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Research Article

Sugarcane Fertilization Innovation: Enhancing Productivity and Sustainability in the Philippines

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ABSTRACT

Economically, the sugarcane industry is one of the major sources of dollar income in the Philippines. It is planted in different types of soil, environments, and cultural management. Sugarcane is a voracious eater of fertilizer. The main purpose of innovating the fertilization activities in the farm is to increase production in order to sustain the sugarcane industry. The study aims to measure the fertilization innovations practice by the farmers that could affect the production of the sugarcane crop in the Philippines. The descriptive method was employed in the study. The instrument used was the validated survey questionnaire used by the group of Oñal in their study in 2021. The 320 sugarcane farmers were randomly identified at the seven locations in the Visayas area of the Philippines. Analysis of variance (ANOVA) implied that there's a significant difference in the production of sugarcane among the different locations in the Philippines. Furthermore, the frequency of applying the fertilizers, the correct placement of fertilizers, maximizing the application of N and K elements, and the combo application of organic-inorganic fertilizers implied a high production respectively. The correct placement of fertilizers and the application of organic-inorganic fertilizers were strongly correlated with sugarcane production but moderately correlated with the level of N and P elements applied. The study revealed that fertilization innovations had a significant relationship in increasing the productivity of the sugarcane crop in the Philippines.

Keywords: *Sugarcane fertilization, Trash deduction, Organic agriculture, Sugarcane innovations, Sustainable production, Production volume, Fertilization frequency*

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Introduction

Economically, the sugarcane industry is one of the major sources of dollar income in the Philippines. It is planted in different types of soils, environments, and cultural management, including innovations in fertilization. Despite the continuous education given to the farmers, momentum on production could not be realized until this time. In lieu of this, farmers are doing different innovations at the farm level.

Relatively, farmers' innovations do not influence the level of productivity, especially on the sugarcane fertilization (Oñal et al, 2021.

Innovations employed in farming are usually done by integrating the existing sugarcane production technologies. The main purpose is to increase production and the sustainability of the sugarcane industry (Singh et al, 2019; Misra & Bhatt, 2020).

Innovation is an indirect output of effective agricultural extension, which aims to make agriculture more productive and cost-efficient. On the concept, agricultural extension is one of the most important factors that can capacitate sugarcane farmers to accelerate the adoption of technology and could be positively correlated with farm productivity.

Farmers' innovations are new ideas, methods, or practices developed by the farmers themselves, often in response to local agricultural challenges. The extension services often aim to disseminate such innovations to wider audiences.

Agricultural extension services are instrumental in bridging the gap between agricultural research and practical farming. It is the catalyst for disseminating knowledge, technology, and best practices. Traditionally, the indicators of success of agricultural extension services are measures through yield increase or adoption of technology.

The group of Abhijeet in 2023 concluded that the effectiveness of agricultural extension services can be assessed through environmental, social, and economic indicators. Integrating those three factors, agriculture will be more sustainable and equitable, which could benefit the soil and the people in the community, most especially the farmers, in striving to be more innovative.

On the production side, the Philippine raw sugar production for 2025 is projected to reach a volume of 1.85 million metric tons (Pelonia, 2024). As of February 2, 2025, the total raw sugar production in the country is 1,922,586 metric tons with a total tonnage of 21,490,581 or an average of 55.334 tons per hectare (SRA, 2025).

Outside the country, it is noteworthy that sugarcane productivity in the Eastern Brazilian Amazon showed a significant increase from 2012-13 to 2021-22 (Cardoso et al, 2024).

Back in the Philippines, the vast plantations are located in Regions 6, 7, and 8, specified as follows: 207,909 hectares for Region 6; 57,663 hectares for Region 7; and 10,200 hectares for Region 8, respectively. The total area of the three regions is 275,772 hectares or 71.01% of the total area of sugarcane plantation in the Philippines (Balita, 2024).

This study aims to determine the contributions of fertilization innovations practiced by sugarcane farmers in increasing production at different locations. Furthermore, this study will also focus on the fertilization innovations practiced by sugarcane farmers in relation to the volume of production.

Objectives

The general objective of the study is to determine the main effect of fertilization innovations practiced by farmers on the production of sugarcane crops in the Philippines.

Specifically, it aims to;

a. Gather data on the production of sugarcane farmers in seven locations;

b. Re-calibrate the effect on the production of sugarcane on the fertilization innovations practiced by farmers, and

c. Correlate sugarcane production with fertilization innovations practiced by farmers.

Theoretical Background

The diffusion innovation theory refers to the process by which an innovation is adopted and gains acceptance (Rogers, 1995)

The innovation decision theory states that “diffusion” is a process that occurs over time and can be seen as having five distinct stages, namely:

a. ***Knowledge*** – This could also be referred also the awareness stage, where a person knows of the existence of an idea, the practice, or technology. However, he lacks adequate information. In technology promotion, the first stage is to inform people and make them aware (the awakening stage)
b. ***Persuasion*** – This could be the stage where a person is attracted to the technology. Such interest will entice him to know more about the technology – What it is? How Much Does it Cost? Where to acquire the needed inputs? How much will the yield be? (realization stage)
c. ***Decision*** – An individual shows marked interest in the technology as it applies to him, his family, or his work. He tends to obtain or ask more information regarding the technology by obtaining detailed information from researchers, technicians, or extension workers, buying the product, assessing its merit, and even inquiring from others who have tried the technology. (inquisitive stage)
d. ***Implementation*** – This could be referred to as the trial stage, where individuals try and experiment on a small scale the new technology after weighing the advantages and risks involved. (experimentation stage)
e. ***Confirmation*** – There is an adoption or use of the technology if the person is convinced of the technology's relative advantage. There is satisfaction on the part of the user. (self-satisfaction stage)

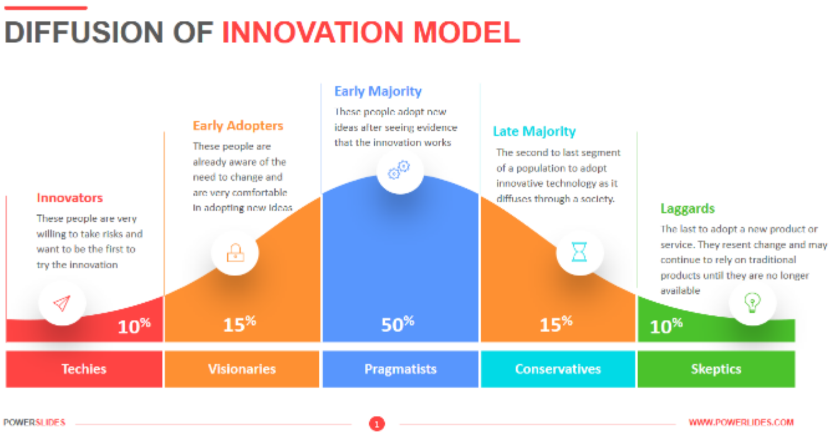

Fig 1. The diffusion innovation theory (Rogers, 1995)

On sugarcane fertilization, diffusion involves two main areas, namely the physical process of nutrient absorption from the soil (Singh, 2021) and diffusion of fertilization practices and innovation (Andrade et al, 2024) among farmers

Methodology

The descriptive correlation method was used in this study. It focuses on the sugarcane farmers' areas, farm profile, and sugarcane production in tonnage in correlation with the fertilization innovations practiced by farmers at the seven locations in the Visayas, Philippines.

Research Environment

Areas planted with sugarcane were chosen as the sampling area. There are seven provinces in the Visayas where the majority of the sugarcane crops are planted to sugarcane. For this study, only six provinces are included, namely: Negros Occidental, Negros Oriental, Capiz, Iloilo, Cebu, and Leyte. As of Crop Year 2021-2022, the total area cultivated with sugarcane for the above-mentioned provinces was 271,622.89 hectares, and produced 15.58 million tons of cane with an average of 57.63 tons per hectare.

Specifically, the study covered the following locations, namely: CEB for Cebu province; LEY for Leyte; ILO for Iloilo; CAP for Capiz; Bayawan for Negros Oriental; San Carlos and Victorias for Negros Occidental. For the seven locations, the total area was 93,354.03 hectares and has produced a total of 5,073,484.90 tons as of Crop Year 2024-2025, with an average tonnage of 54.35 per hectare.

Distribution of the Respondents

The respondents of the study were the sugarcane farmers in the Visayan area, Philippines. Employing *Slovin's* formula, out of 18,539 (Crop Year 2021-2022) sugarcane farmers from the seven locations covered by this study, the sample size of 320 farmers was randomly selected as the actual respondents. The number of respondents was determined by computing the percentages vis-à-vis the total number of sugarcane farmers per location. The percent distribution of the respondents per location is shown in Figure 2.

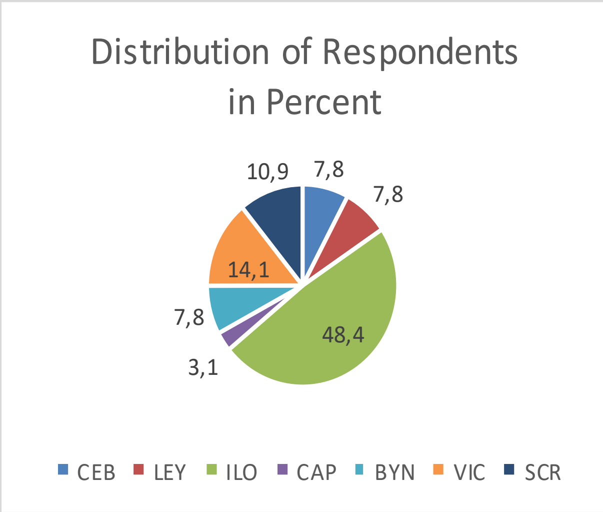

Fig 2. Distribution of respondents at seven locations in the Philippines

Research Instrument

The instrument used to gather data was the validated document used by the group of Oñal (2021) from their previous studies, which focuses on fertilization and fertilizer management of sugarcane crop.

Data Gathering Procedure

Instrument preparation

The researchers had personally prepared the questionnaire/instrument. The instrument had undergone the reliability and validation tests last 2021 already and is being used in all their previous studies, including this one.

Distribution of Instrument and Gathering of Data

The researchers had done the actual orientation on how to fill out the questionnaire with the field enumerators. It personally distributes the instrument to the enumerators. Thereafter, enumerators had commenced the gathering of data.

Retrieval of Instruments

The researchers had personally retrieved the instruments from the enumerators; others were sent through public courier.

Encoding and Statistical Analysis

Upon retrieval of the questionnaire, the researcher had tallied and analyzed the data using the Statistical Package for Social Sciences (SPSS) software under the close supervision and guidance of the statistician. The procedure is presented in Figure 3.

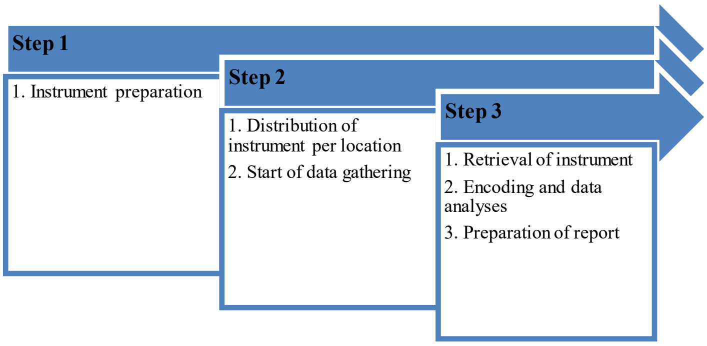

Fig 3. Data gathering procedure

In the analysis of data, the following statistical tools were used in accordance with the nature of the specific objectives.

Frequency and percentage were used to describe the profile of the sugarcane farmers and the farm profile.

Likert's Scale was used in segregating and describing the results.

The mean was used to determine the level of production of sugarcane, as well as the fertilization innovations practiced by the farmers in the Philippines.

One-way Analysis of Variance (ANOVA) was used to determine the difference in the production of sugarcane when respondents were grouped according to location, soil rejuvenation, and post-harvest innovations.

Pearson's r Moment Correlation was utilized to determine the significant relationship between the fertilization innovations practiced by the farmers in the Philippines, and the direct effect on the total volume of sugarcane production.

Results and Discussions

Farmers Profile

Figure 4 revealed the farmers and farm profile at the seven locations in the Visayas in terms of gender, age, level of education, number of years in sugarcane farming, average size of land holdings, and sugarcane production.

The findings reveal that out of 320 farmers involved in the study, there were more males (f=223, 69.7%) than females (f=97, 30.3%).

Furthermore, the findings revealed that the majority of the farmers were elderly or 51 years old and above (f=164, 51.2%), followed by medium age farmers or those between 36-50 years old (f=118, 36.9%), and young farmers or those aged 35 years old and below (f=38, 11.9%), respectively.

As to the educational attainment, the majority of the farmers were at secondary level (f=151, 47.2%), and the least were those who have a vocational attainment (f=12, 3.8%).

The study of Mavaliya et al (2025) on the influence of sugarcane farmers' knowledge on some variables indicates that the age and level of education have no significant impact on the knowledge of farmers.

The findings are related to the work of Gallen (2015), which uses Danish matched employer-employee data. The paper estimates the relative productivity of men and women and finds that the gender "productivity gap" is 8 percent, implying that just under two-thirds of the residual wage gap can be accounted for by productivity differences between men and women.

The productivity gap was measured by estimating the efficiency units lost in a firm-level production function if a worker is female, holding other explanatory covariates such as age, education, experience, occupation, and hours worked constant.

In India, women perform a crucial role in agriculture, either directly or indirectly, starting from producing, processing, and ultimately marketing agricultural produce (Mallick & Anshuman, 2023).

In the Philippines, employment in the agricultural sector by gender in the year 2019 was 28.70% male and 13.60% female.

For the number of years in sugarcane farming, 38.4% have been in sugarcane farming for more than 20 years, while only 26.5% have been doing it for 10 years or less.

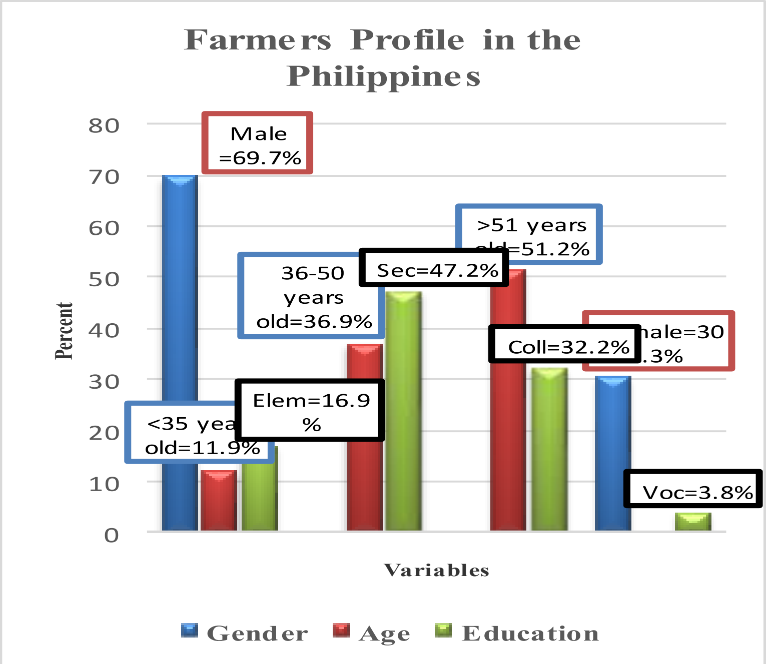

Fig 4. Farmers' profile in the Philippines

Farm Profile

For the size of farm holding, 69.7% of the respondents have an area below 25 hectares, while 6.6% have an area of 51 hectares or more, as indicated in Table 1.

As to the land topography, 65.3% of the area has a soil gradient of 6.24 degrees, while 15.9% have a slope gradient of less than 5 degrees.

Around 53.9% of the area had an average production of less than 49 TC/ha, and 18.8% had an average production of 56 to 64 TC/ha.

Table 1. Farm Profiles at the different locations in the Visayas, Philippines.

Variables	Number of Farmers	Percentage
Average Size of Land Holdings		
51 ha & above	21	6.6
26-50 hectares	76	23.8
25 ha & below	223	69.7
Land Topography		
>25 degrees	60	18.8
6-24 degrees	209	65.3
<5 degrees	51	15.9
Average Production		
>65 TC/ha	88	27.5
50-64 TC/ha	60	18.8
<49 TC/ha	172	53.8
TOTAL	**320**	**100.0**

The fertilization practices of sugarcane farmers in the Visayas, Philippines

The data in Table 2 shows that the mean analysis on the fertilization innovations practice of the sugarcane farmers in the seven locations in the Visayas is “moderately innovative” (M=2.44). This indicates that the practice of innovating the fertilization of sugarcane crops in the seven locations in the Visayas was average.

On the basis for application of fertilizers it is categorized as “moderately innovative (M=2.00), which mean that farmers applied the fertilizers based on the results of soils laboratory done three years ago. The frequency of fertilizer application is rated as “more innovative” (M=2.75), the farmers did the split application of fertilizers (one month after planting for new plant or immediately after stubble shaving for ratoon crop and the last dose before closing the field).. The practice of correct placement of fertilizer materials is rated as “more innovative” (M=2.71). The fertilizers are applied on the furrow slice, or a hole is dug using “tama” or a manual soil digger at a distance of 12 inches away from the base of the plant, and completely covering the fertilizer with soil. On the method of fertilizer application, it is rated as “moderately innovative” (M=2.19), sometimes applied through irrigation or localized placement. The practice of substituting the P with other fertilizing materials is rated as “moderately innovative” (M=2.08); the farmers applied 100% inorganic P fertilizer as required.

On the level of N applied, it is rated as “more innovative” (M=2.75), around 200 kg of N is applied per hectare. As to the level P applied, it is rated as “moderately innovative” (M=2.37); the farmers applied 50 kg P per hectare. The level of K applied is rated as “more innovative” (M=2.74); the farmers applied a total of 400 kg of K per hectare. Lastly, the practice of applying both inorganic and organic forms of fertilizers is rated as “more innovative” (M=2.76), respectively.

The results of the study reveal that fertilization innovations practiced by the farmers in the seven locations in the Visayas, four innovations are classified as “moderately innovative” and five were “more innovative”, respectively.

Adoption is the decision by an individual or community to implement and use a new agricultural practice, technology, or innovation as a result of extension efforts.

The innovation of applying mill waste like mud press and bagasse to sugarcane as organic fertilizers, the group Dotaniya in India (2016) has conducted a study on the utilization of the same. They studied the effect of sugarcane by-products on crop productivity and soil properties. Results show that the application of sugar mill by-products improves soil fertility, physical composition, and biological properties. Specifically, the by-products improve the organic matter of the soil, and they enhance the yield of sugarcane. Their study projected further that if mudpress is recycled around 32,464; 28,077; 14,038; 3,424; 393; 1,030; and 240 tons of N, P, K, Fe, Zn, Mn, and Cu, respectively, can be made available, hence the problem of storing can be partially solved.

Relatively, Adenya (2025) relates in his review work that biomass produced during decomposition undergoes carbon neutrality that can assure rural development while protecting the environment, including sugarcane crops.

The findings correlate with one of the items as mentioned by a book authored by the group of Patro (2024). Innovation is a crucial work for redefining the role and scope of agricultural extension for knowledge dissemination and skills development of a farmer especially on their technology innovation and adoption.

The study of the group of Kosim (2021), on the other hand, shows that farmers who joined the program in agricultural extension increased by 9.05 tons, higher than those who have not availed the services of extension, which provides training on technology adoption and innovations

By category, the study of Dlamini and Worth (2016) reveals that extension is in a good position to address sugarcane production challenges through improved teaching and learning, updated information management, and effective technology adoption, including innovations, among others.

Table 2. Mean result of the fertilization practice of sugarcane farmers in the Visayas, Philippines, as categorized by innovation

Fertilization Practices of Sugarcane Farmers	Means of farmers' practices by innovation category			Total Mean	Description	SD
	Innovative	Semi-innovative	Traditional			
1. Basis for application of fertilizers	2.27	1.96	1.77	2.00	Moderately innovative	0.001
2. Frequency of fertilizer application	2.84	2.74	2.66	2.75	More innovative	0.345
3. Placement of application of fertilizers	2.84	2.65	2.63	2.71	More innovative	0.053
4. Method of fertilizer application	2.68	2.07	1.83	2.19	Moderately innovative	0.375
5. Fertilizers used to substitute for P	2.07	2.13	2.04	2.08	Moderately innovative	0.494
6. Level of N applied	2.91	2.63	2.72	2.75	More innovative	0.480
7. Level of P applied	2.83	2.52	1.77	2.37	Moderately innovative	0.352
8. Level of K applied	2.75	2.74	2.73	2.74	More innovative	0.412
9. Organic-inorganic combo fertilization	2.85	2.74	2.71	2.77	More innovative	0.318
Total Mean	**2.67**	**2.46**	**2.20**	**2.44**	**Moderately innovative**	

Production of sugarcane in the Visayas, Philippines, when grouped according to the category of innovation

Table 3 shows the production in the Visayas, Philippines, using the mean. The results revealed that, in general, the production in the Visayas, Philippines, when grouped into categories of innovations (M= 2.44), was high.

The innovations practiced by farmers were categorized into three, namely: innovative, semi-innovative, and traditional ones. Innovative practice is classified when farmers use 100% of the technologies recommended. Semi-innovative practice, on the other hand, is when the farmer is still trying to adopt the recommended technologies from his usual way of farming. Traditional practice is when farmers do not employ any recommended technology. The classification was done by the group of Oñal last 2021.

The integration of innovations like system diversification, reducing cost, including the increase of processing plant system has ensured an increase in production (Mohanty et al, 2025)

Table 3. Mean result of production in the Visayas, Philippines, when grouped according to the category of innovation

Innovations Category	Innovation Mean	Description
Innovative	2.67	High
Semi-innovative	2.46	High
Traditional	2.20	Medium
Total Mean	**2.44**	**High**

Difference in sugarcane production in the Visayas, Philippines, when grouped by farmers' practice on fertilization

The data in Table 4 presents the difference in sugarcane production in the Visayas, Philippines, when grouped by farmers' fertilization innovations practice using One-way ANOVA. It further revealed that there is a significant difference in sugarcane production in the Visayas, Philippines, when grouped by farmers' fertilization innovations practiced.

This means that sugarcane production in the Visayas, Philippines, when grouped by farmers' fertilization innovation practices, is not comparable. Specifically on the frequency of fertilization, placement of fertilizers, level of N applied, level of K applied, and the combo application of organic-inorganic fertilizers (ɑlpha = 0.01).

The result relates to the study of Oñal and Jinon (2022), which revealed that the different combination levels of NPK significantly affected the sugarcane tonnage and sugar yield in the two locations in Central Philippines. The NPK combinations of 140N and 240K got the highest tonnage and sugar yield.

Still on the application of NPK at different levels, Parajuli and Kumar (2018) found that the application of 100% recommended dose of NPK resulted in significantly higher yield of 64.1 tons per hectare as compared to other treatments. It also produces the highest number of millable stalks and the biggest diameter.

On the role of P in sugarcane farming, Bhatt (2022) revealed on his study done at Punjab, India, that lower production is observed on non-application of P on deficient areas. He further discussed that K is very important for the activation of plant enzymes, regulates turgidity by controlling the stomatal cells' opening, enhances root growth, and improves the solubilization process of N element.

The group of Vajantha (2021) discussed in their study that low yield of sugarcane was due to scarcity of water, low plant population per unit area, and inadequate level of fertilizers applied.

Results of the study of Kumar & Kumar (2025) implied that the majority of the farmers-respondents had a fair adoption of the fertilizer and manure management portion of the data they gathered.

On combining the application of organic and inorganic fertilizers on sugarcane, Sudiarso & Prihandarin (2018) found that a significant difference in height, length, and diameter of stalks was observed on sugarcane applied with the combination of organic bio-fertilizers and inorganic fertilizers.

Table 4. Analysis of Variance of sugarcane production in the Visayas, Philippines, when grouped by farmers' fertilization innovations practice.

Farmers Fertilization Innovations Practice	Innovation Production Mean	F	Sig	Production Description
Frequency of fertilization	2.75	3.864	0.004**	High Production
Placement of fertilizers	2.71	4.346	0.038**	High Production
Level of N applied	2.75	0.824	0.001**	High production
Level of K applied	2.74	8.508	0.001**	High Production
A combo of organic-inorganic fertilization	2.77	7.179	0.001**	High production
Total Mean	**2.74**			**High Production**

***significant at 1% level*

Difference in sugarcane production in the Visayas, Philippines, when grouped by location

The data in Figure 5 presents the difference in sugarcane production in the Visayas, Philippines, when grouped by location using the One-way ANOVA. It further revealed that there is a significant difference in sugarcane production in the Visayas, Philippines, when grouped by location (F=2.816, alpha =0.05). This means that sugarcane production in the Visayas, Philippines, when grouped by location, is not comparable.

The results relate to the findings of the study by Oñal et al (2022) found that there is a significant difference in the level of productivity of sugarcane farms, also when grouped as to location (alpha =0.05)

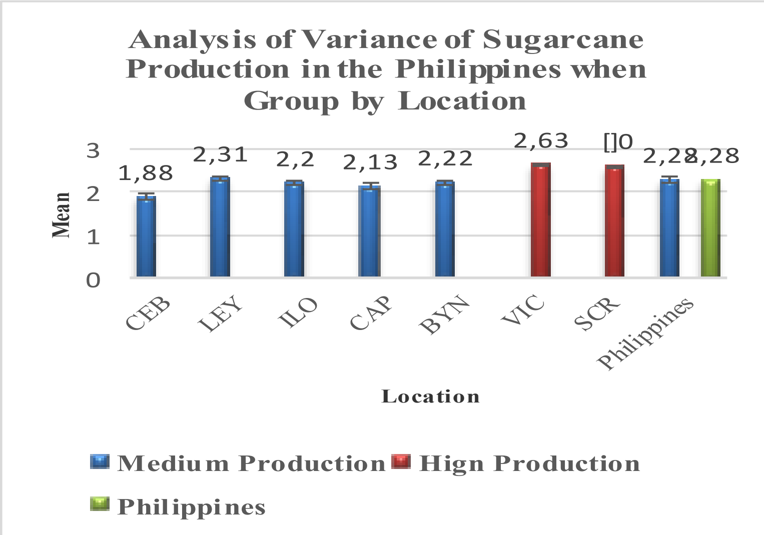

Fig 5. ANOVA of sugarcane production in the Philippines when grouped by location

Relationship between fertilization innovations practice by sugarcane farmers and volume of production

The data in Table 5 showed the relationship between the farmer's fertilization innovation practice and volume of production in the seven locations of Visayas using Pearson's r. It could be deduced from the data that there was a significant relationship between five fertilization innovations practiced by farmers and the volume of production. Hence, five out of nine fertilization innovations practiced in the Visayas affect the volume of production (αlpha = 0.01). Notably there's a strong relationship between the production and frequency of fertilizer application (*r*-value = 0.846) and combo application of organic-inorganic fertilizers (*r*-value = 0.813). A moderate relationship was implied between the production and level of N (*r*-value = 0.336) and K (*r*-value = 0.472) applied. While a weak relationship is figured out between production and the frequency of fertilizer application (*r*-value = 0.197), respectively.

On fertilization, the group of Vajantha (2021) revealed that a significant uptake of N by the sugarcane crop was recorded in all stages. Furthermore, the application of a 125% rate dosage of N had the highest mean yield. They further discussed that for every 100 tons of cane produced per hectare, the sugarcane removes around 207 kg of N, 30 kg of P, and 233 Kg of K from the soil, respectively.

Relatively, Vaghela et al (2020) found that a higher yield of 119.50 TC/ha was produced from sugarcane applied with 312.5 kg/ha of N planted at a distance of 2 meters-furrow.

About the findings of the study, activating the agricultural extension services system is of great importance. Jaiswal (2014) commented that there are enough viable and modern technologies for innovations that have been developed already, but many of these have not reached to farmer level because of poor delivery of extension services. Moreover, farmers are not aware of the technology available, hence they cannot properly adapt and innovate farming undertakings.

The inefficient delivery of agricultural extension services limits the use of modern technology as well as farm innovations. The lack of technical know-how, plus the limited financial resources, were most of the problems for the farmers in adopting sustainable-modern agricultural practices.

Table 5. Correlation analysis between the fertilization innovations practice by the farmers and the volume of sugarcane production

Fertilization innovation	Pearson r	Sig	Strength of Relationship
Frequency of fertilization	0.197	0.001**	Weak relationship
Placement of fertilizers	0.846	0.038**	Strong relationship
Level of N applied	0.336	0.001**	Moderate relationship
Level of K applied	0.472	0.001**	Moderate relationship
A combo of organic-inorganic fertilization	0.813	0.001**	Strong relationship

***significance of 1% level of probability*

Conclusion

This study aims to determine the contributions of fertilization innovations practiced by sugarcane farmers at the seven locations in the Visayas, Philippines, and their relationship to sugarcane production in terms of tons per hectare.

There were 320 respondents involved in the study, which covers six provinces within the four regions of the Philippines. The majority of the respondents were male, 51 years old and above, with secondary education, have been in sugarcane farming for more than 20 years, and are tilling an average area of 25 hectares and below.

In general, the results revealed that sugarcane farmers were moderately innovative in terms of their practice of fertilization. Specifically, there are five practices classified as more innovative and only four were moderately innovative.

The study indicates that on per location it realized a medium production of 50-64 TC/ha especially in five locations while two locations have a high production more than 65 TC/ha.

In terms of fertilization innovations the correct placement of fertilizers and the combo application of organic-inorganic fertilizers have a strong relationship with production, while moderate relationship on the level or volume of N and K applied.

Presently, the present status of the sugar industry in the Philippines, specifically in the area of the Visayas, has a medium production of 50-64 TC/ha.

In view of the results that the majority of the fertilization innovations practiced by sugarcane farmers have a strong to moderate relationship with production, it is a must to strengthen the agricultural extension to maintain the same. The government and the academe should unify their effort in conducting more research and development undertakings to further improve productivity.

Conflict of Interest

No other group is involved in this study. No monetary contribution is given to this study.

Ethical Considerations and Data Privacy

The researcher takes responsibility for securing the sanctity and confidentiality of all information/data generated through this instrument. Data will be used for academic/research and in designing programs/projects for the industry.

The respondents agreed to publish all generated data.

Acknowledgement

Our sincere gratitude to the sugarcane farmers and the technical enumerator who were involved during the data gathering and processing of the same.

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