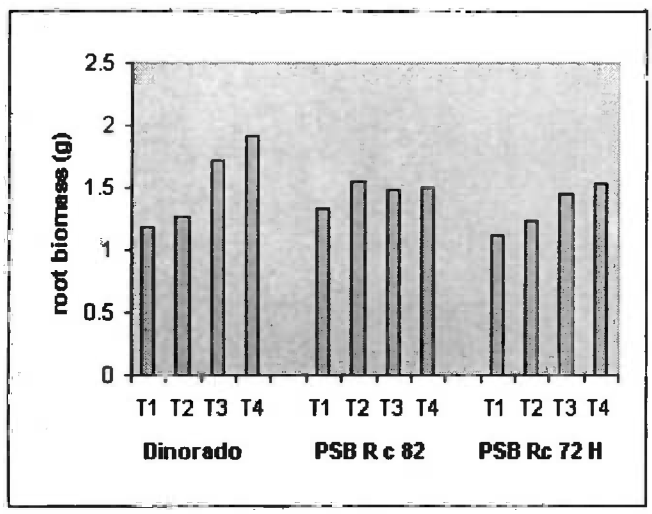
T: Pr > F = 0.94
V: Pr > F = 0.0001
VxT: Pr > F = 0.84
Ctrl vs Others: Pr > F = 0.99
Bio and Org vs Syn: Pr > F =0.93
Org vs Bio: Pr > F = 0.55

Figure 1. **Yield and other agronomic parameters from varieties grown under different production practices. (T1 = control/ctrl, T2 = synthetic/syn, T3 = organic/org, T4 = biodynamic/bio)**



1e. Root length

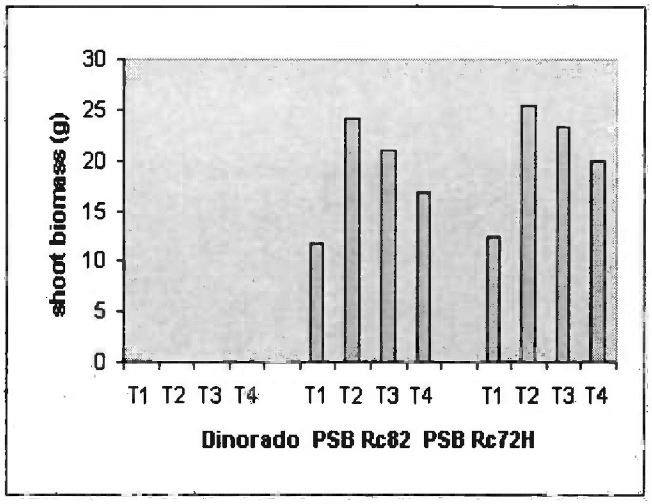
T: Pr > F = 0.003
V : Pr > F = 0.0001
V x T : Pr > F = 0.47
Ctrl vs Others: Pr > F = 0.004
Bio and Org vs Syn: Pr > F =0.006
Org vs Bio: Pr > F = 0.67



1f. Root biomass

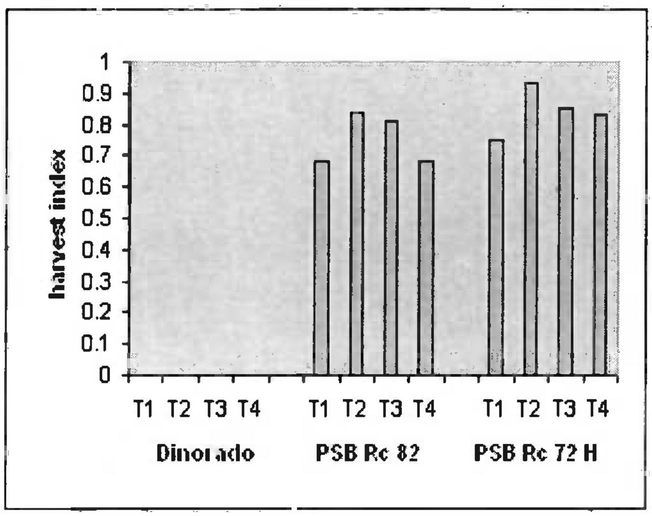
T: Pr > F = 0.0001
V : Pr > F = 0.02
V x T : Pr > F = 0.023
Ctrl vs Others: Pr > F = 0.0001
Bio and Org vs Syn: Pr > F =0.001
Org vs Bio: Pr > F = 0.20

Figure 1. **Yield and other agronomic parameters from varieties grown under different production practices. (T1 = control/ctrl, T2 = synthetic/syn, T3 = organic/org, T4 = biodynamic/bio)**



1g. Short biomass

T: Pr > F = 0.0001
V : Pr > F = 0.0001
V x T : Pr > F = 0.0001
Ctrl vs Others: Pr > F = 0.0001
Bio and Org vs Syn: Pr > F =0.0001
Org vs Bio: Pr > F = 0.0001
Note: No shoot biomass data from Dinorado due to lodging



1h. Harvest index

T: Pr > F = 0.0003
V : Pr > F = 0.0006
V x T : Pr > F = 0.11
Ctrl vs Others: Pr > F = 0.0004
Bio and Org vs Syn: Pr > F = 0.001
Org vs Bio: Pr > F = 0.012
Note: No yield data from Dinorado.

Seed and Grain Quality

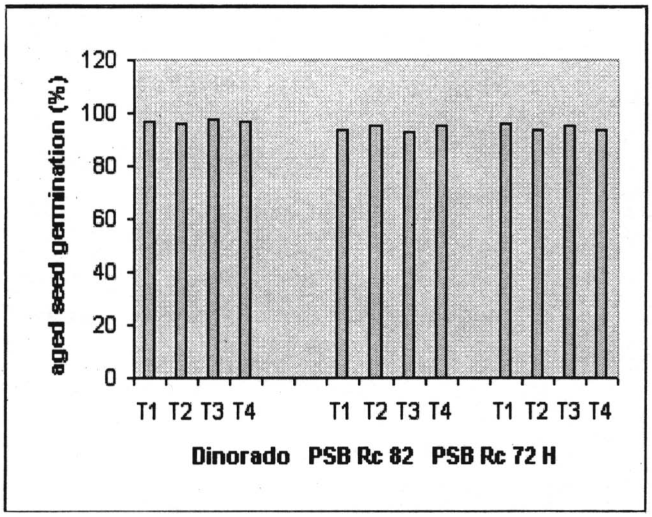
Although Dinorado lodged during the reproductive stage, sufficient seeds were still harvested for seed quality analysis. Germination percentage of Dinorado that had been subjected to accelerated aging was highest among the varieties, although all treatments had values above 90% (Figure 1i). Production practices did not lead to differences in storability.

Grain acceptability to consumers was assessed on the 7-month old grain stocks by a panel of seven who are already well-trained in sensory evaluation of common rice grain. The trend in varietal differences as reported by PhilRice for fresh rice had been validated in this study for stored rice, using several sensory parameters such as raw grain quality, eating quality of freshly cooked rice and that kept for six hours after cooking (Tables 2a-p). Varieties differed in rating for raw rice whiteness, translucency, gloss, and general acceptability (Tables 2a-d). Among the tested varieties, PSB Rc82 obtained the highest score on whiteness, translucency and gloss and tended to have higher general acceptability than PSB Rc72H and Dinorado (Table 2d).

In terms of quality of freshly cooked rice, varieties also differed from each other (Tables 2e-j). PSB Rc72H was the highest in cooked rice for gloss, cohesiveness and smoothness (Tables 2e-g). For tenderness and taste, however, PSB Rc82 obtained the highest score (Tables 2h and 2i). PSB Rc72H was highest in general acceptability among varieties (Table 2j). Overall PSB Rc72H was most preferred with cooked rice while Dinorado was the least preferred, with ratings that were wide apart (ie, 5 vs 10). PSB Rc82 was nearer to PSB Rc72H in preference.

With grain evaluation six hours after cooking, significant differences in scores were also observed among varieties in terms of gloss, cohesiveness, tenderness, smoothness, taste and general acceptability (Tables 2k-p). As in freshly cooked rice, the old cooked rice of PSB Rc72H was highest in cohesiveness, tenderness and smoothness, while the highest score on taste was attained by PSB Rc82. PSB Rc72H also obtained the highest score on general acceptability (Table 2p).

Figure 1. Yield and other agronomic parameters from varieties grown under different production practices. (T1 = control/ctrl, T2 = synthetic/syn, T3 = organic/org, T4 = biodynamic/bio)



1i. Seed germination after accelerated aging

T: Pr > F = 0.96
V : Pr > F = 0.016
V x T : Pr > F = 0.77
Ctrl vs Others: Pr > F = 0.73
Bio and Org vs Syn: Pr > F = 0.68
Bio vs Org: Pr > F = 0.98

Table 2. **Sensory evaluation of various rice grain parameters (paddy was stored for 7 months) of three varieties grown under different production practices**

VARIETY	PRODUCTION PRACTICES				Average
	Control	Synthetic	Organic	Biodynamic	
a) Whiteness of raw grain					
Dinorado	7.54	7.51	8.50	7.15	7.67 b
PSB Rc82	9.45	9.20	9.87	10.11	9.68 a
PSB Rc72 H	7.71	8.00	9.02	8.58	8.33 ab
Average	8.23 a	8.27 a	9.13 a	8.61 a	
b) Translucency of raw grain					
Dinorado	10.71	8.51	10.44	9.04	9.67 a
PSB Rc82	9.98	10.51	9.42	9.98	9.97 a
PSB Rc72 H	8.77	9.40	8.74	8.15	8.76 b
Average	9.82 a	9.47 a	9.53 a	9.06 a	
c) Gloss of raw grain					
Dinorado	0.50	0.55	0.70	0.65	0.60 b
PSB Rc82	1.91	1.71	1.47	1.88	1.74 a
PSB Rc72 H	0.61	1.28	1.84	0.72	1.11 ab
Average	1.00 a	1.18 a	1.33 a	1.09 a	
d) General acceptability of raw grain					
Dinorado	10.02	10.01	9.77	10.40	9.68 b
PSB Rc82	12.14	10.85	11.37	11.70	11.51 a
PSB Rc72 H	10.77	10.51	11.11	10.87	10.81 a
Average	10.98 a	10.46 a	10.75 a	10.49 a	
e) Gloss of cooked grain					
Dinorado	2.01	1.90	2.08	1.60	1.90 c
PSB Rc82	5.48	5.24	6.82	3.98	5.38 b
PSB Rc72 H	8.00	7.67	6.07	5.55	6.82 a
Average	5.16 a	4.93 a	4.99 a	3.71 a	

Means followed by the same letter within the column or row are not significantly different from each other using LSD at 5 % level of significance. Interaction between production practice and variety is not significant.

Table 2. Sensory evaluation of various rice grain parameters, continued

VARIETY	PRODUCTION PRACTICES				Average
	Control	Synthetic	Organic	Biodynamic	
f) Cohesiveness of freshly cooked grain					
Dinorado	1.01	0.52	1.11	0.94	0.90 b
PSB Rc82	6.20	6.72	8.38	6.40	7.08 a
PSB Rc72 H	8.14	7.12	6.67	6.70	7.16 a
Average	5.32 a	4.79 a	5.39 a	4.68 a	
g) Smoothness of freshly cooked grain					
Dinorado	2.10	1.10	1.95	1.84	1.75 b
PSB Rc82	7.12	6.27	8.24	6.70	7.08 a
PSB Rc72 H	8.15	7.30	6.61	7.24	7.32 a
Average	5.79 a	4.89 a	5.60 a	5.26 a	
h) Tenderness of freshly cooked grain					
Dinorado	2.55	1.64	2.37	2.57	2.20 b
PSB Rc82	7.40	6.74	8.15	6.82	7.28 a
PSB Rc72 H	7.94	7.05	6.27	6.57	6.96 a
Average	5.97 a	5.14 a	5.60 a	5.21 a	
i) Taste of freshly cooked grain					
Dinorado	2.75	1.51	2.31	2.04	2.31 b
PSB Rc82	4.28	3.52	4.52	3.52	3.96 a
PSB Rc72 H	4.32	3.44	4.25	4.25	3.93 a
Average	3.79 a	3.04 a	3.52 a	3.27 a	
j) General acceptability of freshly cooked grain					
Dinorado	5.20	4.45	5.10	4.84	4.90 c
PSB Rc82	8.90	7.95	9.41	8.00	8.56 b
PSB Rc72 H	11.31	10.27	9.84	10.41	10.46 a
Average	8.47 a	7.56 a	8.11 a	7.75 a	

Means followed by the same letter within the column or row are not significantly different from each other using LSD at 5 % level of significance. Interaction between production practice and variety is not significant.

Table 2. Sensory evaluation of various rice grain parameters, continued

VARIETY	PRODUCTION PRACTICES				Average
	Control	Synthetic	Organic	Biodynamic	
k) Gloss of grain six hours after cooking					
Dinorado	1.74	1.18	1.70	1.25	1.47 b
PSB Rc82	3.22	3.52	4.77	4.45	4.13 a
PSB Rc72 H	6.04	3.60	5.24	4.35	4.82 a
Average	3.67 a	2.78 a	4.09 a	3.35a	
l) Cohesiveness of grain six hours after cooking					
Dinorado	0.58	0.42	0.54	0.58	0.53 c
PSB Rc82	3.95	4.92	6.42	4.75	5.01 b
PSB Rc72 H	7.54	6.05	7.51	6.75	6.96 a
Average	4.02 a	3.80 a	4.82 a	4.03a	
m) Tenderness of grain six hours after cooking					
Dinorado	1.31	1.68	1.08	1.64	1.43 c
PSB Rc82	3.71	4.20	6.18	4.71	4.70 b
PSB Rc72 H	8.20	4.24	6.44	6.52	6.35a
Average	4.40 a	3.38 b	4.57 a	4.29 ab	
n) Smoothness of grain six hours after cooking					
Dinorado	1.64	1.50	1.55	2.12	1.70 c
PSB Rc82	4.02	3.84	6.45	5.10	5.00 b
PSB Rc72 H	7.65	4.91	6.54	5.92	6.26 a
Average	4.44 ab	3.60 b	4.85 a	4.38 ab	
o) Taste of grain six hours after cooking					
Dinorado	1.05	0.94	1.22	1.58	1.20 b
PSB Rc82	2.60	3.07	3.95	2.72	3.08 a
PSB Rc72 H	4.32	3.28	3.52	3.11	3.56 a
Average	2.66 a	2.43 a	2.90 a	2.47 a	

Means followed by the same letter within the column or row are not significantly different from each other using LSD at 5 % level of significance. Interaction between production practice and variety is not significant.

Table 2. Sensory evaluation of various rice grain parameters, continued

VARIETY	PRODUCTION PRACTICES				Average
	Control	Synthetic	Organic	Biodynamic	
p) General acceptability of rice six hours after cooking					
Dinorado	5.31	4.68	5.24	6.52	5.44 b
PSB Rc82	7.62	7.98	7.78	7.82	8.30 a
PSB Rc72 H	10.65	9.51	9.31	9.02	9.25 a
Average	7.86 a	6.90 a	8.11 a	7.79 a	

Means followed by the same letter within a column or row are not significantly different from each other using LSD at 5 % level of significance. The higher the

Grain quality of cooked rice in general became different parameters.

Table 3. Count of insect pest and natural enemies of rice varieties at vegetative stage under different production practices (Average of four growth stages)

VARIETY	PRODUCTION PRACTICES				Average
	Control	Synthetic	Organic	Biodynamic	
Count of Insect Pests					
Dinorado	197	196	200	201	198 a
PSB Rc82	158	162	176	142	166 b
PSB Rc72 H	138	146	142	137	140 b
Average	164 a	167 a	172 a	169 a	
Count of Natural Enemies					
Dinorado	97	101	102	104	100 ab
PSB Rc82	103	101	94	98	99 b
PSB Rc72 H	102	106	111	110	107 a
Average	100 a	103 a	102 a	104 a	

Means followed by the same letter within the column or row are not significantly different from each other using LSD at 5 % level of significance. Interaction between production practice and variety is not significant.

slightly poorer six hours after cooking. In any of the sensory parameters, no significant differences among production practices were detected. Thus, raw or uncooked grain from control, 'organic,' 'biodynamic' or 'chemical' were essentially the same in the evaluation for grain quality. However, 'organic' had the highest frequency of being most preferred in many

Insect Pest and Natural Enemies

There was a significant difference in insect pest populations among varieties (Table 3), but the populations of natural enemies, averaged from four observations across different stages, did not differ among varieties and among production practices. The common insects present were the green leafhopper and brown planthopper, while spiders and wasps were the most common natural enemies encountered. Among the varieties, Dinorado had the highest insect pest population, but its population of natural enemies was not substantially different from other varieties. Although there was tungro disease in all Dinorado plots, the disease was eventually controlled and the plants recovered after two consecutive sprayings of BD 508 (horsetail).

Table 4. Soil properties of the experimental area, taken before and after the conduct of the experiment.

VARIETY	SOIL ANALYSIS (before planting)	SOIL ANALYSIS (after planting, average over variety)			
		Control	Synthetic	Organic	Biodynamic
pH	5.53	5.32 a	5.43 a	5.44 a	5.54 a
Total nitrogen (%)	0.18	0.15 a	0.15 a	0.13 b	0.13 b
Available phosphorus (ppm)	41.57	39.85 b	40.76 b	49.01 a	49.90 a
Total potassium (meq/100)	23.62	18.36 a	18.28 a	15.87 b	16.32 ab
Organic matter (%)	2.97	2.63 ab	2.76 a	2.50 b	2.75 a
Cation exchange capacity (meq/100)	35.55	35.80 a	35.20 ab	35.53 a	34.61 b

Means followed by the same letter within the row are not significantly different from each other using LSD at 5 % level of significance.

Soil Properties

The initial or pre-cropping and post-cropping values of different soil properties differed but in different degrees (Table 4). The pH did not change significantly after the conduct of the experiment. Available phosphorus was increased after the experiment but only in 'organic' (by 18%) and 'biodynamic' (by 20%). Phosphorus from the control and 'synthetic' plots even slightly decreased from the initial. This higher amount of phosphorus may have led to the 'organic' and 'biodynamic' production practices' having the highest root length and root biomass. Conversely, the greater roots may have led to greater phosphorus solubilization in these plots. Other factors such as microbial activity leading to P solubilization may have also contributed. Total nitrogen, organic matter and cation exchange capacity did not change much after the experiment and even tended to decrease relative to initial values.

Cost and Returns Analysis

Dinorado was excluded from the economic or cost and returns analysis because of lack of yield data as explained above. The PSB varieties and production practices differed from each other in terms of total production cost, gross returns, net profit and return on investment (ROI) (Tables 5). PSB Rc72H was higher than PSB Rc82 in total production cost (by 3%), gross returns (by 13%), net profit (by 32%) and return on investment (by 29%). On the other hand, in terms of production practices, 'synthetic,' 'organic' and 'biodynamic' practices had net profits higher by 48%, 72% and 27%, respectively, than the control. 'Organic' and 'biodynamic' gave 57% and 23% higher ROI, respectively, than the control. 'Organic' thus had highest net profit and ROI among the production practices; 'biodynamic' was second in rank. The advantage of 'organic' over 'synthetic' for net profit was 16% and for ROI was 60%. Its advantage over 'biodynamic' for net profit was 36%, and for ROI was 27%. On the other hand, the advantage of 'synthetic' having had the highest yield was countered by higher costs. It had incurred the highest production cost such that its ROI was even lower than that of the control. 'Biodynamic' had greater ROI (25%) than 'synthetic.'

Table 5. Total production cost, gross returns, net profit and return of investment of two modern rice varieties grown under different production practices.

VARIETY	PRODUCTION PRACTICES				AVERAGE
	Control	Synthetic	Organic	Biodynamic	
Total Production Cost					
PSB Rc82	16,925	25,925	18,825	17,600	19,819
PSB Rc72 H	17,475	26,475	19,325	18,150	20,356
Average	17,200	26,200	19,075	17,875	
Gross return					
PSB Rc82	23,925	37,270	32,272	27,448	30,229
PSB Rc72 H	28,064	41,441	36,090	31.222	34,204
Average	25,995	39,356	34,181	29,335	
Net Profit					
PSB Rc82	07,000	11,345	13,974	09,848	10,542
PSB Rc72 H	10,589	14,966	16,765	13,072	13,848
Average	08,795	13,156	15,370	11,460	
Return of Investment					
PSB Rc82	41.35	42.85	74.23	55.95	53.56
PSB Rc72 H	60.59	56.52	86.75	72.02	68.97
Average	50.97	49.69	80.49	63.99	

GENERAL DISCUSSION

Part of the bigger movement to look for alternative systems to respond to challenges associated with modern or 'chemical' agriculture, 2 distinct sustainable agriculture related practices were tried. These have come from various time-tested approaches, but sometimes lumped together as the new 'organic' form (Fernandez 2000 & 2001). The old 'organic' form considered only changing inputs or practices, but the new one effectively covers all practices of the old form (ie, of using 'organic' inputs) as well as those that are more holistic and include even energies and forces beyond earth realms (ie, cosmic forces). Thus, one treatment chosen was 'organic' (representing use of 'organic' fertilizers); the other was 'biodynamic,' here to translate to no fertilizer treatment at all, but with application of subtle energies through 'biodynamic' (BD) preparations. The timing of operation using the BD calendar had not been totally adopted for practical reasons (synchronized field operations). Planting date fell on a "root" day rather than on a "fruit day," which would have been a more favorable planting time for grain harvest.

Productivity and seed quality of Dinorado Gold of PhilRice (ie, a modified traditional), PSB Rc82 (inbred variety) and PSB Rc72H (hybrid variety) were evaluated during the 2005 wet season. Yield has been the usual indicator of good harvest by mainstream agriculture, thus the choice of the PSBs in this study. This study showed that 'synthetic' or 'chemical' treatment had the highest yield, but its advantage over 'organic' was only 8%. Grain yield of 'synthetic,' 'organic' and 'biodynamic' treatments had a yield advantage in the range of 13-51% over the control. The highest yield was obtained from PSB Rc72H and this directly related the yield components or parameters such as number of productive tillers and harvest index.

PhilRice reports showed that PSB Rc72H had also a yield advantage of 8% over PSB Rc82 during a wet season trial. In this study, Dinorado's yield was not assessed because of severe lodging during the reproductive stage, although some grains were still obtained for other assessments. The crop grew very tall and proved to be lodging-prone under lowland culture and the current soil condition, which was a departure from good soil health and which aggravated the crop's lodging tendency (Lampkin 1990). Despite the fact that no fertilizer was applied in 'biodynamic' production plots, this treatment still gave a 13% yield advantage over the control, while 'chemical' and 'organic' gave 51% and 32% advantage, respectively, over the control.

'Organic' treatment proved most favorable as the cost and returns analysis indicated; it was highest among the production practices (see also Mendoza 2004). This is only based on paddy rice. A premium price for 'organic' grain could even further the advantage of 'organic.'

For future trials, it would be worthwhile to try other types of 'organic' fertilizers where N is not readily mineralized, because in deep 'organic' agriculture systems, the premium of the fertilizer is more on the C:N ratio than an actual N content. Moreover C is important in the formation of humus, this being considered as the foundation of 'organic' farming. Different manures have different suitability as 'organic' fertilizer. Chicken manure is one of the least preferred, under more natural or higher level of sustainable agriculture (Lampkin 1990). The quality of 'organic' fertilizer is more than just analysis of nutrients and also relates more to how animals or green manure crops were raised, ie, if in an 'organic' way.

In terms of plant height, root length and root biomass, Dinorado had higher values compared to PSB Rc82 and PSB Rc72H. It was expectedly the tallest among the varieties, having originally come from a traditional variety; this trait had been maintained in PhilRice' version of Dinorado. Such height predisposed Dinorado to lodging during the reproductive stage where there was frequent heavy rains and strong winds. It was 28 cm (28%) taller than PSB Rc82 and 21 cm (20%) taller than PSB Rc72H. Dinorado had also longer roots and greater root biomass than PSB Rc82 and PSB Rc72H. Such advantage did not relate to lodging resistance. Dinorado genotype thus seems to lean more towards adaptation than productivity. Regardless of variety, 'organic' and' biodynamic' treatments had generally longer roots and greater root biomass than 'synthetic,' and this corresponds to their higher soil phosphorus levels than control and 'synthetic.'

Rice planting time in the study coincided with a "root day" based on the BD calendar (Stella Natura 2005). In 'biodynamic' it has also been established that enhancement of root development can be achieved by planting during a root day (Keyserlingk 1999, Klett 2006, Kolisko 2006 & Pfeiffer 2006).

The high phosphorus levels in 'biodynamic' and 'organic' plots are an intriguing phenomenon that may deserve further research. There is now a growing body of knowledge that points to the importance of root-soil-nutrient interactions, vis-a-vis production systems or practices (eg, Uphoff et al 2006). Microorganism activation is prominent in the discussion.

After accelerated aging, Dinorado gave the highest germination rate among varieties. Although the germination rate was still high for all varieties (ie, above 90%), values in the different varieties were significantly different from each other. The higher germination of Dinorado may be partly due to its thicker hull which may have served as a protection during accelerated aging (Copeland & McDonald 1995). Among the different production practices, 'organic' seeds and 'biodynamic' seeds were generally more storable than 'synthetic' seeds. This trend may in the future be confirmed if also true for naturally stored and especially more deteriorated seeds. In mungbean, it has been confirmed that 'organic' seeds keep longer than chemically produced seeds (Aquino & Fernandez 2001).

Sensory evaluation is one of the bases in recommending a rice variety to the National Seed Industry Council. PhilRice considers this and the variety's response to pests and diseases as important as yield. The sensory evaluation results showed that Dinorado was the least preferred among the varieties whether it was raw, freshly cooked or kept for six hours after cooking. It is important to note that the Dinorado used in the study may have already genetically departed from the traditional Dinorado, which is highly popular among consumers because of good eating quality. In the study the variety did not do very well, probably partly due to its long (seven months) storage before the sensory evaluation was conducted. Additionally, the Dinorado used in the study is already a result of many years of maintenance under a 'synthetic' (or 'chemical') system of lowland farming. The original Dinorado, on the other hand, was originally an upland variety. PhilRice developed and maintained PSB Rc82 and PSB Rc72H under a 'chemical' farming system and had been selected for good yield, resistance to pests and diseases and good grain quality under lowland culture. Thus they were used to the treatments given them.

The study confirms the sensory advantage of these two varieties. PSB Rc82 emerged as most preferred in raw rice form, while PSB Rc72H was most preferred in freshly cooked form and even when kept six hours after cooking. PSB Rc82 is one of the most popular PhilRice varieties because of its long grain and high milling recovery; it also commands a higher price than the other varieties. Although average rating values for the different production practices were not wide apart, the 'organic' produce emerged as the most preferred, followed by control, then 'biodynamic.' The grain from 'synthetic' production practice was least preferred for both freshly cooked rice and that kept six hours after cooking.

Crop health did not differ much for the different varieties and production practices. Dinorado seemed most attractive to pest-type insects. One interesting phenomenon observed during the study was the incidence of the viral disease tungro in Dinorado in all production plots. This could be because Dinorado, which was originally an upland variety, is now put under a different production system which could lower the crop's vitality.

Application of BD 508 (horsetail) twice resulted in the disappearance of tungro symptom and the recovery of crop vitality. This is something worth further looking into, because the mainstream thought is still that tungro is a crop deadend, ie, no recovery. 'Biodynamic,' which is among the deep 'organic' practices dealing more with subtle energies, had thus provided solution to one of modern day's serious challenges in rice production. Experimental studies are already available or have been written (eg, Koepf 1990, Kolisko & Kolisko 2006) but in the Philippines formal research is still scanty (eg, Tung 2006, Yadao 2005) special problem in UPLB (Ni Tint 2007, PhD thesis, in progress), and remains to be promoted and validated under more specific local conditions. So far, the largest adoption of BD is in North Cotabato with more than 4,000 farming families adopting it and successfully marketing their produce, with the help of the NGO Don Bosco Diocesan Youth Center

(Fernandez 2001). For 'biodynamic' research, the soil should be emphasized, so the effect can be demonstrated or more felt in production trials.

The ratio of insect pest population (in terms of actual count of organisms) to that of beneficials or natural enemies, averaged over four stages of growth, was 504:306. In gross terms this ratio could already be enough to prevent imbalance and any harmful effect of pests on crop yield and quality, although there are other factors that determine pest dynamics. Other than Dinorado at the early stage, the health status of crops was generally good up to the end. In many studies, however, it had been shown that 'chemical' systems encourage pests and disease organisms to grow and multiply faster (Lampkin 1990, Chaboussou 2004). Under such system the plant contains more soluble, mineralized or free nutrients which attract potential pests and aggravate pest or disease problems. The 'organic' system, with the proper use and form of fertilizer, prevents such problems, but some 'organic' fertilizers such as poultry manure (especially those from chemical rearing systems) may actually prove less effective as plant health protector because of its synthetic chemical residues and low C:N ratio, making the fertilizer easy to be mineralized.

Earthworms, which are excellent indicators of a living soil, had not been observed before planting and after harvesting. In this study it was found that the pH of the soil under 'organic' was not significantly changed after the study. In the study, soil pH was even decreased although very slightly in the control, 'chemical' and 'organic' treatments. On the other hand, an experiment in soybean (Tung 2006) revealed an increase in pH, even if only slightly; this was observed even with just one cropping under an upland cropping system, and especially with 'biodynamic' treatment. Most marked in the current study was the total phosphorus content of the soil after harvest, which was increased in 'organic' and 'biodynamic' production plots, but was decreased in the control and 'synthetic' production plots. The increase in phosphorus (18%-20%) was quite substantial and of great practical significance. A sufficient amount of phosphorus enhanced root development, possibly contributing to the increase of root development in 'organic' and 'biodynamic,' or it could be vice versa, where the roots enhanced phosphorus solubilization. The dynamics of soil nutrient (eg, phosphorus), soil biology and root development vis-a-vis production practices could prove to be a highly valuable and interesting subject in crop research (Uphoff et al 2006).

Simple economic or cost and returns analysis revealed positive returns in all production practices and varieties where yield data were taken. PSB Rc82 turned out to be more economically beneficial to use than PSB Rc72H. This could be further amplified if the analysis is extended beyond paddy rice. PSB Rc82 has greater milling recovery than PSB Rc72H. 'Organic' production practice obtained the highest rank in net returns and ROI.

Aside from monetary returns, benefits like improvement of the soil properties can be experienced through 'organic' production. Continuous application of the right kind of 'organic' materials is well known to improve soil structure, while a good soil structure is fundamental in sustainable agriculture (Lampkin 1990). Other benefits that can be derived from 'organic' practice are enhanced biodiversity, healthy soil and quality produce, as well as energy savings. Increased plant biomass from 'organic' rice production can also be an added advantage as it can be in demand for 'organic' mulching, feeds for 'organic' livestock, 'organic' composting etc. There is also a premium price for 'organic' products. With 'synthetic' production practices, on the other hand, soil and water system deterioration, toxic residues in products, poor quality produce and general health hazard due to exposure or contamination to 'chemical' fertilizers (Lampkin 1990), are externalities that cannot be anymore ignored.

Summary and Conclusions

The study was conducted in PhilRice during the 2005 wet season to assess the performance of three

PhilRice-maintained or -developed varieties under four different production practices in lowland culture. The following are the highlights of the study:

The two PhilRice developed varieties, PSB Rc82 and PSB Rc72H, differed in performance in many aspects, but in general these differences were only slight. PhilRice's Dinorado performed very differently from the PSB Rcs. Production practice also affected crop performance but rarely changed varietal response. Its interaction with variety was mostly not statistically significant. PSB Rc72H had the highest grain yield but only 8% higher than PSB Rc82. Dinorado yields from lodged crop stand was not assessed because of lack of data for comparison.

The highest values were also obtained in terms of number of productive tillers, shoot biomass, 1000-seed weight and harvest index from PSB Rc72H. This means greater prioritization on yield by the variety. The PSBs were also top in eating quality of polished grain, while Dinorado lagged far behind. This was a departure from older assessments at PhilRice and could be due to the late grain evaluation (ie, seven months after harvest) or to possibly already changed traits of the PhilRice version of Dinorado. Dinorado seeds proved most resistant to accelerated aging, and thus had the highest germination percentage compared to PSB Rc82 and PSB Rc72H. Dinorado had also the highest root length and root biomass, and greatest increase in soil phosphorus after cropping.

Grain yield of 'synthetic' production practice was significant but only slightly higher, 14% and 34% more, than 'organic' and 'biodynamic,' respectively. The three practices were 51%, 32% and 13% higher than control, respectively. 'Organic' and 'biodynamic' production practices gave higher root length and root biomass than 'synthetic,' while that of 'synthetic' was not significantly different from the control. 'Organic' practice, however, gave lower shoot biomass and harvest index than 'synthetic' treatment, implying that an 'organic' crop may not greatly prioritize grain yield production among its functions. After harvest, the amount of soil phosphorus was increased in 'organic' (by 18%) and 'biodynamic' treatment (by 20%), while it was decreased in 'synthetic,' the phosphorus level of which was similar only to control. Seeds from 'organic' and 'biodynamic' treatments had better storability than 'synthetic' treatment, as assessed through the accelerated aging test. However, viability levels of all treatments were above 90%.

Organically produced rice garnered higher scores or greater consumer preferences in many grain quality criteria than synthetically produced ones, which in turn was least preferred among the production practices. Crop health as indicated by the count of so-called pests and natural enemies did not differ among production practices. All Dinorado plots had tungro disease at the vegetative stage but this was effectively controlled by a 'biodynamic' preparation of horsetail (BD 508).

'Organic' production practice gave higher net profit (16%) and return on investment (60%) than 'synthetic.' 'Biodynamic' practice, even without fertilizer application, emerged and gave economic advantage that is way beyond the control (23%) and better than 'synthetic' (25%).

The study confirmed that 'organic' fertilizer (chicken compost) had greater advantages over 'synthetic' or 'chemical' fertilizer in lowland rice production. The grain yield advantage of 'synthetic' was only very slight and not enough to give it the economic advantage that is much desired. Aside from monetary returns, 'organic' treatments also indicated other benefits like better grain quality, better seed storability and increased soil quality.

Longer-term studies using other 'organic' practices and methodologies may prove even more insightful especially if the principles of deep 'organic' are applied, like that of 'biodynamic,' that works already in the realm of quantum mechanics. 'Biodynamic' production practice, in this case the first time to be formally studied at PhilRice premises, shows some promise.

It would be worthwhile to pursue further studies using complete 'biodynamic' practices (ie, including use of the BD calendar and other BD preparations) to fully assess their performance relative to other

PhilRice practices. Many 'biodynamic' studies have already been done in other countries, and therefore it would be worthwhile to further explore this scientific application. Already thousands of farmers in Mindanao already practice it.

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