SVU-International Journal of Agricultural Sciences
Volume 5 Issue (2) pp.: 19-28, 2023
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2023.210148.1284

RESEARCH ARTICLE

Comparative analysis of the three nutrient management decision support tools for irrigated lowland rice (*Oryza sativa* L.) var. NSIC Rc176H in Cantilan, Surigao del Sur, Philippines

Blanco, M.M. [1], B.C. Ratilla [2] and D.M. Baňoc [2]*

[1] *Cantilan Municipal Local Government Unit, Cantilan, Surigao del Sur, Philippines.*
[2] *Department of Agronomy, Visayas State University, Visca 6521-A, Baybay City, Leyte, Philippines.*

Abstract

Nutrient management adopting various decision-support tools plays a key role in obtaining better rice yield. Thereby, three nutrient management strategies; i.e., Regional Soil Laboratory (RSL), Rice Crop Manager (RCM), and Farmers' Fertilizer Practice (FFP) for lowland rice production were tested. The experiment was laid out in an RCBD with four treatments and three replications. The treatments were T_0 = Control; T_1 = RSL; T_2 = RCM; T_3 = FFP. Results revealed that rice plants under FFP applied with higher amounts of N, P_2O_5, and K_2O significantly headed and matured late than unfertilized control and RSL but no significant difference from that of RCM. Rice plants under RCM developed significantly more productive tillers when compared to all other treatments except for RSL which produced a similar number of productive tillers. Rice plants under RSL obtained significantly higher grain yields but were comparable with RCM. The highest gross margin and highest return on investment (ROI) were obtained in plants under RSL with Php 65,226.73 ha^{-1} and 90.55%, respectively while the control plants obtained the lowest gross margin of Php 9,294.44 ha^{-1}. The nutrient requirements of NSIC Rc176H should follow both RSL and RCM for excellent growth, better yield, and higher income. Therefore, RSL and RCM nutrient management decision tools are strongly recommended for rice farmers' adoption to assure of achieving better yield, high gross margin, and equitable ROI under irrigated lowland ecosystems.

Keywords: farmers' practice; lowland rice; nutrient management; soils laboratory.

1. Introduction

Rice (*Oryza sativa* L.) is the staple food of more than half of the world's population (Ricepedia, 2018). It is the most important agricultural crop and a major source of income for millions of farmers in the Philippines (Cororaton, 2004). Global rice production relies on the use of fertilizer to ensure a sufficient supply of staple food for half the world's population (GRiSP, 2013). Fertilizer typically represents about 10–30% of total production costs for irrigated rice in Asia (Moya *et al.*, 2004; Pampolino *et al.*, 2007).

.*Corresponding author: **Dionesio M. Baňoc**
Email: dionesio.banoc@vsu.edu.ph
Received: May 10, 2023; Accepted: May 26, 2023; Published online: May 27, 2023.

Nutrient management has been recognized as one of the complex innovations that require substantial knowledge of soil properties, variety, weather, and local growing conditions. Unfortunately, farmers have limited access to this information, especially soil chemical analysis. Soil test results provide the farmer with the estimated amount of nutrients present in the soil as the basis of fertilizer recommendations (Baker *et al.*, 2002). Applying the appropriate amount of the needed fertilizer will give the farmer a chance to obtain the desired crop yield. The soil analysis deals interpretation only with the fertility level (Plant nutrients) of the soil. Other factors of production or management may still cause low yields, even though nutrients are adequate. The accessibility to laboratories is another limiting factor since it is only located in regional offices.

A recent rice crop nutrient decision support tool is the Rice Crop Manager (RCM), a computer-based decision support tool that provides irrigated and rainfed lowland rice farmers with a crop and nutrient management guideline customized to the needs of an individual farmer (IRRI, 2019). The RCM technology has been disseminated to rice farmers across the country through the Department of Agriculture and various Local Government Units (LGUs). However, data revealed that only a few farmers who were provided with the RCM guidelines had followed its recommendations (Agting *et al*., 2017). Farmers still opted to use their traditional practices because of the hesitancy to follow the recommendations, feeling the need to adjust the recommendations, inability to access the input markets, and late receipt of the recommendation (Manalo *et al*., 2021).

The challenge is how to make this technology adaptable to rice farmers. There is a need to showcase these technologies so that the saying to see is to believe the mentality of Filipinos can be resolved. Documentation and comparative study of these crop nutrient decision support tools in rice are necessary to evaluate their effectiveness and promote adoption by farmers. Hence this study is to evaluate the Regional Soil Laboratory (RSL), Rice Crop Manager (RCM), and Farmers' Fertilizer Practice (FFP) as the basis for nutrient management decisions for irrigated lowland rice; compare the nutrient requirements of NSIC Rc176H (Pioneer 73) based on the RSL, RCM, and FFP under Cantilan, Surigao del Sur conditions. Evaluate the agronomic characteristics and yield components of NSIC Rc176H applied with fertilizer based on the three rice crop nutrient management decision support tools. And to determine the marginal cost and return analysis of rice production using the three rice crop nutrient management decision support tools under irrigated lowland ecosystems.

2. Materials and methods

This study was conducted in an irrigated lowland ecosystem in Brgy. Calagdaan, Cantilan, Surigao del Sur, Philippines from June 5, 2022, to September 24, 2022. One-on-one interview with the target farmer-cooperator was conducted before seed sowing to generate fertilizer recommendations based on RCM. Another survey interview was conducted with ten randomly selected rice farmers in Cantilan, Surigao del Sur, Philippines to indicate their common fertilizer application rates for the Farmers' Fertilizer Practice. Ten soil samples were collected randomly from the experimental area before land preparation. These were composited, air-dried, pulverized, sieved, and submitted for analysis. The result of the soil analysis was used as the basis for the Regional Soils Laboratory fertilizer recommendation of the study. A total area of 315 m^2 was utilized in this study. The soil was puddled three times using a hand tractor at weekly intervals.

2.1. Experimental design and treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four treatments and three replications. The four treatments were T_0 = Control; T_1 = Regional Soil Laboratory (RSL); T_2 = Rice Crop Manager (RCM); T_3 = Farmers' Fertilizer Practice (FFP). Each plot measured 4 m × 5 m (20 m^2) with bunds constructed around each treatment plot with a dimension of 0.5 m wide with a height of 15 cm to avoid contamination of treatments. To further avoid treatment contamination, canals were made in between replications at a width of 0.5 m.

2.2. Cultural management practices

Table 1 shows the amount of inorganic fertilizer applied per plot. The experimental area was submerged for leveling the field was drained during transplanting to facilitate the transplanting operation. Fifteen-day-old seedlings were transplanted at a spacing of 20 cm x 20 cm with two seedlings per hill. Missing hills were replanted one week after transplanting. Rotary weeding was undertaken two weeks after transplanting, followed by hand weeding one week later to remove the weeds around the hill which were not removed during rotary weeding. Proper irrigation was implemented throughout the growth and development of the rice plant. Spraying of molluscicide (Sure kill) was done one day before transplanting to control the golden apple snail (*Pomacea canaliculata* Lamarck). Vermitea was sprayed on 20 DAT and every two weeks thereafter to control pests' infestations like leaf folder and rice bugs (*Leptocorisa acuta* Thunb). Scarecrows were also installed at the grain-filling stage until harvest to protect the crop from birds. Rice was harvested when 85% of the panicle grains in each treatment plot had ripened as indicated by its firm grains. Sharp sickles were used to cut the rice panicles at the base. All sample plants per treatment in the harvestable area (15.12 m^2) were used for gathering the agronomic characteristics, yield and yield components, and harvest index.

Table 1. Amount (kg ha^{-1}) of N, P_2O_5, and K_2O applied per hectare

Treatment	N	P_20_5	K_20	Total
T_0 – Control	-	-	-	-
T_1 – Regional Soils Laboratory	105.50	25.00	7.00	137.50
T_2 – Rice Crop Manager	63.76	16.38	16.38	96.52
T_3 – Farmers' Fertilizer Practice	183.50	35.00	95.00	313.50

2.3. Data gathered

The agronomic characteristics gathered were the number of days from sowing to heading, number of days from sowing to maturity, plant height (cm), and leaf area index (LAI). For yield and yield components, the following parameters were gathered: the number of productive tillers, percent filled and unfilled spikelets, panicle length (cm), panicle weight (g), the weight of 1,000 grains, and grain yield. Other parameters gathered were the harvest index, soil test results, and climatic data.

2.4. Statistical analysis

The analysis of variance (ANOVA) of all data was done using the Statistical Tool for Agricultural Research (STAR). Honestly, a significant difference or Tukey's test was used for comparison among treatment means based on a 5% level of significance.

3. Results and discussion

3.1. Climatic Data

Table 2 shows the total weekly rainfall (mm), temperatures (Minimum and maximum, ºC), and relative humidity (%) throughout the conduct of the study. The amount of rainfall from sowing to harvesting ranged from 18.59 mm to 175.06 mm with an average weekly rainfall of 66.08 mm. The average minimum and maximum temperatures were 27.15°C and 29.51° C, respectively while the average relative humidity was 80.63%. The data shows that the recorded average weekly rainfall of 66.08 mm is within the weekly rainfall requirement for normal vegetative and reproductive growth of rice crops which is from 45 to 75 mm (Yoshida 1981). Moreover, the average minimum and maximum temperatures (27.15°C - 29.51°C) during the growing period of rice were close to the temperature range requirement of 27°C to 32°C for normal growth and development (Yin *et al*., 1996). The average relative humidity of 80.63% was within the recommended range for rice cultivation between 60 to 85% (Rathnayake *et al*., 2016). Hence, the amount of rainfall, temperature, and relative humidity values were within the range for optimum growth and development of the rice plants.

Table 2. Total weekly rainfall (mm), average daily minimum, and maximum temperatures (°C) and relative humidity (%) during the duration of the study (June 5, 2022, to September 24, 2022)

Week Period	Rainfall (mm)	Temperature (°C)		Relative humidity (%)
		Minimum	Maximum	
1 (June 5 - 11, 2022)	52.09	27.01	29.10	81.25
2 (June 12 - 18, 2022)	18.59	27.32	29.37	77.88
3 (June 19 - 25, 2022)	28.40	26.88	29.16	77.88
4 (June 26 - July 2, 2022)	81.14	27.14	28.94	84.31
5 (July 3 - 9, 2022)	47.33	26.84	29.13	84.56
6 (July 10 - 16, 2022)	58.36	27.28	29.84	76.31
7 (July 17 - 23, 2022)	65.27	27.04	29.12	82.00
8 (July 24 - 30, 2022)	34.04	27.55	30.08	77.31
9 (July 31 - Aug 6, 2022)	80.02	26.87	28.83	83.50
10 (Aug 7 - 13, 2022)	66.84	26.89	29.19	84.62
11 (Aug 14 - 20, 2022)	51.63	26.85	29.57	83.25
12 (Aug 21 - 27, 2022)	111.65	27.08	29.63	78.25
13 (Aug 28 - Sept 3, 2022)	34.09	27.53	30.12	82.38
14 (Sept 4 - 10, 2022)	47.83	27.04	29.67	82.12
15 (Sept 11-17, 2022)	175.06	27.41	30.39	77.06
16 (Sept 18 - 24, 2022)	104.93	27.59	30.10	77.44
Total	1,057.27	434.33	472.23	1,290.12
Mean	66.08	27.15	29.51	80.63

3.2. Farmers' Interview

The demographic profile of the farmer–respondents are presented in Table 3 based on the farmer's interview conducted for RCM and FFP. Data showed that out of the 11 farmer-respondents, seven were male and four were female. Most of the farmers were above 40 years old of age. The average age of the rural farmer respondents was 52 years old. Most of them did not complete any formal schooling wherein four farmers were elementary undergraduates and college level, one was a high school undergraduate and only two farmers were college graduates. In terms of source of income, six of the farmer-respondents were full-time farmers, three have part-time jobs as laborers and unskilled workers such as housemaids and tricycle drivers, and only two were employed. Their average monthly income was Php7,036.36 which was below the poverty threshold, of Php9,064.00 (Philippine Statistics Authority, 2016).

Table 3. Demographic profile of farmer – respondents for RCM and FFP

Farmer	Gender	Age	Civil status	Educational Attainment	Source of income	Average monthly income (Php)
1	Female	62	Married	Elementary level	Farming	3,500.00
2	Female	34	Married	College level	Farming	5,500.00
3	Male	50	Married	College level	Farming, Tricycle driver	6,000.00
4	Male	46	Married	College level	Farming	2,000.00
5	Female	38	Married	College Graduate	Farming	7,000.00
6	Male	59	Married	High School level	Farming, Employed	12,000.00
7	Male	58	Married	Elementary level	Framing, Laborer	7,700.00
8	Male	53	Married	Elementary level	Farming	7,700.00
9	Female	65	Married	Elementary level	Farming, Housemaid	5,000.00
10	Male	58	Married	Elementary level	Farming	6,000.00
11	Male	45	Married	College Graduate	Farming, Employed	15,000.00
	Average	52				7,036.36

Most of the farmer-respondents were tenants and small land-holders with an average farm size of 0.82 hectares as presented in Table 4. They have been into rice farming for over ten years. Most of the farmer-respondents used the Pioneer 73 hybrid rice variety during the previous dry cropping season wherein their average yield was 4.48 mt ha^{-1}.

Table 4. Farm profile of farmer – respondents for RCM and FFP

Farmer	Farm area (Hectares)	Land tenure	Years in farming	Hybrid variety	Yield (MT/ha)
1	1.00	Tenant	39	Pionner 73	4.23
2	1.00	Tenant	12	Pionner 73	4.30
3	0.85	Tenant	18	Pioneer 79	4.32
4	1.00	Tenant	15	Bigante Plus	3.02
5	0.79	Tenant	10	Bigante Plus	3.75
6	1.00	Owner	35	LP937	5.90
7	0.13	Laborer	28	LP937	4.54
8	0.50	Tenant	23	Pionner 73	3.47
9	1.02	Tenant	35	Bigante Plus	4.38
10	1.00	Tenant	30	Pionner 73	5.04
11	0.73	Owner	20	Pioneer 73	6.12
Average	0.82		24		4.48

3.3. Soil Chemical Properties

Table 5 shows the soil test results before planting and after the harvest of irrigated lowland rice (NSIC RC176H). The initial soil analysis showed that the area had a pH of 5.06 and 3.40 % organic matter, 8 ppm available P, and 241 ppm exchangeable K. The data indicated that the soil was very strongly acidic with a low amount of organic matter and available P based on Landon (1991). A slight decrease in soil pH, OM, and amount of total P and K were noted after harvest compared to the initial soil analysis. These findings could be due to the utilization of organic matter, phosphorus, and potassium elements through plant uptake.

Table 5. Soil test results before and after harvest of irrigated lowland rice (NSIC RC176H) under different nutrient management decision support tools

Treatment	Soil pH	OM (%)	P (ppm)	K (ppm)
Initial Soil Analysis	5.06	3.40	8.00	241.00
Final Soil Analysis				
T_0 – Control	5.05	2.90	7.00	62.00
T_1 – Regional Soils Laboratory	4.92	2.90	6.00	83.00
T_2 – Rice Crop Manager	4.83	3.00	6.00	97.00
T_3 – Farmers' Fertilizer Practice	4.92	2.80	7.00	84.00

3.4. Agronomic Characteristics

The agronomic characteristics of irrigated lowland rice (NSIC RC176H) as affected by the different nutrient management decision support tools are presented in Table 6. Analysis of variance showed that only the number of days from sowing to heading and maturity of rice were significantly affected by the different nutrient management decision support tools adopted.

Table 6. Agronomic characteristics of irrigated lowland rice (NSIC RC176H) as influenced by the different nutrient management decision-support tools

Treatment	Number of days from sowing to		Plant height (cm)	Leaf area index
	Heading	Maturity		
T_0 – Control	68.67^{c}	100.00^{d}	107.47	2.64
T_1 – Regional Soils Laboratory	72.67^{b}	105.67^{c}	113.30	3.37
T_2 – Rice Crop Manager	74.00^{ab}	107.33^{b}	116.43	4.42
T_3 – Farmers' Fertilizer Practice	75.33a	110.67^{a}	110.18	3.20
C.V. %	1.24	0.75	7.04	37.85

Columns having the same letter(s) are not significantly different from each other at 5% level of significance

Rice plants under farmers' fertilizer practice (FFP) significantly headed later (75.33 days) than unfertilized control (T_0) (68.67 days) and RSL (T_1) (72.67 days) but no significant difference than that of RCM (T_2) with 74.0 days. Relative to the number of days from sowing to maturity, FFP significantly matured late (110.67 days) when compared to all other treatments tested. According to Sedeek *et al.* (2009), differences in the number of days to complete a heading among rice varieties are influenced by fertilization coupled with the effect of environmental factors such as soil, and weather conditions. The result of this study implies that increasing the amount of N, P_2O_5, and K_2O lengthens the number of days to complete heading and maturity.

Relative to plant height and LAI, results revealed that plants under RCM obtained slightly higher plant height and LAI compared to the other treatments but it did not contribute significant differences between the two parameters. According to a study by Wu *et al.* (2020), plant height increased potentially due to the addition of nitrogen, which promotes cell expansion, increasing stem elongation and consequently obtaining a longer plant height. The favorable effect of nitrogen on both leaf development and leaf area duration of the plant can be linked to the increase of LAI (Fageria, 2007). The results of this study did not conform to the findings of Wu *et al.* (2020) and Fageria (2007) since RCM fertilizer recommendations applied only with smaller amounts of nitrogen (63.76 kg ha^{-1}) compared to RSL (105.50 kg ha^{-1}) and FFP (183.50 kg ha^{-1}).

3.5. Yield and yield components and harvest index

Tables 7 and 7a show the yield and yield components and harvest index of irrigated lowland rice (NSIC RC176H) as affected by the different nutrient management decision support tools tested. Analysis of variance showed that yield and the yield components of NSIC RC176H were not significantly affected by the different nutrient management decision support tools except for the number of productive tillers and grain yield.

Rice plants under RCM (T_2) developed significantly more productive tillers (13.97 tillers) when compared to all other treatments except for RSL (T1) which produced an almost similar number of productive tillers (13.13 tillers). This result conforms with the findings of Fernandez (1991) that the application of inorganic fertilizer to rice plants using the RCM (T_2) tool resulted in the development of more productive tillers compared to the unfertilized (control). This is also superior to that of the farmers' practice (T_3). Moreover, rice plants under RSL (T_1) produced a significantly higher grain yield (7.63 mt ha^{-1}) than those of other treatments except RCM (T_2) which produced a closely similar yield of 6.72 mt ha^{-1}. The study showed that plants under RCM (T_2) obtained a relatively higher percentage of filled spikelets per panicle and slightly heavier grain weight which also resulted in a higher harvest index. This could be due to the ability of crops to absorb nutrients and improve grain quantity and grain weight per panicle during grain development. Rice plants under RCM (T_2) also obtained comparable results with RSL (T_1) in the weight of 1,000 grains and harvest index.

Rice plants under FFP (T3) with more amount of fertilizer applied did not obtain the highest grain yield. Results indicated that an increase in the amount of fertilizer does not always guarantee an increase in grain yield. According to Smith (2023), over-fertilization can lead to sudden plant growth with an insufficient root system to supply adequate water and nutrients to the plants. Excess fertilizer also alters the soil by creating too high of a salt concentration, and this can hurt beneficial soil microorganisms. This was supported strongly by the findings of Mukherjee (2013) mentioned that excessive application of nitrogen (N) fertilizer can harm the soil because too much N might be detrimental to the growing plants since excess N is transformed into nitrates which are not useful anymore for plant growth. This finding reminds the results of (Saladaga and Baňoc, 2022) stipulated that the combined application of both organic and inorganic fertilizers at lower rates of application promoted significantly the agronomic characteristics, yield, and yield component parameters especially the weight of marketable ears of sweet corn resulting in to achieve high profit. They emphasized further that the combined application of organic and inorganic fertilizers to sweet corn is one of the best adaptation strategies for solving the negative effect of climate change particularly relative to drought. Thus, the result implies that it is better to use RCM or RSL, as it guides the rice farmers on the right amount and nutrients the plants need, which are important in improving grain yield components.

Table 7. Yield components of irrigated lowland rice (NSIC RC176H) as affected by the different nutrient management decision support tools

Treatment	Number of productive tillers	Spikelets per panicle (%)		Panicle length (cm)
		Filled	Unfilled	
T_0 – Control	11.90b	89.08	10.92	29.82
T_1 – Regional Soils Laboratory	13.13ab	85.56	14.44	29.39
T_2 – Rice Crop Manager	13.97a	91.16	8.84	29.21
T_3 – Farmers' Fertilizer Practice	11.83b	86.99	13.01	30.55
C.V. %	5.59	4.00	29.86	2.32

Columns having the same letter(s) are not significantly different from each other at 5% level of significance

Table 7a. Yield, yield components, and harvest index of irrigated lowland rice (NSIC RC176H) as affected by the different nutrient management decision support tools

Treatment	Panicle weight (g)	Weight of 1,000 grains (g)	Grain yield (Tons/ha)	Harvest index
T_0 – Control	7.33	30.00	3.09c	0.43
T_1 – Regional Soils Laboratory	6.33	33.33	7.63a	0.47
T_2 – Rice Crop Manager	6.00	33.33	6.72ab	0.47
T_3 – Farmers' Fertilizer Practice	7.33	30.00	6.63b	0.46
C.V. %	11.32	13.93	7.83	5.92

Columns having the same letters are not significantly different from each other at 5% level of significance

3.6. Marginal cost and return analysis

The marginal cost and return analysis of irrigated lowland rice (NSIC RC176H) as affected by the different nutrient management decision support tools is presented in Table 8. The highest gross margin among all the fertilizer management decision tools used was obtained in T_1 (Regional Soils Laboratory) with Php 65,226.73 ha^{-1}. This was followed by the RCM treatment (T_2) with Php 43,576.78 ha^{-1}. On the other hand, rice plants under control (T_0) obtained the lowest gross margin with Php 9,294.44 ha^{-1} only. In terms of gross return, RSL also obtained the highest return on investment (ROI) of 90.55% followed by RCM (56.39%).

The marginal cost and return analysis revealed that plants following the RSL fertilizer management decision tool resulted in a higher gross margin and ROI. This may be due to the relatively higher yield (7.63 t ha^{-1}) obtained in this treatment that even though it incurred higher variable costs, still it gained a higher gross margin. Moreover, the result implies that it is important to know the right nutrient and amount of fertilizer the rice plant needs to obtain better results (PalayCheck System, 2023).

Table 8. Marginal cost and return analysis (ha^{-1}) of irrigated lowland rice (NSIC RC176H) as affected by the different nutrient management decision support tools

Treatment	Grain yield (t ha^{-1})	Gross income (Php ha^{-1})	Total variable cost (Php ha^{-1})	Gross margin (Php ha^{-1})	Return of investment (%)
T_0 – Control	3.09	55,555.56	46,261.11	9,294.44	20.09
T_1 – Regional Soils Laboratory	7.63	137,263.17	72,036.45	65,226.73	90.55
T_2 – Rice Crop Manager	6.71	120,853.02	77,276.23	43,576.78	56.39
T_3 – Farmers' Fertilizer Practice	6.63	119,250.79	85,642.59	33,608.21	39.24

The calculation of gross income is based on the current price of dried palay at Php 18.00 kg^{-1}

4. Conclusion

The Based on the results obtained from the study, the following conclusions can be drawn to wit: the nutrient requirements of NSIC Rc176H (Pioneer 73) showed that RSL and RCM involved the lower application of nutrients (N, P_2O_5, and K_2O) than the rest of the nutrient management decision support tools. The agronomic characteristics and yield components of NSIC Rc176H (Pioneer 73) applied with fertilizer based on the three rice crop nutrient management decision support tools only showed significant results on the number of days from sowing to heading and maturity, the number of productive tillers per hill and the grain yield. Results revealed that rice plants under farmers' fertilizer practice (FFP) significantly headed later than unfertilized control (T_0) and RSL (T_1) but no significant difference from that of RCM (T_2). Relative to the number of days from sowing to maturity, FFP significantly matured late when compared to all other treatments tested. Rice plants under RCM (T_2) developed significantly more productive tillers (13.97 tillers) when compared to all other treatments except for RSL (T1) which produced an almost similar number of productive tillers (13.13 tillers). Moreover, rice plants under RSL (T_1) obtained significantly higher grain yield (7.63 mt ha^{-1}) which was comparable with RCM (T_2) which produced a closely similar yield of 6.72 mt ha^{-1}. The marginal cost and return analysis of NSIC Rc176H rice production under irrigated lowland ecosystem showed that RSL obtained the highest gross margin of Php 65,226.73 ha^{-1} and the highest ROI of 90.55% among the other nutrient management decision tools tested.

Recommendations

Based on the results of this study, RCM and RSL nutrient management decision tools are recommended to be used by farmers for better yield, gross margin, and return on investment. A similar study is suggested to be conducted to further evaluate the performance of the different nutrient management decision tools used in this research undertaking.

Authors' Contributions
All authors are contributed in this research.
Funding
There is no funding for this research.
Institutional Review Board Statement
All Institutional Review Board Statements are confirmed and approved.
Data Availability Statement
Data presented in this study are available on fair request from the respective author.
Ethics Approval and Consent to Participate
Not applicable
Consent for Publication
Not applicable.
Conflicts of Interest
The authors disclosed no conflict of interest starting from the conduct of the study, data analysis, and writing until the publication of this research work.

5. References

Agting, C.S., Estacion, C.S., Estoy, G.F., Collado, W.B., Regalado, M.J., Buresh, R.J. (2017). 'Performance of Rice Crop Manager in Agusan Del Norte, Philippines'. *Philippine Journal of Crop Science*, Vol. 42. pp. 145.

Baker, R.D., Ball, S.T., Flynn, R. (2002). *'Soil Analysis: A key to soil nutrient management Guide A-137',* College of Agricultural, Consumer and Environmental Sciences, New Mexico State University. September 2002. Accessed 30 October 2021 from https://aces.nmsu.edu/pubs/a/A137/welcome.html 230 October 2021\.

Cororaton, C.B. (2004). 'Rice Reforms and Poverty in the Philippines', *A CGE Analysis*, June 2004. Accessed 30 October 2021.

Fernandez, M.O. (1991). *'Response of three upland rice varieties to nitrogen fertilizer',* (Unpublished Undergraduate Thesis), Leyte State Univerity, Visca, Baybay City, Leyte, Philippines.

Fageria, N.K. (2007). 'Yield Physiology of rice', *journal of plant nutrition*, 30, pp. 843-879. http://dx.doi.org/10.1080/15226510701374831.

GRiSP (Global Rice Science Partnership. (2013). *'Rice Almanac'*, 4th edition. Los Baños (Philippines): International Rice Research Institute. 283 pp.

International Rice Research Institute. (2019). *'Rice Crop Manager – Philippines',* Accessed 30 October 2021. https://www.irri.org/crop-manager.

Landon, J.R. (1991). *'Booker Tropical Soil Manual',* Longman Scientific and Technical. Essex England. 474 pp.

Manalo, J.A. IV, Sonny, P.P. & Bautista, M. (2021). 'Understanding the complexities in the adoption of the Rice Crop Manager tool in the Philippines', *International Journal of Agricultural Sustainability*, DOI: 10.1080/14735903.2021.1934363.

Moya, P.F., Dawe, D., Pabale, D., Tiongco, M., Chien, N.V., Devarajan, S., Djatiharti, A., Lai, N.X., Niyomvit, L., Ping, H.X., Redondo, G., Wardana, P. (2004). *'The economics of intensively irrigated rice in Asia',* In Dobermann, A., Witt, C., Dawe, D. (Eds.), Increasing Productivity of Intensive Rice Systems through Site-Specific Nutrient Management. Science Publishers, Enfield, NH (USA) and International Rice Research Institute (IRRI), Los Baños, Philippines, pp. 29–58.

Mukherjee, S. (2013). *'Soil conditioner and fertilizer industry',* In Mukherjee S (eds) The science of clay, *Capital Publishing Company*, New Delhi, India. Pages 159-172.

PalayCheck System (2023). *'Pinoy Rice Knowledge Bank'*, Accessed 06 January 2023 https://www.pinoyrice.com.

Pampolino, M.F., Manguiat, I.J., Ramanathan, S., Gines, H.C., Tan, P.S., Chi, TT.N., Rajendran, R., Buresh, R.J. (2007). 'Environmental impact and economic benefits of site-specific nutrient management (SSNM) in irrigated rice systems', *Agr. Syst.*, 93, pp. 1–24. https://doi.org/10.1016/j.agsy.2006.04.002.

Rathnayake, W.M., De Silva, U.K., Dayawansa, N.D.K. (2016). 'Assessment of the Suitability of Temperature and Relative Humidity for Rice Cultivation in Rainfed Lowland Paddy Fields in Kurunegala District', *Tropical Agricultural Research*, 27 (4), pp. 370– 388.

Philippine Statistics Authority. (2016). *'Poverty Incidence Among Filipinos in 2015',* Retrieved from https://psa.gov.ph/poverty-press-releases.

Ricepedia. (2018). *'The global staple',* Accessed 05 November 2021 from https://ricepedia.org/rice-as-food/the-global-staple-rice-consumers.

Saladaga, F.J.S., Bañoc, D.M. (2022). 'Performance of three corn (*Zea mays* L.) varieties as influenced by the combined application of organic and inorganic fertilizers', *South Valley University – International Journal of Agricultural Science (SVU-IJAS)*, 4(4), pp. 145 – 157.

Sedeek, S.E.M., Hammoud, S. A.A., Ammar M.H., Metwally, T.F. (2009). 'Genetic variability, heritability, genetic advance, and cluster analysis for some physiological traits and grain yield and its components in rice (*Oryza Sativa* L.)', *J. Agric. Res. Kafr El-Sheikh Univ*., 35, pp. 858-878.

Smith, Kit. (2023). *'The Perils of Over-Fertilizing Plants and Trees',* UCCE Dorado County Master Gardener. Accessed 29 January 2023 at https://mgeldorado.ucanr.edu/files/170168.pdf.

Wu, K., Wang, S., Song, W., Zhang, J., Wang, Y., Liu, Q., Yu, J., Ye, Y., Li, S., Chen, J. (2020). 'Enhanced sustainable green revolution yield via nitrogen-responsive chromatin modulation in rice', *Science*, 367, eaaz2046.

Yin, X., Kroff M.J., Goudriann, J. (1996). 'Differential effects of day and night the temperature on development to flowering in rice', *Annals of Botany*, 77, pp. 203-213.

Yoshida, S. (1981). *'Fundamentals of Crop Science',* International Rice Research Institute, College of Agriculture, Los Baños, Laguna, Philippines. 26.

Mukherjee, S. (2013). *'Soil conditioner and fertilizer industry',* In: Mukherjee S (eds) The science of clays. Capital Publishing Company, New Delhi, India, pp. 159-172.