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Increasing SRI-Organic Rice Yields through Double Rows Planting Pattern and Using Location and Season adapted Rice Cultivar

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Abstract Systems of Rice Intensification (SRI) is a dynamic system and not as a package of technology (POT). Hence, one or two features maybe modified. In this particular study , 2 questions were addressed: a)Which planting pattern is best for SRI-organic? b)What cultivar type or genotype (inbred, or hybrid) yields well under SRI-organic? Three (3) planting patterns(first study) and 20 varieties (second study) were evaluated to determine their performance under SRI-organic . The field trial were conducted at Maitim, Bay Laguna, Philippines during the dry season of Crop year 2014 to answer these questions .Test plots were laid out in randomized complete block design (RCBD) and replicated 3 times . Of the 3 planting patterns, highest grain yield was obtained in the double row at 8.4 t ha^{-1}. This high yield was due to high panicles per ha (3.49 million), percent filled (%) grains per panicle (93.6%)and weight of 1000 grains (22.3 grams while only 21.1 gm and 21.4 gm for the single row and 20cm x 20cm spacing, respectively).When compared with the yield of conventionally established and managed , the yield was only 4.49 t ha^{-1} (1.87 times higher in SRI-double row) . The proportion of unfilled grain was high at 17% in conventional rice cultivation but only 7.7% in the organic SRI-double row. For the 20 cultivars , highest grain yields was obtained among the inbreds (Milyang 23 at 7.49 t ha^{-1}, PSB RC 240 at 6.99 t ha^{-1}, PSB RC 222 at 6.81 t ha-1).Of the 3 hybrids, NSICRc 202H yielded the highest at 6.78 t ha^{-1}. The farmer-bred cultivar Masipag 10-1 yielded 6.38 t ha^{-1} . The yield differences are not statistically significant. A 0.5 t ha^{-1} difference may not be significant statistically but this amount to PhP10,000(227 USD ,1USD=PhP44).

SRi-Organic rice yields of up to 8.5 t ha^{-1} had been realized during the dry season - January to April cropping of 2014 in double row planting pattern using the locally adapted rice cultivar PSB Rc 18. This showed the prospects of increasing rice yield using low cost method and locally available materials. Adopting organic method of rice farming is also climate change adaptive , oil energy bill and carbon emission reducing .

Keywords: organic rice, planting pattern, doublé rows, system of rice intensification (SRI)

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Introduction

Modern agriculture and the accompanying economic growth had lessened the poor .Cheap food in the past, had supported population increase from less than a billion pre- oil based industrial agriculture to more than 7 billion now. This averted the Malthusian prognosis of massive food shortage .Before the millennium ended, there was food surplus (Mendoza, 2008). But close to a billion (850 million) are poor and hungry, despite food supply surplus, which implied an affordability and inaccessibility of food . The world population shall expand further to about 9.2 billion by 2050" (IAASTD, 2008) or 26% higher than the current year (2016). Addressing the food requirements of the growing number of mouths to be fed, considering finite land, water, production inputs, and the amount of energy required to produce and distribute the food is a big challenge. How could this be achieved in the light of worsening global warming and climate change, resources degradation and per capita resources decline as their supply had reached their peak (Goodchild, 2006). Especially important is fossil fuel oil where all human activities and meals revolve around (Rodolfo, 2004). Industrialized societies have functioned very much like drug addicts (Hill, 1990) willing to do almost anything to ensure ongoing access to the desired resources, including going to war to secure this access , and blinded to the consequences that these resources and of our addictive dependence upon them (Slater, 1980; Schoef, 1987; Rodolfo, 2004).

Rice is the food staple across Asia that consumes 90% of all rice where about 88% of all rice is also produced. The ASEAN region with 600 million people consume 22% of all rice indicating a high per capita consumption(144kg per cap)) at 2.5times higher than the average world consumption at 57.5 kg per cap. Up to the present, rice is mostly produced through the high external input Green Revolution strategy which appeared to be a great mismatch is term of the environment and resources of small scale capital scarce farmers. This is on top of the well known non-point pollution , pesticides residues that moves across the food chain , and the health hazards associated with pesticides residues in food. Furthermore, the high external input Green Revolution strategy disempowered farmers (Bachmann *et al.*, 2009) as they are made dependent on seeds , inputs and management required (credit, market, distribution) (IAASTD, 2008, Mendoza and Villegas, 2014). It favored only the resource rich farmers farming in favorable rice environment. Considering the totality of situations i.e., diminishing oil, green house gas emission attributed to using so much oil, and continuous soil deterioration, farmers empoverishment, pollution, health hazards of poisons that moves across the food chain, the way to go is through organic agriculture (Mendoza

2010; Mae-Wan Ho, 2008; Vidal, 2007; Tilman *et al.,* 2002, IFOAM, 2015). Organic agriculture is localized, uses adapted crop species (Altieri, 1999; Arboleda-Rivera and Compton, 1974; Atlin and Frey, 1990) and as it addresses the food sufficiency of the region, it minimized processing, packaging, storage and long distance transport of food commodities (Pimentel, 1983). This reduced the energy bill and the ensuing GHGe of the post production - distribution, and consumption of food. Localized organic agriculture is centered on biodiversity (Mendoza, 2014, Altieri, 1987 ; Pretty *et al*., 2003; Pretty and Hine, 2001). Greater emphasis must be made on safeguarding natural resources and on agroecological practices by using natural fertilizers and traditional seeds, intensifying natural processes and reducing the distance between agricultural production and the consumer (IAASTD, 2008 ; Mendoza and Villegas, 2014). Thus, paving for the local/village/household level supply of nutritious and healthy foods, arresting malnutrition and other illnesses associated with food centered on only few food caloric energy source.

Organic agriculture is an all encompassing philosophy , systems and practices of environmental conservation, resource recycling, soil quality enhancement , avoidance of high cost chemical inputs, production methods applicable and adapted to the local community, and thus contribute to meaningful socio-economic and ecologically sustainable development(MacRae *et al*., 1989, MacRae *et al.,* 1999a,b). But only 37.5 million hectares of agricultural land are certified according to organic standards covering 0.87% of the world's agricultural land. The leading countries are : Australia 12Mha, Argentina 3.1 Mha and U.S 2.2 Mha (FiBL and IFOAM, 2014) .There were arguments and doubts that organic farming can feed the world population. Badgley *et al.* (2007) studied past data on yields of both organic and conventional farming and found that the average yield of organic farming is 92.2% of conventional farming in developed countries, and 180.2% in the global south .The Philippines has an enabling law on organic agriculture (RA 10068 ,the Phillippines Organic Agriculture Act of 2008). Adoption of organic farming is still low despite t encouragement under the law.

Rice, the staple food of about 80% Filipinos , is where green revolution technology was first tested in the Philippines. Rice yield increased dramatically. From thereon, yields had plateaud at 4 t per ha and input application has to increase further to get same yields as before or to increase yields further (Mendoza, 2010; Mendoza and Villegas, 2014). A system of rice intensification (SRI) was innovated by civil society actors in Madagascar which improved the production of irrigated rice for poor, resource-limited households. Its concepts and methods have now been extended also to upland, unirrigated rice production; to larger-scale, even mechanized production; and even to other crops like wheat, sugarcane and fingermillet (Uphoff, 2012; Stoop and Kassam, 2005; Stoop, 2011). SRI methods have been reported in almost 50 countries to give higher yield than is achieved with usual rice-growing practices– by changing the management of plants, soil, water and nutrients, and not requiring either new, higher-yielding seeds or agrochemical inputs http://sri.ciifad.cornell.edu). The increases are achieved with reduced inputs of seeds and water, and resulting rice plants are less vulnerable to pests and disease losses and to climatic stresses (Uphoff, 2011). In 2011, a new world record of 22.4 tons per hectare using SRI was obtained by a farmer Sumant Kumar in India beating the world record held by the Chinese scientist Yuan Longping by 3 tons (Chang, 2013;Vidal, 2013).

SRI is a set of agronomic principles and practices. Stoop (2011) listed the following practices of SRI to achieve the best results:

1. Use of very young, 8- to 12-day-old seedlings with just two leaves and transplanted, quickly, shallow and carefully, to avoid trauma to the roots and to minimize transplanting shock;
2. Widely spaced hills, ranging from 20 × 20 up to 50 × 50cm; to permit more growth of roots and canopy and to keep all leaves photosynthetically active;
3. Alternate wet and dry soil moisture regime (no permanent flooding) to maintain aerobic soil conditions .This improves root growth and supports the growth and diversity of aerobic soil organisms;
4. Use of organic, rather than mineral, fertilizers
5. Frequent weeding, preferably performed using a surface rotary hoe, during early crop development stages so as to control weeds, aerate the soil, and promote deeper root growth.

SRI is a system and not as a package of technology (POT) characterizing Green Revolution technology. Hence, one or two components cold be modified to suit the situations and to achieve such reported high yields in the country. Meanwhile, when someone adopts SRI – organic, 2 basic questions are asked and they are as follows: a)Is the square planting the best pattern or other planting pattern should be tested ? b)What cultivar type or genotype (inbred, or hybrid) yields well or highest under SRI-organic?

Macrae *et al*. (1999b) argued that we won't be successful in our efforts to change the food and agriculture system until we really understand how the current system works, where its vulnerabilities lie, and what set of strategies have a realistic and progressive ability to transform it. Hill and MacRae (1999a) stressed the need to reorganize production systems according to ecological principles that optimize use of available resources. Comparisons between organic and inorganic or conventional farming systems and have shown that significantly lower yields were obtained for organic systems. Murphy *et al.*

(2007) described that these comparisons may be biased toward higher yields in a chemical intensive conventional system. Any crop production systems start from the seeds- the alpha and omega of any crop agriculture is a common knowledge. In the Philippines, all of the current released and introduced rice cultivars were developed using conventional system which uses high external input and chemical intensive agricultural system. All of the national seed board released varieties grown by farmers in about 95% of rice lands were mostly bred in an environment where high inorganic chemical inputs have been used. Can these varieties obtain similar yield potential or perform equally when grown in an environment where no chemical inputs or organic farming is practiced? It may or may not be so as genotype by interaction (GXE) is generally observed (Arboleda-Rivera and Compton1974;Atlin and Frey 1990).

That rice varieties (inbred and hybrid) bred under conventional system will also adapt or 'forced to adapt' under organic system is the present hypothesis of farmers who are into organic rice culture. But it is also possible that the rice varieties bred and selected under conventional system will not produce high yields. Stoop (2011) suggested the need to identify/develop rice varieties adapted to aerobic soil conditions and that have a suitable growth cycle and plant architecture; and the optimum plant spacing to maximize the interception of solar radiation at the time of panicle initiation and flowering, instead of aiming for early canopy closure that would minimize weeding expenditures, and the interdependence of plant spacing on weeding, irrigation , age of seedlings , and cultivar types

This study was conducted to evaluate and to identify which of the 3 planting patterns is most suitable for SRI-organic, and at the same time provide the highest yield; and to evaluate the performance of 20 varieties of different genotypes and to identify which of them may give the highest yield and the yield component(s) that enable them to exhibit high yields.

Methodology

The three (3) planting patterns tested were: PP1 –The conventional 20cm x 20cm square planting which gives 250,000 hills per ha; PP2 --Single row spacing at 40cm x 10cm (40cm between rows and 10cm between hills). This leads to same population – 250,000 hills per ha as in PP1 ; and PP3 --Double rows planted at 20cm x 10cm and 40cm between the double rows. This leads to 333,333 hills per ha or 33% higher population density compared to PP1 and PP2.

For the rice variety/genotypes, twenty (20) rice cultivars were used. Six best Korean cultivars were selected from the adaptability test in Nueva Ecija, 1 Farmer-bred, 3 traditional and 10 selected Philippine-released varieties which were bred by PhilRice and IRRI and UP Los Banos. The Korean cultivars, being new introductions in the Philippines had already passed the seed quality inspection requirements of the government. The rice cultivars and some characteristics/classification are as follows:

	Variety	Maturity	Ecotype	Type	Remark
1.	PSBRc 14	110	Upland	Inbred	UPLB
2.	Burdagol Laguna (mabango)	120	Lowland	Inbred	Farmer selected
3.	PSBRc 18	123	Lowland	Inbred	IRRI
4.	PSBRc 82	110	Lowland	Inbred	IRRI
5.	NSICRc 222	115	Lowland	Inbred	IRRI
6.	Ennano II	125	Upland	Inbred	Farmer sel
7.	Hangangchal 1	115	Lowland	Inbred	KOR
8.	NSICRc 202H	110	Lowland	Hybrid	PhilRice&UPLB
9.	NSICRc 204H	111	Lowland	Hybrid	PhilRice&UPLB
10.	NSICRc 218 (mabango)	120	Lowland	Inbred	PhilRice
11.	SL 18		Lowland	Hybrid	SL Agritech
12.	Saegyejinmi	113	Lowland	Inbred	KOR
13.	NSICRc 238 (mabango)	110	Lowland	Inbred	IRRI
14.	NSICRc 240	115	Lowland	Inbred	PhilRice
15.	Hanareumbyeo	111	Lowland	Inbred	KOR
16.	Dasanbyeo	111	Lowland	Inbred	KOR
17.	Hanareumbyeo 2	108	Lowland	Inbred	KOR
18.	Milyang 23	115	Lowland	Inbred	KOR
19.	Masipag 10-1	115	Lowland	Inbred	MASIPAG-bred
20.	Iniput-ibon	120	Upland	Inbred	Farmer selected

The specific SRI practices that were followed were as follows: 10 day old seedlings at transplanting, intermittent irrigation – 1-2 days flooded but keeping the soil moist , but oftentimes dry at the surface before the next turn of irrigation, rotary and manual weeding to arrest weed growth and to aerate the soil. SRI was popularized with wide spacing up to 50cm x 50cm (Stoop, 2012; Kassam and Uphoff, 2011; Mishra, *et al*. 2006) but in this trial, the spacing adopted was 20cm x 20cm and 1 seedling per hill.

SRI must be organic (Stoop2012) as cited above. For nutrient management, the following practices were adopted from Nature Farming but modified to use locally available resources as suggested by Hill and Macrae (1995) and are described below…

a) Compost mixture of cattle manure and carbonized ricehull (1:1 ratio) sprayed with IMO at 1 li per ton, and applied at 5 tons per ha before the final harrowing.
b) Indigenous microorganisms (IMO) was applied during the first harrowing at 2 gal/ha to facilitate crop/ weeds residues decomposition.
c) Liquid cattle manure fertilizer (2 kg cattle dung + 2 kg molasses in 200li water plastic drum). Mixture was stirred clock and counter clockwise for 10 minutes, done every day for 7 days. The liquid slurry was spread evenly in the test plots. This was repeatedly done at 2 weeks, 4 weeks, 6 weeks after transplanting.
d) At grain filling period, another preparation was applied. The middle soft tissues of the banana stem after harvesting the whole bunch of banana, were obtained, cut into small pieces and mixed with molasses at 1:1 ratio by weight. This mixture was allowed to ferment for 3 weeks and diluted at 1:10 fresh water ,then sprinkled the diluted solution to the test plots. Figure 1 shows the crop establishment starting from land and seedling preparation, marking the field to facilitate planting at one seedling per hill.

Fig.1. Crop establishment from land, seedlings preparation, marking prepared land to facilitate planting at 1 seedling/hill.

The field trial was conducted at Maitim, Bay Laguna, Philippines during the dry season of Crop year 2014. The 2 sets of experiments' test plots were established in January 11 and harvesting started April 23 and ended May

5,2014. Both the test plots for the 3 planting patterns (spacing) and 20 varieties were laid out in randomized complete block design (RCBD) and replicated 3 times. For both of the 2 trials, the following grain and grain yield components data were gathered: grain yield/ha, harvest index, % productive panicle bearing tillers, filled and unfilled grains per panicle, % filled and unfilled grains, productive tiller per ha, number of grains per panicle, weight of grains per panicle (gm), weight of 1000 grains (gm). For the 20 varieties only, tiller number were counted twice at 30 and 45 days after transplanting.

All the data were subjected to usual statistical analysis – ANOVA and DMRT (Analysis of Variance and Duncan Multiple Range Test for mean comparison).A stepwise multiple regression analysis was done
to find out which of the yield components significantly affect grain yield (Y) at harvest. The equation is shown below…

Y = X1b1 + X2b2 +…… Xnbn + e , where : Y= grain yield per ha (t/ha), Xn= are the yield components (harvest index, % productive panicle bearing tillers, filled and unfilled grains per panicle, % filled and unfilled grains, productive tiller per ha, number of grains per panicle, weight of grains per panicle (gm), weight of 1000 grains (gm).

Results and Discussion

Table 1 shows the grain yield and other yield components of rice grown in 3 planting patterns and SRI-organic. Significantly (0.05 p- level) highest yield was obtained in the double rows at 8.49 t ha-1 which was 26% (1.73 t ha-1) and 28% (1.86 t ha-1) higher than 20cm x 20cm, and single row , respectively. Higher yields was obtained in the double row and this was attributed mainly to its 33% higher plant density at 333,333 hills/ha while the single row and the 20cm x 20cm spacings had only 250,000 hills/ha. This initially high plant density was sustained till harvest time at 3.49 million panicles per ha although panicle number did not vary significantly (0.05 p- level) from the single row.

Likewise, there were lesser unfilled grains per panicle. Percent filled (%) grains per panicle was 93.6% which was 4% higher than the single row (89%) and 20cm x 20cm spacing (89.4%). Related to this, the weight of 1000 grain was also highest in the double row at 22.3 grams while only 21.1 gm and 21.4 gm for the single row and 20cm x 20cm spacing, respectively.While there was no statistical difference in terms weight of 1000 grains, 1.2 gm/grain translate to 4.18 t per ha (linear estimate 1.2 gm/grain x 3.49 million panicles per ha).

The conventional rice cultivation which involved transplanting seedlings in clump at no less than 5 seedlings per hill, planted in 20cm x 20cm spacing, irrigated the flooding way, fertilized with 6 bags of fertilizer (3 bags 14-14-14 and 3 bags 45-0-0), sprayed with pre- and post-emergent herbicides, one time spraying molluscides and once spraying of insecticides at grain filling stage was not included as treatment in the experimental set-up. But yield samples were gathered in exactly the same manner as the SRI-organic treatments in the conventionally cultured rice field separated only with levee and planted with cultivar NSIC Rc 222 . The yields obtained were 5.33 t ha-1, 3.78 t ha-1 and 4.35 t ha-1 for the 3 samples or an average yield of 4.49 t ha-1. With this yield, the SRI- organic planted in double row had 1.87 times higher yields (3.91 t ha-1) than the heavily fertilized conventional rice. This could be attributed mainly with the high proportion of unfilled grain at 17% in conventional rice cultivation and only 7.7% in the Organic SRI-double row.

Table 1. Summary of Grain yield data for PSB RC18 grown in 3 planting patterns, SRI-ORGANIC .

Planting configuration (PC)	Hill per ha	Grain yield t/ha [1]	Weight of grains/ 10 panicles(gm) panicles	No.of panicles per ha x1,000, 000	Plt height at harvest(cm)	Harvest Index (HI)	No. of filled grains/ panicle	No.of unfilled grains/ panicle	%Filled grains/ panicle	Weight of 1000 grains(gm)
PC 1 - 20cm X20cm	250, 000	6.67b	223.70 a	2.95 b	80	0.57	109 a	11.7b	89.40 a	21.4 a
PC 2 - Single row	250, 000	6.54b	283.70 a	3.47 a	80	0.59	122 a	12.3b	89.00 a	21.1 a
PC 3 - Double row	333, 333	8.49a	248.40 a	3.49 a	80	0.57	108 a	7.7 a	93.60 a	22.3 a

[1]Means with the same letter are not significantly different at 5%p-level
PC 2-Single row at 40cm between rows and 10 cm between hills
PC 3- Double row at 40cm between double rows and 20cm x 10 cm between hills of the double rows

The yield and yield components of the 20 different rice cultivars or genotypes are summarized in Table 2. There was considerable variation in yields obtained. Pairwise mean comparison(Duncan multiple range tests) led to 4 clusters of varieties. While mean yields are different, the differences(low or high) are not statistically different at 5% level of significance. The variety clusters are as follows:

Cluster A Variety (5.38>7.44, yield difference=2.06tha -1)

Milyang , NSIC Rc 240 ,NSIC Rc 222, NSIC Rc 204H, NSIC Rc 238, Masipag 10-1,Hangangchal 1, PSB RC18 , NSIC Rc 202H , Hanamrebeyo2 , Ennano1, SL8 ,Burdagol ,PSBRc14 ,Hanareumbeyo , NSIC Rc 218

Cluster B Varieties (4.84-6.98= yield difference=2.14 tha -1)

NSIC Rc 240 , NSIC Rc 222, NSIC Rc 202H , NSIC Rc238,Masipag 10-1 , Hangangchal , PSB_RC18, NSIC Rc 202H ,hanamrebeyo2, Ennano1, SL8 ,Burdagol , PSBRC14, Hanareumbeyo , NSIC Rc 218, Saegyenjinnii, PSBRC82

Cluster C (4.64- 6.44 =, yield difference= 1.79 tha -1)

NSIC Rc 238, Masipag10-1_, Hangangchal 1, PSBRC18 , NSIC Rc 202H , Hanareumbeyo, Ennano1, SL8 , Burdagol , PSB_RC14 , hanareumbeyo , NSIC Rc 218, Saegyenjinnii , PSB_RC82, Dasanbey

Cluster D (3.73- 5.45 , yield difference= 1.72 tha -1)

PSB_RC14 , Hanareum, PSB_RC21,Saegyenj ,PSB_RC82 ,Dasanbeyo, Iniput-ibon

Custer A varieties highest grain yields was obtained among the inbreds (Milyang 23 at 7.49 t ha-1, NSIC Rc 240 at 6.99 t ha-1, NSIC Rc 222 at 6.81 t ha-1). NSIC Rc 204H yielded the highest at 6.78 t ha-1 among the 3 hybrids (SL8H@5.85tha-1and5.96t ha-1 for NSIC Rc204H). The farmer selected cultivar type Masipag 10-1 yielded 6.38 t ha-1 which was about 1 t ha-1 lower than the highest yielder Milyang 23, a Korean variety; Masipag yielded 0.61 t ha-1 lower than NSIC Rc 240, an inbred and about 0.40 t ha-1 for the hybrid NSIC Rc202H. The yield differences were not statistically significant at 0.5 p-level.

Cluster A variety yield ranged from 5.38 -7.44, or a yield difference=2.06tha -1 , for Cluster B varieties at 4.84-6.98 = yield difference=2.14 t ha -1 , Cluster C at 4.64- 6.44 =, yield difference= 1.79 t ha -1) and Cluster D at 3.73- 5.45 , yield difference= 1.72 t ha -1) .

While a 0.5 t ha-1 is not statistically significant, but this is worth PhP10,000(227USD) .From the farmers point of view, this is an acceptable yield difference among varieties reared under the same conditions. Using this cut-off yield level, Milyang 23 and NSIC Rc 240 difference in grain yield was 0.5 t ha-1. Milyang 23 is a Korean variety. Milled rice fetches as high as PhP60/kg or about PhP30/kg unmilled rice

. A 0.5 t ha-1 is worth PhP 30,000 (682 USD, 1USD=PhP44.0). On a monetary basis, the difference is obviously high. A 2 tons per ha yield difference amounts to PhP 40,000(909USD; 1USD=PhP44)

The unique plant traits of the 2 highest yielding cultivar for SRI-organic were as follows:

RC240 had the highest number of grains per panicle at 206.36, hence, highest grain weight per panicle at 4.71 gram. Milyang 23 had only 117.27. The second highest was Masipag 10-1 at 165.25 grains/panicle.

Milyang 23 had the heaviest 1000 grain weight at 24.01g (at par with the other 2 Korean varieties Hanareumbyeo (24.44g) and Dasanbyeo (24.88g). Grain size and weight (Milyang 23) and number of grains per panicle (NSIC Rc 240) were the 2 dominant yield components affecting grain yield per ha.

All the genotype had greater than 0.50 harvest index except Iniput-ibon which had only 0.39 which means, Iniput-ibon had more straw yields (it is a tall variety averaging 1.2 m at harvest). It's grain has black bran while it becomes white grain when fully milled. All the genotypes had 92% or more filled grains under SRI-organic. NSiC RC 222 had only 83% filled grains under conventional rice culture.

Both inbred (Milyang 23) and hybrid genotypes (NSIC Rc 204H) had high number of tillers (46 days after transplanting) 16.7 and 15.7 tillers, respectively. But had the lowest % tiller that had panicles at harvest (59% and 54%, respectively). This implies that remobilization of stored carbohydrates in the tiller that were aborted to support the grain filling requirements of heavier grains in Milyang 23 and the large number and heavy grains as in the case of NSIC Rc 204H.

This leads to a divergent points in SRI where the rice plants produce many tillers but only to be aborted (50%). Or, they do not develop into productive grain-bearing panicles. The remobilization of carbohydrates could be the plant adaptive mechanism when there is stress (water or diseases) that lessen photosynthesis later in their reproductive stage to support grain filling (Saeedipour and Moradi, 2011).

Table 2. Grain yield (t/ha) yield component data, Ma , Bay,Laguna, Dry season , 2014

	Variety	Grain Yield ton/ha	Harvest Index (HI)	%Filled Grains	No.days to harvest	Tiller 11-Feb	Tiller 26-Feb	No. Prod. Tiller	% Tiller with Panicle	Productive tiller/ha x 1,000,000	Number of Grains/ panicle	Weight of Grains/ panicle(gram)	Weight of 1000 grains (gram)
1	PSB RC14	5.45 abcd	0.54	94.6	103	15.1	17.3	12	71	3.03	104	2.25	21.6
2	Burdagol	5.79 abc	0.57	94.2	106	7.7	9.7	7	76	1.8	112.23	3.37	30.04
3	PSB RC18	5.98 abc	0.58	94.0	103	8.6	11	8	79	2.11	138.32	3.18	23
4	PSB RC82	4.70 bc	0.55	95.3	103	10.7	14.3	11	79	2.83	105.95	2.39	22.6
5	NSIC Rc 222	6.81ab	0.62	93.2	106	11.4	18.7	13	69	3.18	104.93	2.36	22.48
6	Ennano 11	5.91abc	0.51	94.1	106	9.2	13	9	72	2.3	91.48	2.09	22.87
7	Hangangchal	6.27 abc	0.59	93.7	106	11.2	13.7	9	67	2.3	136.9	3.17	23.17
8	NSIC Rc 218	5.38 abcd	0.6	94.6	106	8.3	12	8	72	2.08	112.49	2.94	26.11
9	SL8	5.88 abc	0.64	94.1	106	7.6	9	6	66	1.46	199.7	4.52	22.63
10	Saegyenjinnii	4.94 bcd	0.49	95.1	110	8.7	12	9	74	2.18	72.73	1.53	21.07
11	NSIC Rc 240	6.99 ab	0.56	93.0	110	7.6	10.3	8	73	1.91	206.36	4.71	22.81
12	hanareum beyo	5.40 abc	0.68	94.6	106	13.5	15.3	10	69	2.6	121.41	2.97	24.44
13	Dasanbeyeo	4.64 cd	0.62	95.4	106	9.7	13.7	10	71	2.38	128.07	3.19	24.88
14	hanamrebyeo2	5.95 abc	0.59	94.1	106	6.3	17	14	82	3.47	27.68	0.57	20.56

15	Milyang 23	7.44 ab	0.61	92.6	106	11.5	16.7	10	59	2.43	117.27	2.82	24.01
16	NSIC Rc 238	6.44ab	0.56	93.6	106	13.8	17.3	11	65	2.83	116.61	2.72	23.28
17	Masipag 10-1	6.38ab	0.61	93.6	110	10	12.3	9	70	2.16	165.25	3.7	22.4
18	NSIC Rc 202H	5.96ab	0.61	94.0	106	12.2	15.7	9	57	2.2	145.64	3.61	24.79
19	NSIC Rc 204H	6.78ab	0.63	93.2	106	13.1	18	10	54	2.42	140.17	3.29	23.46
20	Iniput-ibon	3.73d	0.39	96.3	117	6.8	11	10	93	2.55	136.41	1.96	14.39

Discussion

It should be pointed out that this trial did not follow all the six(6) features of SRI as listed earlier ,particularly , the wide row 35cmx35cm to 40cm x 40cm square planting. The rests of the features of SRI were adopted . The reasons why we did not adopt the wide row spacing is because the variety we are using do not tiller as high as 50 to 70 tillers per hill since they are breed/selected under 20cm x 20 cm spacing. Instead, a modified spacing or planting pattern was tested. As pointed out earlier, SRI is a continuing search of modification that is suitable to the location and cultural management practices. Stoop (2011) suggested the need to study the optimum plant spacing to have more plants producing tillers(Zhu *et al.*, 2002)to maximize the interception of solar radiation at the time of panicle initiation and flowering (Tao *et al.,* 2002), instead of aiming for early canopy closure within rows that would minimize weeding expenditures. The interdependence of plant spacing on weeding, irrigation , age of seedlings , and cultivar types inorganic farming must also be studied as Murphy *et al.* (2007) had shown evidence on varietal adaptation to organic farming systems.

A 20cm x 20cm spacing as the benchmark spacing was adapted because the present cultivars (genotypes) that are being used are bred for this spacing. At 20cm x 20cm spacing, rice do not tiller much, which explains why seedlings are planted in clump (>5 seedlings per clump) under conventional planting. There is quick canopy closure which leads to early weed suppression . Dense and closed canopies lead to dark and higher relative humidity beneath the canopies, the condition which is favorable for blast fungus and hopper population build up.Bottrella and Schoenlyb (2012) had analyzed the resurgence of BPH. They believed that insecticides application was the most tangible outbreak factor primarily because of their harmful effects on natural enemies. BPH resistance to insecticides and especially imidacloprid has increased the probability of outbreaks as farmers have applied increasing quantities of insecticide in an attempt to combat resistant populations. Similarly, heavy use of nitrogen fertilizer, especially on hybrid rice, has increased the potential for outbreaks. Other factors triggering outbreaks are less documented, but they discussed the possibility that the high outbreak synchrony in geographically separated populations of BPH may suggest a “Moran effect” such as climate that promotes an environment favoring above-average increases in BPH populations.

Established in SRI-organic , no pesticides were sprayed and there was no blast fungus and hopper infestation that was observed.

The main drawback of 20cm x 20cm is that the transplanted seedlings are close to each other. This made rotary weeding and hand weeding so difficult. A missed step would trample the seedlings. It is organic- no herbicides were sprayed. Weed suppression was done through rotary weeding and manual/hand weeding. Early hand weeding which was a week after transplanting was done not only to remove weeds but also to replant missing hills (mostly eaten by golden snails, since no molluscides were sprayed).

This led us to try the double row spacing at 40cm between 2 rows and 10 cm between hills (the plant density at 333,000 hills) and also single row at 40cm x 10 cm whose plant population was the same with the 20cm x 20cm spacing at 250,000 hill per ha. The wide space (40cm) between the double rows (Fig.2) remedied the earlier difficulties that was encountered when doing rotary and hand weeding in the 20cm x 20cm spacing. It was so easy and convenient to pass in-between- the larger interval rows. This allowed us also to pass the rotary weeding more frequent as the weeds emerge as it was faster and easier. (The large space between the double row allows Muscovy ducks to graze favoring rice + duck integration).

Since there was wider spacing, there was extended canopy closure, in turn, extended duration of weeding. It is important to point out that only once rotary weeding was done in the narrower 20 cm x 10cm double rows as the canopies closed –in quickly. Any remaining weeds were removed manually.

Fig.2. The double row planting pattern (20x10cm—40cm) at various growth stages.

There was longer period of time before the canopy closed-in (about 50 days versus 25-30 days in the 20cm x 20 cm spacing).This led to sustained rotary weeding to suppress weed growth , soften, and aerate the soil. Others may point out that rotary weeding is added labor. It is true but rotary weeding cultivate 3-5 cm the top soil or even deeper due to footstep. This induced the rice plant to grow roots deeper which in turn , was the plant adaptation to moist or relatively "surface-dry" soil (no extended flooding in SRI). Earlier, researchers had found the interrelationships of root growth, rotary cultivation, weeding, extended duration of greenness of the flag leaf and the high chlorophyll content of the leaves (Soejimaet *et al.,* 1995) which explain the extended photosynthesis of the leaves and hence, the prolonged supply of carbohydrates for grain filling. In turn, this led to the higher % of filled grains and heavier grain weight in the double rows and its higher yield. Also, the extended duration of no canopy closure could have allowed the nitrogen fixing algae to fixed atmospheric nitrogen (Martinez-Goss, 2009). This contributed to the supply of nitrogen that support the need for high photosynthesis for grain filing . Under conventional farming, this is remedied by top dressing Urea-N.

It should be accepted that the double row spacing departed clearly from the usual 20cm x 20cm planting pattern. It could not be easily done by the rice transplanters just like planting one small seedlings which made rice them initially averse. In our case, this was remedied by paying the transplanters daily wage so the area that they could plant is immaterial. The current practice is a pre-negotiated contract payment per area basis at 15 mandays per ha (In Bay , Laguna ,1manday = PhP250; 1USD=PhP44).

To summarize, why yields of rice in the double row spacing was highest compared with the (20 x 20) cm2 spacing and 40 cm x 10 cm spacing could be attributed to the following:1.During the vegetative stage, the large (40 cm) space between the double rows a) allowed more rotary weeding to suppress weed growth and to soften/aerate soil, which in turn made the rice plants to grow deeper roots for deeper rhizosphere root interface (more water and nutrient absorption) and b) provided extended period of light transmission that allowed the N - fixing algae to photosynthesize and do N - fixation donating their N - fixed to the rice plant.Aalgae N - fixation had been found to be operation in rice paddies (Martinez-Goss 2009); 2)There was early build-up of tiller population (13 - 15) tillers/hill with 2 -3 weeks of planting. In turn, these tillers developed panicles with high percent filled grains/panicle ; 3)The flag leaf is the main supplier of photosynthate for grain filling. The wide space between double rows provided sufficient space for the flag leaf to intercept sunlight. This lead to high percent (%) filled grains/panicle. The calculation below showed how the 8.5 tons/ha was achieved:

Double row plant population: 333,333 ;Average panicle/hill = 10.5 @11. 21 tillers/hill; Filed gains /panicle=108,

Average weight of grain/panicle = 2.42 g/panicle @ 93.6% filled grains/panicle ; Average weight of grain = .0023 gm

Total grain weight = 2.42 g/panicle x 10.5 panicle/hill x 333,333hills= 8,469,991 grams = 8.5 tons/ha

Stoop (2011) had been emphasizing the need to do specific breeding and selection for SRI. Breeding and selecting genotypes (hybrid or inbred) for SRI-organic demands a closer look for specific yield components. The number of grains per panicle both for the hybrid and inbred takes a pivot role as it can compensate for the lesser number of productive panicle bearing tillers as in the case of NSIC RC 240. It is a high tiller producer but tiller mortality was also high. This made the surviving tillers bear more grains per panicle as the remobilized carbohydrates from aborted tillers support the grain filling requirements (Saeedipoor and Moradi, 2011). The result of the stepwise regression analysis showed that of the 12 yield components, the grain weight of 10 panicles determine grain yield (Y) was the main determinant though at at 0.0862 p-level only . The regression equation is described as : Y = X1b1 + X2b2 +…… Xnbn + e , where : Y= grain yield per ha (t/ha), Xn= are the yield components (harvest index, % productive panicle bearing tillers, filled and unfilled grains per panicle, % filled and unfilled grains, productive tiller per ha, number of grains per panicle, weight of grains per panicle (gm), weight of 1000 grains (gm)).

In this particular study, we used 20 recommended and tested genotypes/cultivar types (inbreds and hybrids, farmer-related breeds). That the yield of varieties tested varied significantly, merely showed that there is further room for cultivar improvement. (Fig.3 shows the crop stand of the top yielders. Their yields are not significantly different at 0.05 p-level).The weight of 10 panicles appeared to a good selection criteria that plant breeders may use even at early stage of selection.

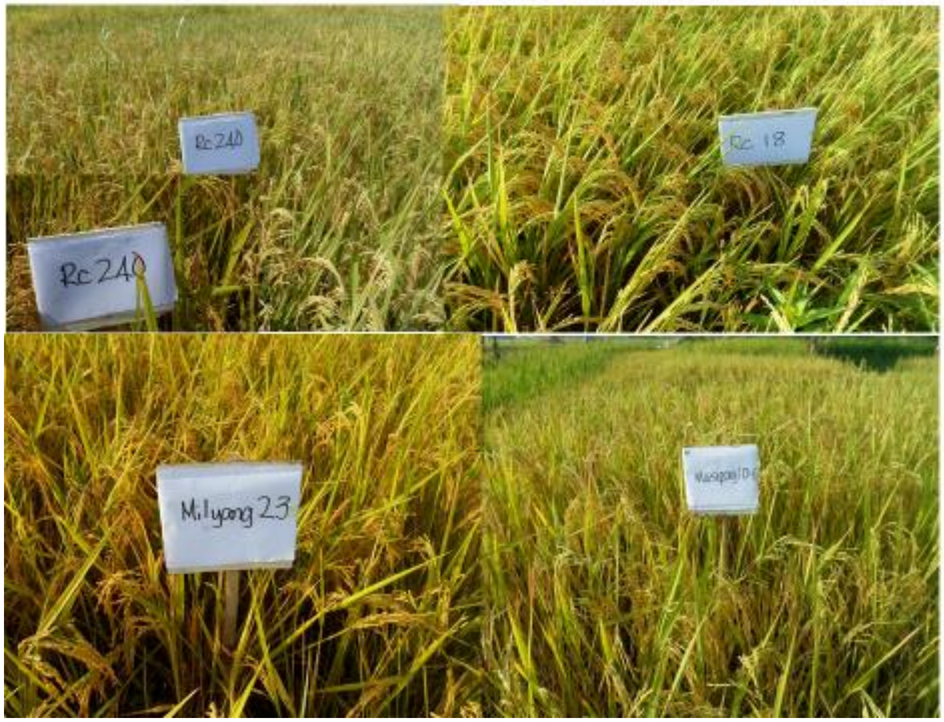

Figure 3. The top varieties found high yielding when grown under SRI-organic.

From the cultivars tested, the parents that can be used for bi-parental or reciprocal crosses to begin with were as follows: 1)PSBRC 40 , that exhibited the highest number of panicle can be crossed to Milyang 23, NSIC Rc 238, NSIC Rc 222, PSBRC14. These were the varieties that produced 16-18 tillers. Hybridization shall fuse the desirable traits of Milyang 23 to the PhilRice-bred cultivars. It is indigenizing further the Korean cultivars under Philippine condition specifically for SRI-organic.

SRI- specifically bred varieties were not yet available during the trial planting but young seedlings with roots intact (12 days in this study) had promoted early growth which was sustained, thus , achieving higher yields as observed earlier by Mishra and Salokhe, 2008; Pasuquin *et al.* 2008). As stated earlier, the s tepwise regression analysis showed that the weight of grains per 10 panicle (gm) determined grain yield (Y) at 0.0862 p-level. This is suggestive of the contribution of the number of grains per panicle and the individual weight of grains in the panicle. Earlier, Song Chen *et al.* (2008) also reported that sink size and more grains per panicle and more panicles per square meter are the main determinants of high yield in rice. Why tiller number did not exert much influence on yield, this could be attributed to the narrower planting distance at 20 cm x 20 cm. Because of narrow distance, tillers per hill ranged from 13-17. At 40 cm square planting, tillering could go as high as 100-180 tillers per hill (Versola, 2011).

PSBRC 18 was selected to be used for the planting pattern study mainly because it was the highest yielding inbred-cultivar in the previous trial surpassing the yields of other varieties including the hybrids and the Korean cultivars (results of earlier trial but data were not shown here). The differences in yields among the top yielders are not significantly different in this trial . Higher yields (1.87 times higher) in SRI-organic compared with the conventional and chemically grown rice was revalidated as explained earlier. But one (1) component practice was not adopted. It was the double row planting pattern. But Stoop (2011) had emphasized that SRI is a sytems and not a package of technology. Mishra and Salokhev (2010) had also tested other planting pattern and water regime to determne their effects on root morphology, physiology and grain yield. That the double row planting pattern [40cm x (20cm x 10)] had the highest yield under SRI-organic remain to be sustained or validated using more varieties or genotypes since there was only one variety used in the trial. Bigger area must be used and farmers must be involved. As pointed out earlier , the double row planting pattern is a departure to the usual 20cm x 20cm planting pattern . Promoting farmers' acceptance of this planting pattern remains to be done .

Earlier, Stuart (1990) had been proposing to redesign agroecosystems, and this case, what we redesigned was the planting pattern to initially increase plant population and tillers, and at the same time to allow easy passage of rotary weeder. Duck raising is also facilitated as they can graze between the larger interval rows of the double rows as one unique feature of the double row planting pattern. Altering one component, the planting pattern is critical not only for the added practical benefits. San-oh *et al.* (2006) reported that planting pattern influenced the rate of photosynthesis and related processes during ripening . But the effects could be singularly attributed to one factor. Cultivation of rice interrows (interrow rotary weeding) positively affects the roots systems as they grow deeper as observed also by Mishra and Salokhev (2010) .The organic materials /composts and the nature farming preparations that were applied, altogether, would explain the positive results obtained in this study at 8.49 t /ha although still way very compared with the reported yield of 22 t/ha.

There are many researchers who had expressed divergent views against SRI .According to them, SRI is non-sensence, non-science(Sheehy *et al.,* 2004, 2005; McDonald *et al.* 2006) and agronomic UFOs (Sinclair and Cassman 2004) primarily due to reported high yield. But Mishra *et al.* (2006) claimed that SRI is a challenge for science to validated such high yields. Sri-organic open an opportunity for farmers to increase rice yield and be empowered . Samson *et al.* (2015) was suggesting that scientists must increase their support to farmers by working on-farm. Their scientific knowledge can make important contributions in providing solutions to field constraints to achieve higher crop yields. The double row planting pattern is one of the numerous possibilities together with breeding cultivars specifically for SRI-O

Conclusion

Rice grown through organic method and in double row planting pattern using the locally adapted rice cultivar PSB Rc 18 had yielded up to 8.49 t/ha obtained during the dry season - January to April cropping of 2014. Increasing organic rice yield is achievable using low cost method and on-farm /locally available materials. This is responding directly to the challenge of increasing rice yields in the same areas(land) and significantly reducing the water to produce 1kg of rice to as low as 1700 li per kg (or about 65% reduction per kg of rice produced under SRI-organic)using the yields obtained in this study. To sum up, adopting SRI-organic method is climate change adaptive farming(less water use), oil energy bill and carbon emission reducing. Organic method does not use oil based agro-chemical inputs- fertilizer and pesticides.

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References

Altieri, M. A. (1987). Agroecology: the scientific basis of alternative agriculture. 2nd Ed. Boulder, Colorado: Westview Press.

Altieri, M. A. (1999). The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems and Environment 74:19-31.

Arboleda-Rivera, F. and Compton, W. A. (1974). Differential response of maize (Zea mays L.) to mass selection in diverse selection environments. Theoretical and Applied Genetics publishes original research 44:44-81.

Atlin, G. N. and Frey, K. J. (1990). Selecting oat lines for yield in low-productivity environments. Crop Science 30:556-561.

Bachmann, L., Cruzada, E. and Wright, S. (2009). Food security and farmer empowerment. A study of the impacts of farmer-led sustainable agriculture in the Philippines, MASIPAG, Los Banos, Philippines. 152 pp.

Badgley, C., Moghtader, J., Quintro, E., Zakan, E., Chappell, J. M., Aviles-Vasquez, K., Saulon, A. and Perfecto, I. (2008). Organic agriculture and the global food supply. Renewable Agriculture and Food Systems 22:86-108.

Birkhofer, K., Bezemer, T. M., Bloem, J., Bonkowski, M., Chritensen, S., Dubois, D., Ekelund, F., Fliessbach, A., Gunst, L., Hedlund, K., Ma der, P., Mikola, J., Robin, C., Setala¨, H., Tatin-Froux, F., Van der Putten, W. and Scheu, S. (2008). Long-term organic farming fosters below and aboveground biota: implications for soil quality, biological control and productivity', Soil Biology and Biochemistry 40:2297-2308.

Bottrella, D. G. and Schoenlyb, K. G. (2012). Resurrecting the ghost of green revolutions past: the brown planthopper as a recurring threat to high-yielding rice production in tropical Asia. Journal of Asia-Pacific Entomology 15:122-140.

Brancourt-Hulmel, M., Heumez, E., Pluchard, P., Beghin, D., Depatureaux, C., Giraud, A. and Le Gouis, J. (2005). Indirect versus direct selection of winter wheat for low-input or high-input levels. Crop Science 45:1427-1431.

Chang, G. G. (2013). Rice production records set with new method. World Affairs Journal.

Dobermann, A. (2004). A critical assessment of the systemof rice intensification (SRI). Agricultural Systems 79:261-281.

FAO (2011). Organic agriculture and climate change mitigation. A report of the round table on organic agriculture and climate change. Rome, Italy.

FiBL and IFOAM (2014). The world of organic agriculture statistics and emerging trends 2014. https://www.fibl.org/fileadmin/documents/shop/1636-organic-world-2014.pdf

Glover, D. (2011). The system of rice intensification: time for an empirical turn, NJAS – Wageningen Journal of Life Sciences 57:217-224.

Goodchild, P. (2006). Peak oil and the myth of alternative energy. Countercurrents. Retrieved from http://countercurrents.org/po-goodchild061006.htm.

IAASTD (2008). The international assessment of agricultural knowledge, science and technology for development. Retrieved from http://www.agassessment.org.

Kassam, A., Stoop, W. and Uphoff, N. (2011). Review of SRI modifications in rice crop and water management and research issues for making further improvements in agricultural and water productivity. Paddy and Water Environment 9:163-180.

MacRae, R. J., Hill, S. B., Henning, J. and Mehuys, G. R. (1989). Agricultural science and sustainable agriculture: a review of the existing scientific barriers to sustainable food production and potential solutions. Biological Agriculture and Horticulture 6:173-219.

MacRae, R. J., Hill, S. B., Henning, J. and Bentley, A. J. (1990a). Farm-scale agronomic and economic conversion from conventional to sustainable agriculture. Advances in agronomy 43:155-198.

MacRae, R. J., Hill, S. B., Henning, J. and Bentley, A. J. (1990b). Policies, programs and regulations to support the transition to sustainable agriculture in Canada. American Journal of Alternative Agriculture 5:76-92.

Mendoza, T. C. (2008). Why food prices increase and what can be done. Philippine Journal of Crop Science 33:87-101.

Mendoza, T. C. (2010). Organic agriculture: the logical sequence to chemical agricuture . Annals of tropical resaearch 32:112-129.
Mendoza, T. C. and Villegas, P. M. (2014). The opportunities and challenges in green agriculture in the asean: focus in the Philippines. Chapter 5, In ASEAN Food Security and Sustainable AGRIculture in a Green Economy. Cross sectoral and Interdisciplinary Perspectives. Eds Wayne Nelles et al. Chulalongkorn University Press, Bnk.
Mendoza, T. C. (2014). Achieving farm multifunctionality through a small-scale biodiverse, integrated and organic (bio) method of farming. Journal of Agricultural Technology 11:753-789.
Mishra, A. and Salokhe, V. M. (2008). Seedling characteristics and the early growth of transplanted rice under different water regimes. Experimental Agriculture 44:1-19.
Mishra, A. and Salokhe, V. (2010). The effects of planting pattern and water regime on root morphology, physiology and grain yield of rice. Effects of some SRI practices on rice growth.Journal of Agronomy and Crop Science 196:368-378.
Mishra, A., Whitten, M., Ketelaar, J. W. and Salokhe, V. M. (2006). The system of rice intensification (SRI): a challenge for science, and an opportunity for farmer empowerment towards sustainable agriculture', International Journal of Agricultural Sustainability 4:193-212.
Murphy, K. M., Campbell, K.G., Lyon, S. R. and Jones, S. S. (2007). Evidence of varietal adaptation to organic farming systems. USDA-ARS/UNL Faculty. Retrieved from http://digitalcommons.unl.edu/usdaarsfacpub/422.
Pasuquin, E., Lafarge, T. and Tubana, B. (2008).Transplanting young seedlings in irrigated rice fields: early and high tillering production enhanced grain yield. Field Crops Research 105:141-155.
Pimentel, D., Berardi, G. and Fast, S. (1983). Energy efficiency of farming systems: organic and conventional agriculture. Agriculture, Ecosystem and Environment 9:359-372.
Pfeiffer da. (2003). EatingFossilFuels. Retrieved from http://www.fromthewilderness.com-/free/ww3/100303_eating_oil.html.
Pretty, J. and Hine, R. (2001). Reducing food poverty with sustainable agriculture: a summary of new evidence. Final report from the 'safe world' research project, University of Essex. Retrieved from: http://www2.essex.ac.uk/ces/ResearchProgrammes-/SAFEWexecsummfinalreport.htm.
Pretty, J. N., Morison, I. L. and Hine, R. E. (2003). Reducing food poverty by increasing agricultural sustainability in developing countries. Agriculture, Ecosystems and Environment 95:217-234.
Rodolfo, K. (2008). "Peak oil": the global crisis of diminishing petroleum supply,and its implications for the Philippines. Asian Studies Journal 41:41-101.
Samejima, H., Kondo, M., Ito, O., Nozoe, T., Shinano, T. and Osaki, M. (2004). Root-shoot interaction as a limiting factor of biomass productivity in new tropical rice lines. Soil Science and Plant Nutrition 50:545-554.
Samson, R., Delaquis, E. H., Lem, E. C. and Yank, A. (2015). Climate smart agriculture experiences in the peanut basin of senegal and Gambia . Presentation at the Climate Smart Agriculture Forum, July 21, 2015, Ottawa, Canada.
San-oh, Y., Sugiyama, T., Yoshita, D., Ookawa, T. and Hirasawa, T. (2006). The effect of planting pattern on the rate of photosynthesis and related processes during ripening in ice plants. Field Crops Research 96:113-124.
Sheehy, J. E., Peng, S., Dobermann, A., Mitchell, P. L., Ferrer, A., Yang, J., Zou, Y., Zhong, X. and Huang, J. (2004). Fantastic yields in the system of rice intensification: fact or fallacy?'Field Crops Research 88:1-8.

Sheehy, J. E., Sinclair, T. R. and Cassman, K. G. (2005). Curiosities, nonsense, non-science and SRI'.Field Crops Research 91:355-356.

Saeedipour, S. and Moradi, F. (2011). Effect of drought at the post-anthesis stage on remobilization of carbon reserves and some physiological changes in the flag leaf of two wheat cultivars differing in drought resistance .Journal of Agricultural Science. DOI: 10.5539/jas.v3n3p81.

Schoef, A. W. (1987). When society becomes an addict. San francisco: harper and row.

Sinclair, T. R. and Cassman, K. G. (2004). Agronomic ufos?'.field crops research 88:9-10.

Slater, P. (1980). Wealth Addiction. New York: Dalton.

Soejima, H., Sugiyama, T. and Ishihara, K. (1995). Changes in the chlorophyll contents leaves and in the levels of cytokinins in root exudates during ripening of rice cultivars Nipponbare and Akenohoshi'. Plant and Cell Physiology 36:1105-1114.

Stoop, W. and Kassam, A. (2005). The SRI controversy: a response, Field Crops Research 91:357-360.

Stoop, W. A. (2011). The scientific case for system of rice intensification and its relevance for sustainable crop intensification, International Journal of Agricultural Sustainability 9: 443-455.

Song, C., Fang-rong, Z. and Guo-ping, Z. (2008). Characterization of high-yield performance as affected by genotype and environment in rice*J Zhejiang Univ Sci B. 2008 May; 9:363–370.

Stuart, H. B. (1990). Environmental sustainability and the redesign of agroecosystems. Retrieved from http://eap.mcgill.ca/publications/EAP34.htm.

Tao, L. X., Wang, X. and Min, S. K. (2002). Physiological effects of SRI methods in the rice plant.in: N. Uphoff, E. Fernandes, L. P. Yuan, J. M. Peng, J. Rabenandrasana, S. Rafaralahy (Eds.), Assessments of the System of Rice Intensification: Proceedings of an International Conference, Sanya, China, April 1–4, 2002, CIIFAD, Ithaca, NY. pp. 132–136.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R. and Polasky, S. (2002). Agricultural sustainability and intensive production practices. Nature 418:671-677.

Vidal, J. (2007). Global food crisis looms as climate change and fuel shortages bite, The Guardian. Retrieved from http://www.guardian.co.uk/environment/2007/nov-/03/food.climatechange.

Uphoff N. (2011). The System of Rice Intensification (SRI) as a System of Agricultural Innovation. Retrieved from http://www.future-agricultures.org/farmerfirst/-files/T1c_Uphoff.pdf .

Uphoff, N. (2012). Comment to 'The System of Rice Intensification: Time for an empirical turn NJAS - Wageningen. Journal of Life Sciences 59:53-60.

Verzola, R. (2011). System of rice intensification (SRI): the record-breaking method of rice growing. Presentation SRI Pilipinas rverzola@gn.apc.org.

Vidal, J. (2013). India's rice revolution. The observer (London: The Gardian).

Zhu, D. F., Cheng, S. H., Zhang, Y. P. and Lin, X. Q. (2002). Tillering patterns and the contribution of tillers to grain yield with hybrid rice and wide spacing, in: N. Uphoff, E. Fernandes, L.P. Yuan, J.M. Peng, J. Rabenandrasana, S. Rafaralahy (Eds.), Assessments of the System of Rice Intensification, CIIFAD, Ithaca, NY. pp.125-131.

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