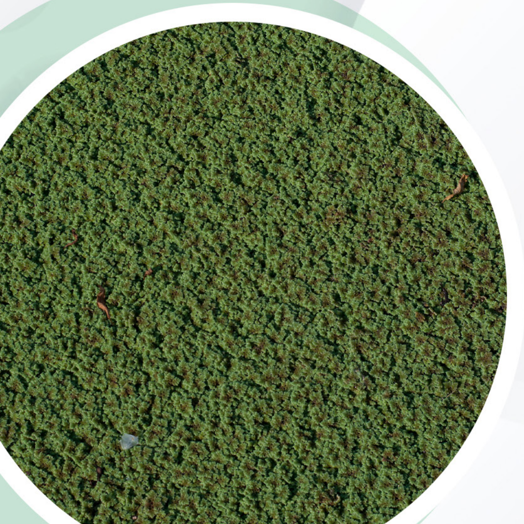
Organic-based Nutrient Management for Rice Production

(Research Results from Long-term Studies)



DEPARTMENT OF AGRICULTURE
1898
PHILRICE

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Abbreviations:

CM	Chicken manure
DAT	Day after transplanting
DBT	Days before transplanting
DMRT	Duncan multiple range test
DS	Dry season
EF	Emission factor
EMAS	Effective microorganism activated solution
EMBI	Effective microorganism-based inoculant
FDA	Fluorescein diacetate hydrolysis analysis = a measure of the total microbial activities in the soils
FRR/FR	Full recommended NPK rate per hectare
GHGs	Greenhouse gases
GHG EF	Greenhouse gas emission factors
GM	Green manure like azolla, indigo, sunflower, *Leucaena sp*, or even weeds
HR	Half the recommended NPK rate per hectare
IBNM	Inorganic-based nutrient management
K	Potassium
LCC	Leaf Color Chart
MOET	Minus-One Element Technique
MOP	Muriate of potash
N	Nitrogen
NH4-N	Ammonium nitrogen
NMO	Nutrient management options
OB	Organic-based
OBFR	Organic based with the full recommended NPK rate per hectare
OBHR	Organic based with half the recommended NPK rate per hectare
OBNM	Organic-based nutrient management
PBA	Partial budget analysis
P	Phosphorus
RSEM	Rice straw with effective microorganism
RSC	Rice straw compost
R&D	Research and development
WS	Wet season

ORGANIC-BASED NUTRIENT MANAGEMENT

Introduction

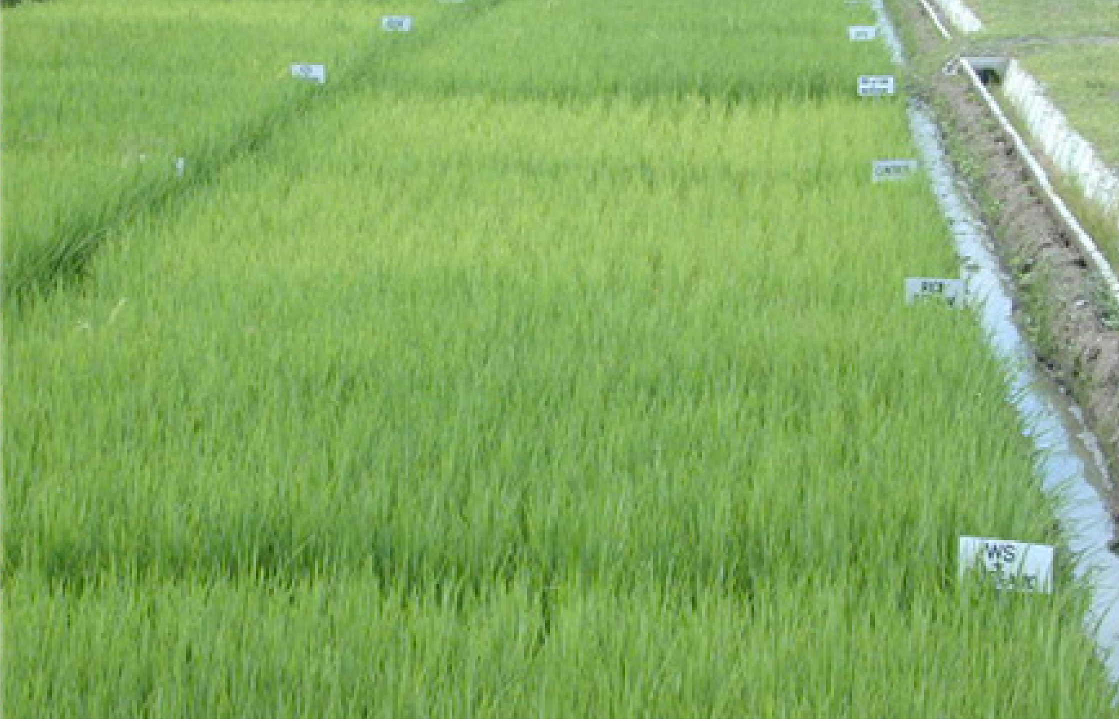
Wellness and long life are included in the top 10 aspirations of farmers as shown by a 2022 study of the Department of Agriculture-Philippine Rice Research Institute. However, the realization of these aspirations may be affected by chemical use, which is detrimental to health when utilized injudiciously.

“Chemical” farming is generally practiced due to its perceived benefits of high yield. This dominant practice is gradually opposed with more consumers demanding for healthy, safe food. The Philippine government also supports the advocacy for healthier consumption through Republic Act (RA) 11511, which amended RA 10068 or the Organic Agriculture Act. Signed in 2021, the law is hoped to benefit over 165,000 organic farming practitioners.

Contrary to dominant perceptions, organic-based nutrient management can sustain yield higher than 5t/ha by reincorporating organic fertilizer especially rice straw to planting rice. Our study also showed that organic-based nutrient management with half of the NPK recommended rate can achieve an average yield of 4t/ha. Moreover, 10 years of continuous organic fertilizer application showed that the highest soil exchangeable potassium increases by 34% from rice straw and inoculated rice straw.

In this publication, we will learn about the scientific bases and proper application of organic fertilizers, grain yield as affected by organic and inorganic fertilizers, and the packaged nutrient management options.

With these researches and body of knowledge, we hope to contribute to a safer rice production and consumption, sound environment, and progressive agricultural system.



TERMINOLOGIES

Mineralization - The decomposition of chemical compounds in organic matter by which nutrients are released to plants in soluble inorganic forms. This process also happens in the breaking down of inorganic compound to release their soluble nutrients; however, the process is done more quick than in organic fertilizer compound.

Nitrogen immobilization - This happens during decomposition of organic fertilizers. Hence, planting rice should not be done during organic fertilizer application. The indigenous soil nitrogen (N) is being used by microorganisms as their energy source to decompose the organic materials. This process may render nitrogen deficiency for the plant's initial growth phase as N will only be released once the decomposition is finished and the microorganizm died.

Grain yield - The final indicator of the total effect of crop management, seasons, and inputs (water, fertilizers, pesticides), and the total weight of harvested *palay* adjusted to 14% grain moisture. Grainy yield can be attained in a rice-rice cropping system during wet and dry seasons, while yield can be realized only once during wet season in mostly rainfed rice ecosystem.

Residual soils nutrient - These are nutrients from inorganic and organic fertilizers not taken by plants and left in the soils for nutrition in future cropping system.

Essential elements - Nitrogen, phosphorous, potassium, zinc, copper, and sulfur are the most essential indigenous or applied elements for rice, without which the growth and development of plants will not be completed. The essentiality of their roles and function cannot be replaced by other elements.

Beneficial elements - are mineral elements, which stimulate the growth and have beneficial effects on certain plant species under specific conditions even at very low concentration. They become toxic in great amounts, may render nutrient imbalances, and are antagonistic to the uptake of the essential elements. Their functions can be replaced by other elements.

Fertilizers are substances that are added to the soil or applied to the plant to supply the elements essential for plant growth and development.

Organic fertilizers are mostly farm waste materials or household wastes that underwent natural process of decomposition or enhanced decomposition with added enzymes, inoculant, or biological agent. They usually have low nitrogen, phosphorus, and potassium (NPK) content, but high in micronutrients.

Inorganic fertilizers are mostly synthetic materials that contain one to four nutrient elements of high concentration and easily available once applied into the soils. They are easily handled but easily lost if not managed properly.

Greenhouse gases or GHGs are compound that trap heat or long wave radiation in the atmosphere that make the Earth's surface warmer. The principal GHGs, also known as heat-trapping gasses, are carbon dioxide, methane, nitrous oxide, and fluorinated gases.

Rice straw composting *in situ* are chopped rice straw by grass cutter or by the combine harvester with chopper, and rice stubbles plowed/reincorporated by dry land preparation. There is no need to collect them as they can be composted in a place, enhanced by the use of effective microorganism-based inoculant, effective microorganism activated solution, chicken manure, vermicast, or any other inoculant. Inorganic nitrogen fertilizer can also be used.

Effective microorganism-based inoculant (EMBI) is an inoculant made from a fermented mixture of 1 part *darak* (bran), 1 part carbonized rice hull, 5% effective microorganism activated solution (EMAS), and 5% molasses. This is in solid form and can be broadcasted into the paddy soils applied with rice straw or other organic fertilizers to hasten their decomposition.

Effective microorganism activated solution (EMAS) is made from the original EM1 mother liquor containing 100 species of beneficial bacteria diluted into 1.1 EM1 to molasses. A liter of mother EM1 can make 200l of EMAS. Example: To make 2l of EMAS: mix 3% EM1 and 3% molasses to 2l of water. Ferment for 5-7 days. This is in liquid form and can be sprayed into the paddy soils. Since they are harmless, they cannot harm the plant when spray mists drop on them.

Vermicasts/vermicompost is a mixture of earthworm castings or worm excreta and undigested organic materials. The beddings are partially composted rice straw, carabao manure, and *Aqua regia* or *Azolla*, or best is banana trunk, which was observed to be more favorable for vermi worms than other substrates.

Green manure are succulent plant materials that contain 3-4% nitrogen and are found to be potential alternative organic-based nitrogen source for rice production. Tested green manures were *Azolla* spp, *Titonia diversifolia* (wild sunflower), *Indigofera tinctoria* (tayum), *Sesbania* spp, *Aeschynomene* spp, *Vigna radiata* (mungbean), and *Chorchorous olitorius* (jute).

Chicken/animal manure are air-dried and applied at 3t/ha in rice paddies giving an equivalent of 60kg N per hectare. Animal manures from carabao, cow, and goat were also tested for the organic-based nutrient management, but chicken manure contains higher N and P than the other manures. Mineralization of these manures is similar to the chicken manure, except for the goat manure due to its cellulosic coverings; hence, the need to grind for faster release of nutrients.

Soil productivity is indicative of sustainable soil health and as a function of the interactive role of the physical, chemical, and biological properties of the soils.

Paddy soils are usually where farm planted to rice is flooded or submerged by irrigation water or shallow tube well irrigation.

SCIENTIFIC BASES AND PROPER APPLICATION OF ORGANIC FERTILIZERS

Soil fertility and health and plant nutrition as effected by organic and inorganic application

These observations are supported by studies on the direct or indirect use of organic fertilizers:

On available elements for rice plants in soil:

- NPK are very critical from the vegetative to reproductive stages of plant growth. An average 6-9% total NPK from applied organic fertilizer is insufficient to complete the needed amount of nutrients for good growth and grain yield production.
- To produce a ton of *palay*, the plants need 17kg N, 3kg P, and 17kg K per hectare, which sole organic fertilizers apparently cannot supply.
- Mineralization studies done in laboratory, pots, and in field trials showed that the mineralized nitrogen from the basally applied organic fertilizers such as rice straw, chicken manure, green manure, and commercial organic fertilizers were observed to have decreased even before panicle initiation (Figure 1).
- NPK from organic fertilizer is only up to the 28-30th days after transplanting; hence, the need for the alternative topdress organic N to supply later growth stages.

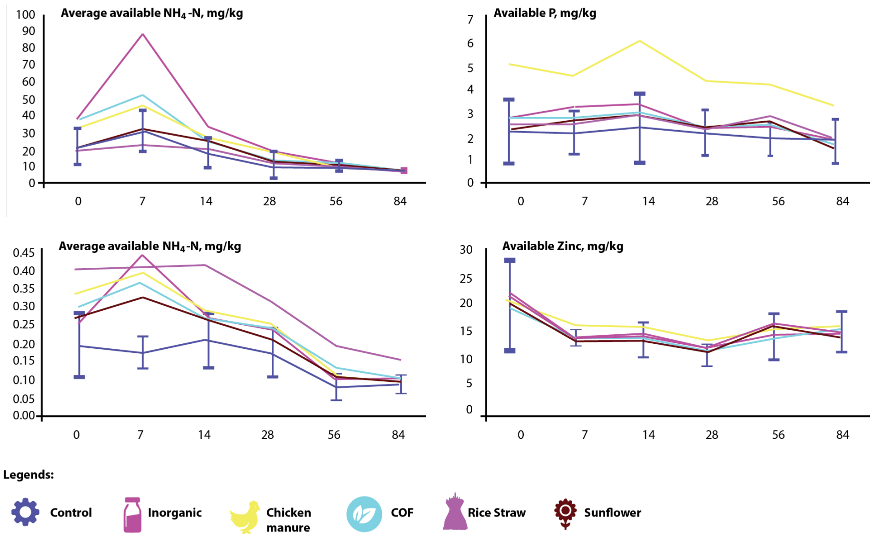


Figure 1. Available nitrogen, potassium, phosphorous, and zinc determined from Maligaya clay soils amended with different organic fertilizers as compared with inorganic fertilizer applied and unfertilized soils. DS 1999-WS 2001. COF = commercial organic fertilizer, inorganic fertilizer at recommended rate of NPK for WS (90-40-40kg) and for DS 120-40-40kg (N-P_2O_5-K_2O/ha)

- Mineralization of green manures takes only 1-2 days after incorporation in paddy soils. The release of nutrient is as quick as inorganic nitrogen fertilizers.
- Assessed green manure: *Azolla, Sesbania, Aeschynomene, Indigo, Corchorus,* and *Vigna* have showed potential nitrogen source.
- Among the *Azolla* species tested in lowland rice ecosystem, *Azolla microphylla* grew and sporulated well under high relative humidity and hot environment.
- *Azolla microphylla* have higher sporulation in soils previously applied with chicken manure or vermicast than other organic fertilizers applied basally.
- Highest phosphorous (P) was observed in chicken manure (CM) treatment in all the parameters evaluated. Continuous application of CM and rice straw (RS) increased P level in soil by 41% and 24%, respectively.
- After 10 years of continuous organic fertilizer application, the highest soil exchangeable potassium increases by 34% and was observed in RS and inoculated RS (RSEM) application. The gradual increase was observed to have started after RS incorporation in six cropping seasons.

- Micronutrients are high in organic fertilizers, but rice plants only needed them in small amount. The observed increased Fe++ after 18 years of organic fertilizer application may become a potential risk when it reaches the critical toxicity level as it will become antagonistic to the uptake of zinc and phosphorous.
- NOTE: Applying foliar fertilizers (dilute fertilizer applied directly to plant leaves), organic or inorganic, is less effective than the solid forms of fertilizers.

On mineralization and proper timing of organic fertilizer application:

- The best time to incorporate organic nutrients in paddy soils in considering mineralization for nutrient availability are:
    - Rice straw for 3-4 weeks before transplanting or at least 30 days before transplanting (DBT)
    - Chicken manure at 7 DBT
    - Commercial organic fertilizer or vermicast/vermicompost at 7-10 DBT
    - Green manure like *Azolla*, wild sunflower, *Sesbania*, *Aeschynomene*, and other legumes at 2 DBT
    - Use pre-decomposed rice straw or apply straw with EMBI (100:1) or air-dried chicken manure in situ in 1-2 weeks before transplanting

On soil chemical, physical, and biological properties

- Generally, applying organic materials into the soil hastens mineralization and increase microbial community and diversity (Figure 2a).

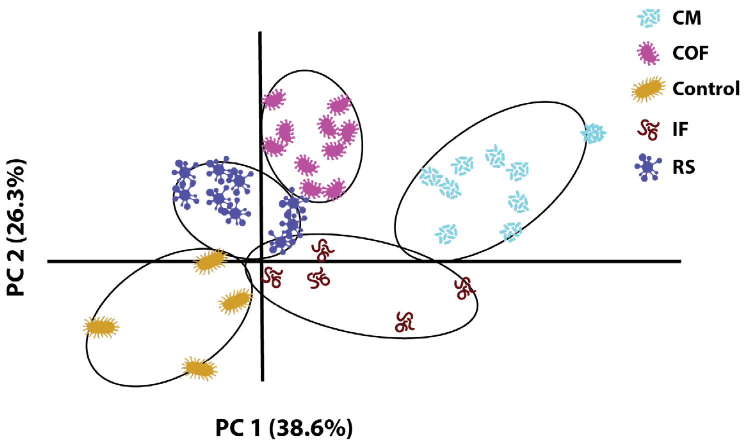


Figure 2a. Bi-plot of the principal component analysis of the carbon utilization profile at 72h of incubation of Biolog EcoPlate inoculated with soils collected from rice field under long-term organic fertilization trial. IF-inorganic fertilizer; RS-rice straw; COF-commercial organic fertilizer; CM-chicken manure

- Each and every organic fertilizer applied produces unique microbial functional community and higher enzyme activities compared to plots continuously fertilized with synthetic inorganic fertilizers (Figure 2b).
- There are no changes in soil pH (acidity or alkalinity) in pure inorganic fertilizer plots (Figure 3).
- Soil pH slightly decreases when organic fertilizers are continuously applied due to the release of carbonic acid into the soils as a result of decomposing applied organic C materials.

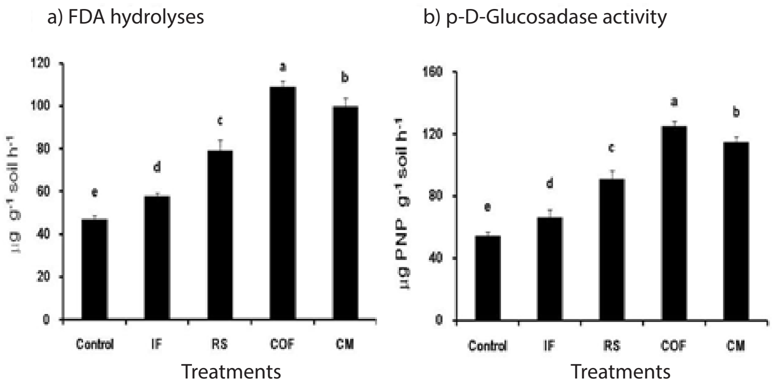


Figure 2b. FDA hydrolyses (a) and p-d-glucosadase (b) activity of paddy soils after eight years of organic and inorganic fertilizer application. Data are treatment means and standard deviation (bars). Letters indicate significant differences between treatments based on Tuckey's Test at 5% level of significance. IF-inorganic fertilizer; RS-rice straw; COF-commercial organic fertilizer; CM-chicken manure.

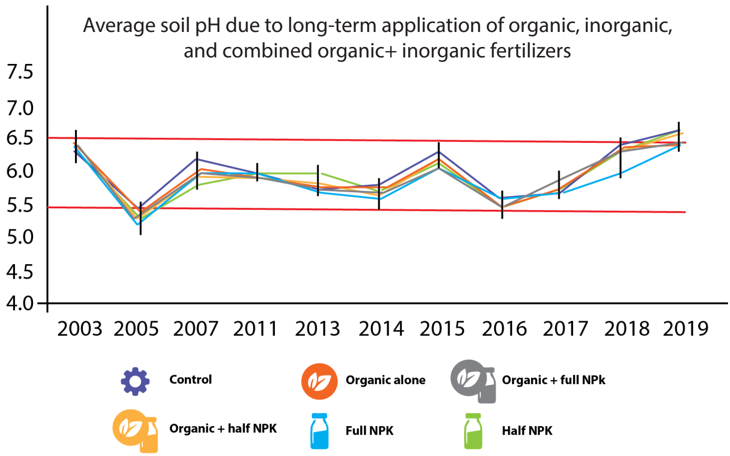


Figure 3. Trend of soil pH as affected by the average effect of different organic fertilizers alone (OB), inorganic fertilizers alone (half rate or HR and full rate or FR), and in combination with half (OBHR) or full (OBFR) NPK recommended rate.

- Applying organic fertilizers results in higher carbon exchange capacity (CEC) in soils indicating a higher absorption of the released or available nutrient from either organic or inorganic fertilizers.
- The soil continuously applied with organic fertilizer had relatively lower bulk density (BD) than the unfertilized and those applied with inorganic NPK fertilizers. Lowering BD means the soil is becoming soft and saturated loose.
- Rice straw with or without inoculant has lowest BD among other organic fertilizers applied, with full NPK rate than with half NPK rate.
- Continuously applying organic-based fertilizers in paddy soil has no significant increase in soil organic matter (Figure 4).

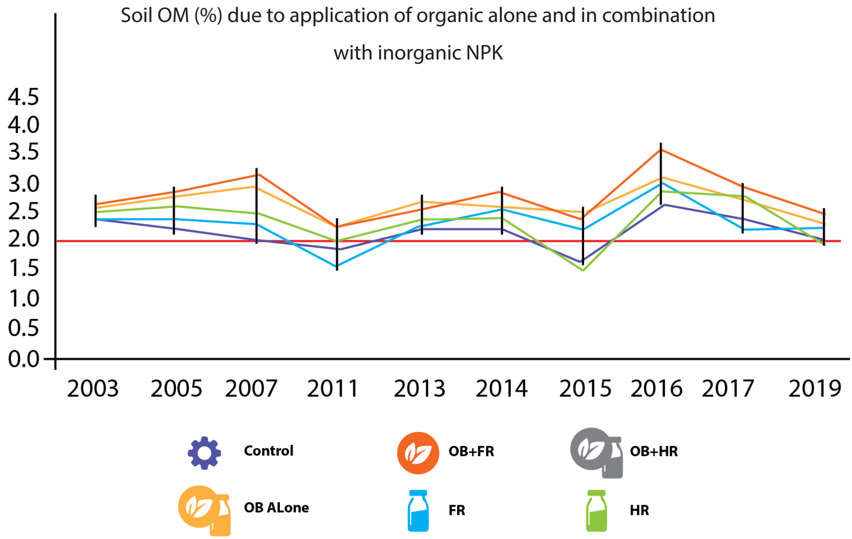


Figure 4. Trend of soil organic matter as affected by the average effect of different organic fertilizers alone (OB), inorganic fertilizers alone (HR and FR) and in combination with half (OBHR) or full (OBFR) NPK recommended rate.

On Greenhouse Gas Emissions

- Application of organic fertilizers has high greenhouse gas emission due to its high carbon content and causes the formation of methane gas when it reacts with irrigation water.
- High methane emission is expected when fresh rice straw is incorporated in flooded or submerged paddy soils.
- Fresh rice straw can increase methane (CH_4) emission by 162-250%, while the collection and composting of rice straw will increase methane by only 23-30% (Corton et al., 2000). For every ton of rice straw, methane emission is approximately 129.77kg GHG Emission Factor (GHG EF) during the wet season (WS), and 36.99kg GHG-EF in the dry season (DS). If composted first, the GHG EF is reduced to 13.37kg in the WS and 2.1kg EF in the DS (Quilang et al., 2019).
- Reduction of emission factor (EF) due to the application of organic fertilizers can be done by proper application and timing of application into the flooded soils:
    - Apply or plow under the rice straw and stubbles by dry land preparation at least 30 days before transplanting. Let it decompose *in situ* naturally.
    - If irrigation comes ahead of schedule, apply additional air-dried chicken manure or EMBI during harrowing to further hasten decomposition of rice straw.
    - If not intended to be certified as organic rice, apply 23kg N or 1 bag of urea/ha to lower the carbon/nitrogen (C/N) ratio of rice straw and hasten decomposition.
    - Apply commercial organic fertilizer, manure, and vermicompost at least 14 days before transplanting.

GRAIN YIELD AS AFFECTED BY ORGANIC AND INORGANIC FERTILIZERS

Short-term Effects (1999 WS - 2001 DS)

Yield responses to organic fertilizer as compared to indigenous soil nutrients and inorganic fertilizer applied (1999 WS - 2001 DS)

- Grain yield is low when only organic fertilizers are applied except those applied with chicken manure that have a yield comparable with the inorganic fertilizer especially in the dry seasons (Table 1).

Table 1. Average grain yield per season (Mh/ha) of transplanted PSB Rc 82 as affected by fertilizer treatments under Maligaya clay soil series. Maligaya, Muñoz, Nueva Ecija

Fertilizer treatments	Cropping Seasons						3 years average		Annual average
	1999 DS	1999 WS	2000 DS	2000 WS	2001 DS	2001 WS	DS	WS	
Control	4.47 b	3.96 a	3.52 b	3.90 b	2.88 bc	2.93 c	3.62	3.60	3.61
Inorganic	5.15 a	4.34 a	5.16 a	4.60 ab	5.08 a	4.02 ab	5.13	4.32	4.73
Chicken manure	4.75 ab	4.21 a	4.94 a	5.00 a	5.53 a	4.78 a	5.07	4.66	4.87
COF	5.06 ab	4.83 a	4.59 a	4.60 ab	2.92 bc	3.39 bc	4.19	4.27	4.23
Rice Straw	4.65 ab	4.7 a	3.72 b	5.00 a	2.72 c	3.84 bc	3.70	4.51	4.11
Sunflower	4.36 b	4.40 a	4.76 a	4.80 ab	3.50 b	3.75 bc	4.21	4.32	4.26
CV (%)	9.2	10.7	7.2	11.1	15.2	12.7			

***Grain yield adjusted to 14% moisture content. Means with similar letters are not different at 5% level of significance by DMRT.** COF= commercial organic fertilizer at recommended NPK rate (90-40-40kg N-P_2O_5-K_2O_5 /ha for WS and 120-40-40kg N-P_2O_5-K_2O_5/ha) for DS.

- The annual average grain yield in Mg/ha using different fertilizer treatments in transplanted PSB Rc 82 during the 1999-2001 WS and DS with grain yield adjusted to 14% moisture content showed the following:
    - o Inorganic – 4.73
    - o Chicken manure – 4.87
    - o Commercial organic fertilizer – 4.23
    - o Rice straw – 4.11
    - o Sunflower – 4.26

Varietal yield responses to organic fertilizer application

- There is a varietal response to the organic-based fertilizers applied (Table 2). From inorganic fertilizer application to just organic fertilizer, yield of PSB Rc 82 was reduced by 18% in the DS and 13.82% in the WS; Rc 18 showed yield reduction of 27.81% in the DS and 1.99% in the WS, while hybrid rice yielded reduction by 27.12% in the DS and 10.94% in the WS.

Table 2. Average grain yield, (Mg/ha) of 3 high-yielding varieties as affected by the different fertilizer treatments in Maligaya clay soil series, Maligaya, Muñoz, Nueva Ecija in 2002.

Fertilizer treatments	Irrigated Lowland Varieties			
	PSB Rc 82	PSB Rc 18	PSB Rc 72H	Average
Dry Season 2001				
Control	2.44 c	2.88 bc	3.87 bc	3.06
Inorganic	4.13 ab	5.08 a	6.25 a	5.16
Chicken manure	4.74 a	5.53 a	5.91 a	3.39
COF	3.12 bc	5.92 bc	4.09 bc	3.38
Sunflower	3.06 bc	3.50 b	4.70 b	3.75
Rice Straw	2.49 c	2.72 bc	3.52 c	2.91
CV (%) a= 23.3				
b= 18.2				
Wet Season 2001				
Control	3.02 c	2.93 c	3.56 bc	3.17 d
Inorganic	4.36 a	4.02 ab	4.50 a	4.29 ab
Chicken manure	4.17 ab	4.78 a	4.44 ab	4.46 a
COF	3.34 bc	3.39 bc	3.53 c	3.42 cd
Sunflower	3.72 abc	3.75 bc	401 abc	3.82 bc
Rice Straw	3.80	3.84 bc	4.05 abc	3.90 abc
CV (%) a= 18.1				
b= 12.17				

Means in a column with the same letter are not significantly different from each other at 5% level of confidence by DMRT.
No letter means they are statistically the same.
Average grain yield ajusted to 14% moisture content.
Inorganic fertilizer at recommended NPK rate (90-40-40kg/ha N-P_2O_5-K_2O_5/ha for WS and 120-40-40kg N-P_2O_5-K_2O_5/ha for DS).

- The average grain yield (Mg/ha) of high-yielding varieties using different fertilizer treatments (Table 2) per season shows the following:

Treatments	Dry Season	Wet Season
Inorganic	5.16	4.29
Chicken manure	5.39	4.46
Commercial organic fertilizer	3.38	3.42
Sunflower	3.75	3.82
Rice Straw	2.91	3.90

Yield responses to an integrated fertilizers application/management

- A consistent or sustainable high grain yield is achieved by mixing additional rice-straw to the different inorganic-based nutrient management (Table 3).

Table 3. Adjusted grain yield (Mg/ha)of PSB Rc 28 as affected by different integrated fertilizer managements and strategies under the Maligaya condition. 1999 WS - 2001 DS. DA-PhilRice, Maligaya, Science City of Muñoz, Nueva Ecija.

Fertilizer Management[1]	1999 WS[3]	2000 DS[4]	2000 WS[4]	2001 DS[4]
NPK + RSC	6.39 b	5.96 a	5.73 a	6.38 a
NPK + RSC + Zn	6.01 a	6.31 b	5.42 a	6.39 a
NPK + RSC + Micronutrients	6.65 b	6.3 b	5.29 a	6.34 a
NPK + RSC + legume	6.63 b	6.00 a	5.46 a	6.50 a
NPK S + RSC + Zn			5.36 a	6.58 a
NPK + CM			5.37 a	6.16 a
NPK			5.30 a	6.52 a
Mean Yield per season	6.42	6.15	5.42	6.41
cv (%)	3.2	1.7	7.3	4.3

Means of the same letter are not significantly different at 5% level by DMRT.
[1]NPK = 90-40-100kg/ha in the WS and 120-40-100kg/ha in the DS, RSC = rice straw compost at 2.5t/ha, CM= chicken manure at 0.5t/ha dry weight basis, macronutrient (6kg Rhizocote/ha)
[2] Adjusted grain yield at 14% moisture content [3]Transplanted, [4]Wet directed seeded

Long-term Effects (2004 - 2021)

Yield responses to different organic fertilizers and inorganic fertilizers applied alone or in combination in 36 cropping seasons

- Grain yield of the organically grown rice plants is lower than those applied with NPK rate (Figure 5) especially in dry seasons.

Average Yield from 36 rice croppings or 18 years of trials (2003-2021)

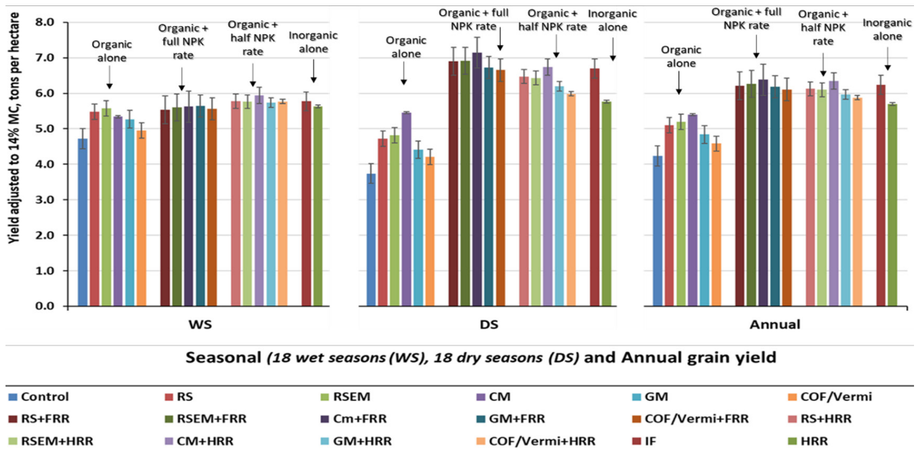
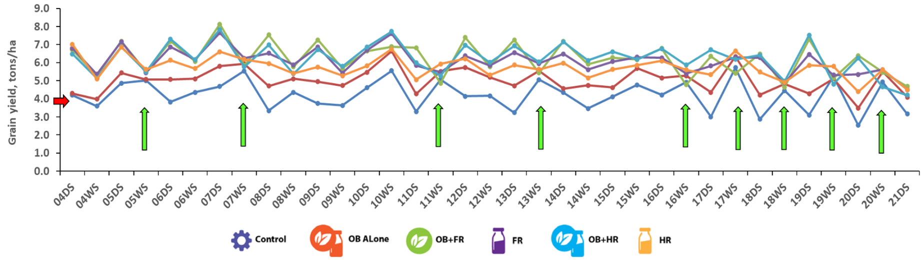


Figure 5. Average seasonal and annual grain yield of PSB Rc 82 as affected by different organic fertilizer applied alone or in combination with half and full NPK recommended rate. Conducted in Maligaya, Science City of Muñoz, Nueva Ecija in 2004-2001.

- Comparable yield among all organic fertilizer used with that of inorganic fertilizer happened every 8 years but only in the wet season.
- Grain yield was sustainably higher with any of the tested organic fertilizers with full NPK rate or half NPK fertilizer rate.
- Average yield increases of 23.7 to 29.8% are achieved when applying organic fertilizer together with half the NPK rate.
- Average yield increases of 25.7 to 33.1% are achieved when applying organic fertilizer with full NPK rate.
- Yields from 100% inorganic plus organic; 50% inorganic plus organic, and 100% inorganic fertilizer exceeded the 6t/ha grain yield average from 2004 to 2021 (Figure 6).
- Rice straw, chicken manure, and green manure as organic fertilizers exceeded the target yield of 4t/ha for solo organic-based nutrient management (OBNM) for both seasons, but only chicken manure exceeded the target yield during the dry season (Figure 7).
- Consistently, high average yield was achieved when organic fertilizers are combined with inorganic fertilizer either with half or full NPK recommended rate. This proves the complementary role of organic and inorganic fertilizers on soil productivity and grain production.

Seasonal yield due to organic vs inorganic sources 2004-2021



Seasonal yield due to organic sources vs inorganic sources and NPK

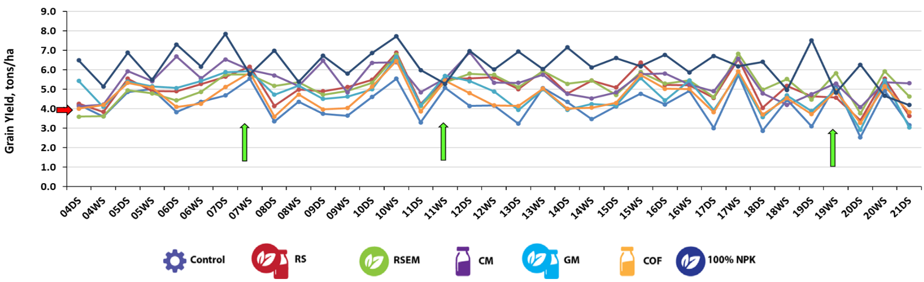
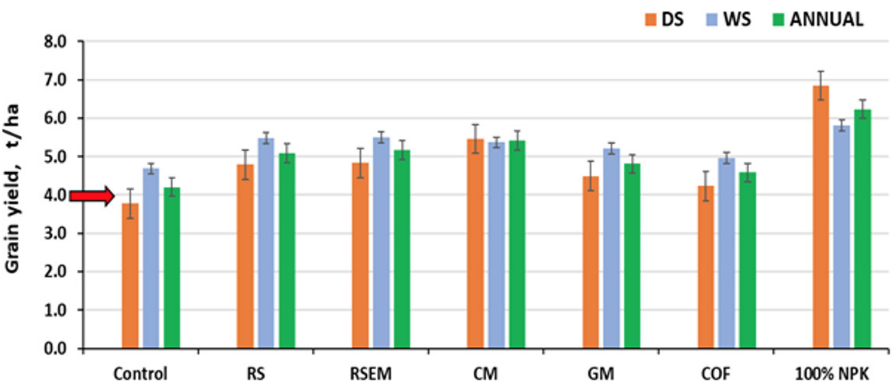


Figure 6. Average seasonal grain yield of PSB Rc 82 as affected by different organic fertilizer applied alone (b) or in combination with half and full NPK recommended rate. 2004-2021. PhilRice Central Experimental Station. Maligaya, Science City of Muñoz, Nueva Ecija. (Arrows indicate comparable yield among all fertilizers used).

Average yield from 2004 to 2021 DS due to different application of sole organic supplements for paddy rice



Legend: RS = rice straw; RSEM= rice straw with EM; CM+ chicken manure; GM = Green manure; COF= commercial organic fertilizer; NPK = inorganic NPK rate

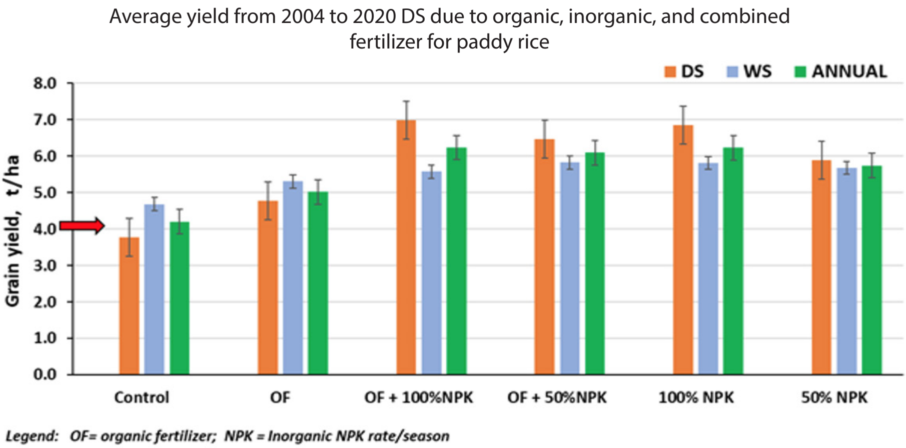


Figure 7. Average yield from 2004 to 2021 due to different application of sole organic fertilizers and in combination with half or full NPK rate for paddy rice. PhilRice Central Experimental Station. Maligaya, Science City of Muñoz, Nueva Ecija. (Red arrow indicates the target yield due to organic-based nutrient management for irrigated rice production).

SUMMARY OF FINDINGS AND TECHNOLOGY IMPORTANCE

> Increasing grain yield by an organic-based nutrient management in WS and DS:

- Compensate organic fertilizers with half or full NPK recommended rates for the season to produce 5-7t grain yield per hectare particularly in the growth stage of maximum tillering to panicle initiation.
- Compensate deficient nutrients from organic fertilizers by (a) applying inorganic fertilizers or (b) by another organic source of nitrogen during the critical stages of rice, particularly at maximum tillering stage and at 5-7 days before panicle initiation.
- Different organic fertilizers should also follow the right timing of their application into the paddy soils to synchronize availability of nutrient elements when the plants need them, and to reduce greenhouse gas emission.
- To maximize the use of rice straw, the most abundant waste in the rice-rice cropping system, it can be re-incorporated into the soil during the first plowing, adding chicken manure or vermicast in the last harrowing, and applying any green manure during the final land levelling.

PACKAGING COMPONENTS FOR IRRIGATED RICE

The effectiveness of packaging organic-based nutrient management is shown by the sustainably high grain yield.

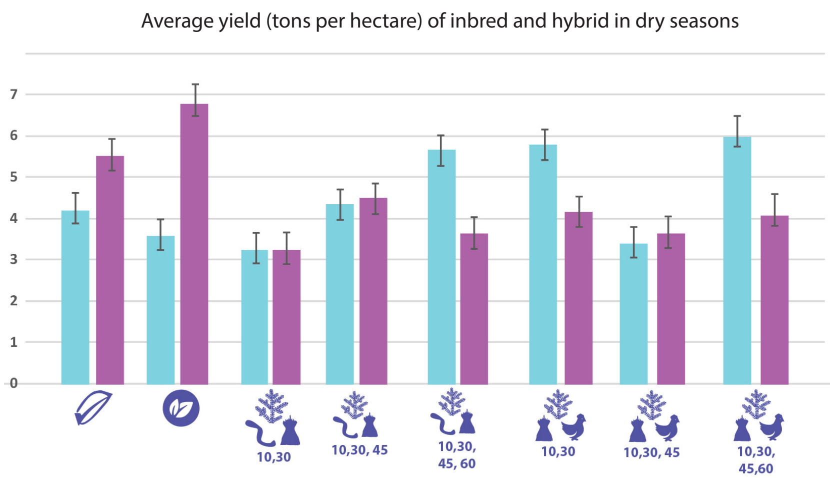
Rice straw as the soil health maintainers prior to cropping

- Incorporation of rice straw into the **soil** at least 30 days before sowing of seeds or planting seedlings as the maintainer of the soil health prior to cropping

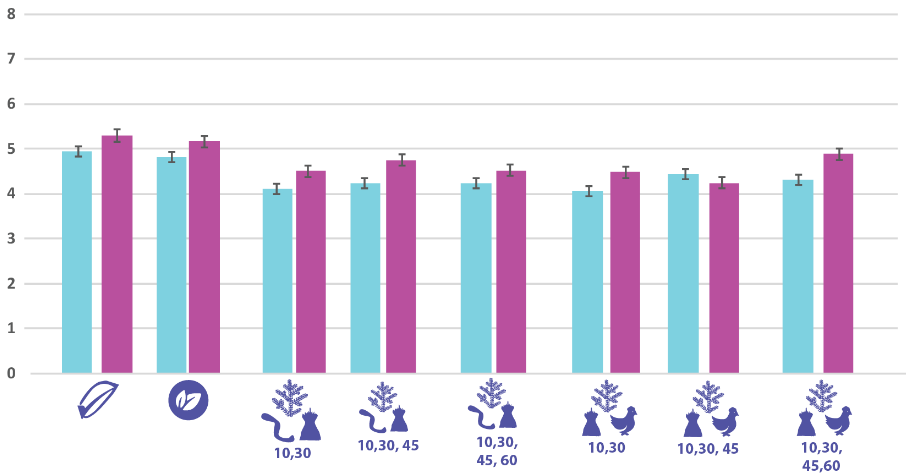
Additional or succeeding added nutrition:

- Grain yield was observed **highest** when organic fertilizer or rice straw with chicken manure was applied prior to applying the full NPK recommended rate following the plant-demand-based nutrient need per given stage and even higher than following the improved conventional nutrient management.
- Other OBNM with rice straw added with either chicken manure or vermicast prior to transplanting, followed by azolla application at 10, 30, 45, 60 days after transplanting also gave yield higher than the target rice yield of sustainable 4t/ha (both in wet or dry seasons) following the OBNM.

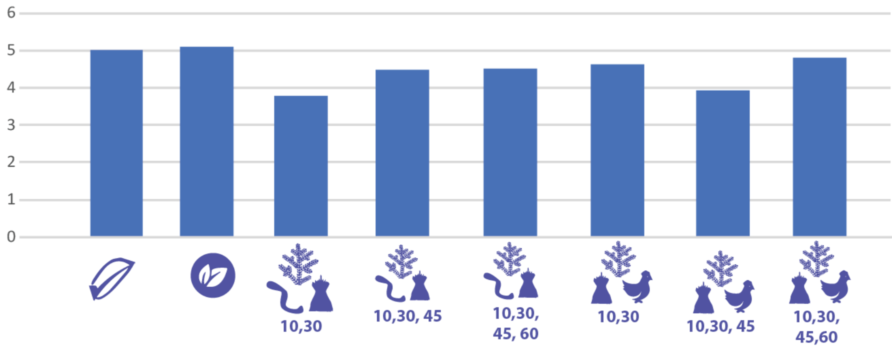
- Hybrid rice is also responsive to the packaged component of the OBNM and achieved the target yield of 4t/ha for organic-based rice in both seasons. Inbred rice only attained the target yield of 4t/ha in the wet season, but hardly attained it in the dry season.
- A sustainable and higher than 5t/ha yield can be attained by re-incorporating organic fertilizer especially in using rice straw as the soil maintainer prior to planting rice, and following the plant-demand-based nutrient application after transplanting rice.
- A sustainable average 4t/ha can be achieved by following the packaged OBNM: rice straw incorporation + chicken manure or vermicast plus *Azolla* as the alternate organic N source for the rice plants after transplanting (Figure 10).
- For those finance-less capable farmer, the OBNM can be followed with half of the NPK recommended rate, and still can achieve an average of 4t/ha.

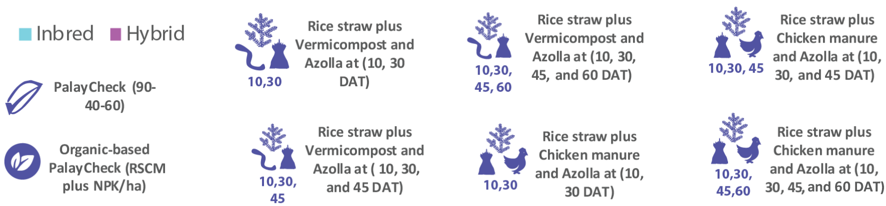


Average yield (tons per hectare) of inbred and hybrid in wet seasons



Average annual yield (t/ha) of rice in response to organic and inorganic-based nutrient management





PACKAGED NUTRIENT MANAGEMENT OPTIONS FOR SUSTAINABLE GRAIN YIELD AND SUSTAINING SOIL HEALTH AND PRODUCTIVITY

Nutrient Management Option 1	Pure organic-based nutrient management (OBNM) for Organic Rice (OBRice) production	Average 2-4t/ha Note: Ideal for farmers who (1) are into certified organic rice production, (2) had limited financial capability to buy organic and inorganic commercial fertilizers, (3) are willing to compost and recycle their own farm waste as soil conditioners and nutrients Outcome/impact: • Sustainable soil health with improved soil physical, biological, and chemical properties rather than higher yield production; • Sustainable yield of at least 4t/ha; • Clean and pleasing farm environment; • Profitable when certified; and health food if pesticide-free.	• 5t/ha of slightly dried rice straw (not pre-decomposed) plus 500kg/ha air-dried chicken manure; or depending on the straw yield, use the ratio of 10 rice straw:1 manure (10:1 ratio) • Topdressing N from *Azolla microphylla* **o** Alternative Option 1: Any green manure available in the farm, Azolla production is the cheapest and has higher partial budget analysis (PBA) among other green manure production. **o** Alternative Option 2: Foliar organic fertilizer. Expensive and more laborious, and has very low partial budget analysis (PBA) if foliar fertilizers are used; hence not really profitable.	1. Basal application: Use whatever rice straw and stubbles left after the preceding harvest: • Chopped fresh or on-site rice straw should be incorporated at least 30 days before transplanting by dry land preparation to avoid high GHG emission. • At the second harrowing, or 14 days before transplanting, apply air-dried chicken or carabao manure. Optional: 30kg to 1 bag urea/hectare can be applied with rice straw for faster decomposition 2. Top dress of alternative organic N sources • Application of 500kg *Azolla microphyla*/ha at 7 DAT; 7,10, 30, and 45 DAT for wet season • Application of 500kg *Azolla microphyla*/ha at 7 DAT; 10, 30, 45 DAT and 60 for dry season Note: Lower the water depth in the paddy field to 2cm for easier incorporation of *azolla* into the soil to start mineralization using either the mechanical paddy weeder or by trampling. By this, N is released at the 2nd day after its incorporation. Not fully incorporated *azolla* may not supply the needed N for rice plants.

Nutrient Management Option 2	Organic-based PalayCheck™ System	6t or more per hectare (at 14% grain moisture content). Note: Ideal for (1) more receptive and more progressive farmers; (2) those who are willing to compost and recycle their own farm waste as soil conditioners and nutrients for the plants	• 5t/ha of slightly dried rice straw (not pre-decomposed) plus 500kg/ha air-dried chicken manure; or depending on the straw yield, use the ratio of 10 rice straw:1 manure (10:1 ratio) • Follow Keycheck #5 of the PalayCheck System or same as Option 1 • **Basal application rate and timing** • Topdressing based on Leaf Color Chart (LCC) readings or using the critical growth stages	1. Basal application: Use rice straw and stubbles left after harvest: • Rice straw should be incorporated at least 30 days before transplanting by dry land preparation to avoid high GHG emission. • At the second harrowing, or 14 days before transplanting, apply air-dried chicken or carabao manure. 2. Inorganic NPK fertilizer application: • Complete fertilizer is applied at 10 DAT using 40-40-40 NPK rate/hectare. • Urea at the rate of 30kg/ha is applied at 20 DAT, 35-38 DAT, and at 45 DAT or early panicle initiation (EPI). • At 45 DAT or EPI, together with urea, 1 bag of muriate of potash is applied at DS and 0.5 bags of MOP/ha at WS. • N application is better using LCC. Note: • Muriate of potash can be eliminated from the recommendation after 3 years of rice straw application. • Phosphorous can also be eliminated after 3 years of manure application but should be re-applied as needed based on Minus-One Element Technique (MOET) or soil analyses.
Nutrient Management Option 3	Standard PalayCheck System (Improved conventional and chemical-based rice production)	5-7t/ha (at 14% grain moisture content) Note: Ideal for progressive farmers who are more willing to follow the judicious use of inorganic fertilizers.	• Basal of 6 bags 14-14-14 (7-10 DAT) • LCC based N application from 7 DAT reading to early flowering: apply 23kg N/ha every reading below LCC 3	1. Basal application • Complete fertilizer is applied at 10 DAT using 40-40-40 NPK rate/hectare

			• Muriate of potash if and only necessary at EPI	2. Topdress nitrogen (N) and potassium (K) Option 1: • LCC based N application from 7 DAT reading to early flowering: Apply 23kg N/ha every reading below LCC 3 Option 2: (If LCC is not used as indicator of the right timing of application) • Urea at the rate of 30kg/ha is applied at 20 DAT, 35-38 DAT, and at 45 DAT or EPI • At 45 DAT or EPI, together with urea, 1 bag of muriate of potash is applied at DS and 0.5 bags of muriate of potash/ha at WS. • Half bag of urea/ha is optionally applied when at least 15% of panicle had been exerted 4. At 45 DAT or EPI, as needed, apply N with half bag to 1 bag muriate of potash per hectare
Nutrient Management Option 4	Organic-based PalayCheck™ System with half inorganic NPK fertilizer rate	Average 4-5t/ha (at 14% grain moisture content) Note: Ideal for (1) those who cannot buy the full inorganic NPK recommended rate per hectare but have enough farm waste to use as nutrients and soil conditioners and (2) those who are willing to compost and recycle their own farm waste as soil conditioners and nutrients for the plants.	• 5t/ha of slightly dried rice straw (not pre-decomposed) plus 500kg/ha air-dried chicken manure; or depending on the straw yield, use the ratio of 10 rice straw:1 manure (10:1 ratio) • Complete inorganic fertilizer applied at half the recommended rate for DS and WS. Example: 45-15-15 NPK for WS and 60-20-30 NPK for DS	1. Basal application: Use rice straw and stubbles left after harvest: • Rice straw should be incorporated at least 30 days before transplanting by dry land preparation to avoid high GHG emission. • At the second harrowing, or 14 days before transplanting, apply 500 kg/ha air-dried chicken or carabao manure.

		• Sustainable grain yield but rather than higher yield production • Clean and pleasing farm environment	• Topdressing N is based on LCC readings	2. Application is only half of the inorganic NPK fertilizer recommended rate per season: • Complete fertilizer is applied at 10 DAT using 15-15-15 NPK rate/ hectare in WS; 20-20-20 NPK in DS • Urea at the rate of 15kg/ ha is applied at 20 DAT, and at 45 DAT or EPI for WS; use N rate of 20kg/ha plus K rate of 10kg/ha in the DS Note: • Muriate of potash can be eliminated from the recommendation, after 3 years of rice straw application. • Phosphorous can also be eliminated after 3 years of manure application, but should be again re-applied as needed as per MOET or soil analysis.

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