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Nutrient Requirement of Corn (Zea maize) for Silage Production

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RESEARCH ARTICLE INFORMATION	ABSTRACT

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With the unprecedented increase in the price of fertilizer and the lack of adequate information on the quantity and timing of its application, farmers' income and productivity were affected. With this, the recommended fertilizer rate for corn silage production to increase productivity while reducing costs should be established. This study aimed to verify and establish the recommended fertilizer rate in corn silage production, which can guide farmers' strategies for reducing the cost of production when producing corn silage. The study was laid out in two factorial experiments arranged in a split plot in Randomized Complete Block Design with four levels of fertilizer recommended rate (T1 80%, T2 70%, T3 60%, and T4 50%) as the main plot treatments. The treatments used were based on the soil analysis results of the area, and two varieties (NSIC 2018 GmCn48 and IES GLUT #7) were established as subplots in 5,000 m2 area. Plant height, number of leaves, and length of leaves were collected during the growth stage; herbage yield was collected during harvesting at 75 DAPS; and biomass yield was collected after 21 days of fermentation. A kilogram of samples from each treatment was collected and subjected to proximate analysis. As a result of the study's importance, all of the parameters were analyzed using the Randomized Complete Block Design, and all the growth parameters were found to be non-significant. Meanwhile, 60% is the recommended fertilizer rate for corn silage to produce the optimal yield of open-pollinated variety (OPV) and hybrid corn for silage production.

Keywords: *corn production, fertilizer rate, nutrient requirement, silage, fermentation, ruminants*

Introduction

Among the provinces in the Cagayan Valley, Isabela shared the highest number of farms with 129.7 thousand, covering 240.6 thousand hectares of agricultural land. The total farms in the province accounted for 40.3 percent of the total farms in the region. Areas under agricultural land comprised 22.6 percent of the total land area of the province. Its agricultural land was the largest in the region; 44.5 percent of the total agricultural land area in the region was contributed by this province. This province is the rice and corn granary of Luzon due to its plain and rolling terrain. The livestock industry is the world's largest user of land resources, with grazing land and cropland dedicated to the production of feed representing almost 80 percent of all agricultural land (Hertel et al., 2008).

Furthermore, based on the report of the Fertilizer and Pesticide Authority (FPA) for 2021-2022, five out of the six major fertilizer grades exhibited increasing price levels based on their records. Urea maintained the highest price at PHP 2,544.08 per bag in 2021. It registered an increment of 105.91 percent, an improvement from the previous year's downtrend. Similarly, Urea recovered from the 2021 price drop, and in 2022, it was quoted higher at PHP 2,407.91 per bag. This was a price gain of 94.65 percent. Meanwhile, the 2022 retail prices of Ammonium Phosphate and Muriate of Potash at PHP 2,119.01 and PHP 2,111.25 per bag grew by 72.86 percent and 75.19 percent, respectively. Ammosul, which was priced the lowest at PHP 1,164.40 per bag, increased by 83.96 percent in 2021. Complete fertilizer continued its price increment in 2022 at 76.89 percent; it was priced at PHP 2,293.38 per bag. Additionally, in 2022, the supply of fertilizers, composed of production totaling 2.82 million metric tons, registered an annual increase of 3.67 percent compared with the previous years. The share of production in the total fertilizer supply increased to 18.37 percent from only 1.83 percent in the total fertilizer supply.

Moreover, according to Philippine Statistics Authority (2019), Isabela has a total livestock inventory of 42.3 percent, which is 0.71 percent lower than the previous year's output. Among the five provinces of the region, Cagayan had the biggest share of livestock production, contributing more than 49 percent, followed by Isabela (26.9%). Furthermore, the production of livestock was decreasing, and one of the problems was feed insufficiency for livestock production.

Consequently, to address this aspect of livestock production, fermentation of corn silage and forages was developed to sustain the shortage of non-commercial feeds, especially during the summer season, and to provide feed for animals that is excellent in nutritional profile and can be grown at a cost-effective price. Likewise, according to Alma et al. (2017), feeding corn silage improved nutrition, increased livestock growth rates, and increased quality milk production.

Farm waste from the cultivation of corn is now being processed as the main ingredient for the production of feed formulations for livestock, which is now termed as corn silage. This effectively helps in eliminating environmental problems caused by the burning of corn waste. Corn silage is forage for ruminant animals because it is high in energy, digestible, and a good source of protein. The production of corn silage has also proven its potential in the market for its nutrient content; it is not season-dependent as it can be done any time when there is forage abundance. Likewise, it does not require sophisticated equipment; the shelf-life and quality remain stable under longer storage times. Also, it can be prepared easily on a small or commercial scale (www.mariekrisse.com).

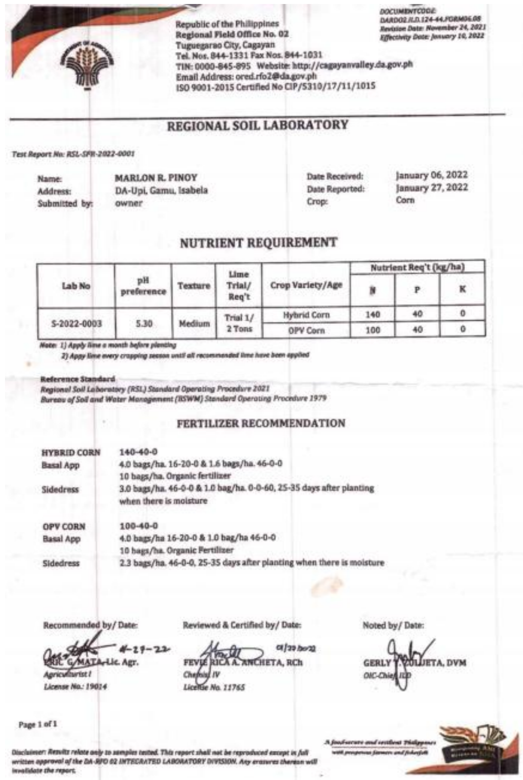
However, factors that greatly influence farmers in the production of corn silage are the cost of farming services and inputs and additional knowledge on the quantity and time of application of fertilizers. With this, assessing the recommended fertilizer grade concerning the factors influencing crop performance and production can guide farmers and the government in reducing the actual cost of production for corn silage. Thus, this research generally aimed to verify four standard fertilizer guidelines for corn silage production. It specifically intended to verify and assess the effect of different fertilizer rates (80% RR, 70% RR, 60% RR, and 50% RR) on the herbage yield and biomass yield of corn silage production, assess the difference in herbage and biomass yield (MT) of OPV and hybrid corn varieties for corn silage, and assess the cost and benefit of different fertilizer recommended rates for corn silage production.

Methods

Establishment and Maintenance of Production Area

1. *Site Selection.* The production area was established last February 01, 2023, at Department of Agriculture-Isabela Experiment Station, Upi, Gamu, Isabela.

2. *Collection of Soil Samples.* Before crop establishment, soil samples were randomly collected from the experimental area using a shovel. These samples were spread out on a paper to air dry. A one-kilogram portion of the soil was then thoroughly pulverized and cleaned to remove any foreign materials. This prepared soil sample was submitted to the Cagayan Valley Integrated Agricultural Laboratory (CVIAL) at the Carig Regional Center in Tuguegarao City, Cagayan, for analysis. The soil's NPK content and pH levels served as the basis for the study's fertilizer recommendations.



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REGIONAL SOIL LABORATORY

Test Report No: RSL-SFR-2022-0001

Name: MARLON R. PINOY
Address: DA-Upi, Gamu, Isabela
Submitted by: owner

Date Received: January 06, 2022
Date Reported: January 27, 2022
Crop: Corn

NUTRIENT REQUIREMENT

Lab No	pH preference	Texture	Lime Trial/ Req't	Crop Variety/Age	Nutrient Req't (kg/ha)		
					N	P	K
S-2022-0003	5.30	Medium	Trial 1/ 2 Tons	Hybrid Corn	140	40	0
				OPV Corn	100	40	0

Note: 1) Apply lime a month before planting
2) Appy lime every cropping season until all recommended lime have been applied

Reference Standard
Regional Soil Laboratory (RSL) Standard Operating Procedure 2021
Bureau of Soil and Water Management (BSWM) Standard Operating Procedure 1979

FERTILIZER RECOMMENDATION

HYBRID CORN 140-40-0
Basal App 4.0 bags/ha. 16-20-0 & 1.6 bags/ha. 46-0-0
10 bags/ha. Organic fertilizer
Sidedress 3.0 bags/ha. 46-0-0 & 1.0 bag/ha. 0-0-60, 25-35 days after planting when there is moisture

OPV CORN 100-40-0
Basal App 4.0 bags/ha 16-20-0 & 1.0 bag/ha 46-0-0
10 bags/ha. Organic Fertilizer
Sidedress 2.3 bags/ha. 46-0-0, 25-35 days after planting when there is moisture

Recommended by/ Date: 4-29-22
G. MATA, Lic. Agr.
Agriculturist I
License No.: 19014

Reviewed & Certified by/ Date:
FEVIE RICA A. ANCHETA, RCh
Chemist IV
License No. 11765

Noted by/ Date:
GERLY T. ZULUETA, DVM
OIC-Chief, ILD

Page 1 of 1

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Figure 1. *Soil Analysis Result*

3. *Land Preparation.* Two plowing operations were done with the use of a tractor. Harrowing was done before planting to level the field and reduce the size of soil clods, and furrowing was done during crop establishment.

4. *Crop Establishment*
   a. *Furrowing and Application of Fertilizers.* Furrows were constructed at a distance of 75 cm before planting using an animal-drawn plow. The soil analysis result was the fertilizer reference for the study. The first application of fertilizer was done during planting for basal and side dressing and before hilling up 25 days after planting.

   b. *Planting.* A planting guide per treatment was provided to ensure a complete population per unit area. One seed was planted per hill at a 25-cm distance between hills. The seeds were covered with fine soil and foot-pressed to have uniform germination.

   c. *Establishment of Production Layout.* In a 5000 sq. meter production area with 100 meters length by 50 meters width, 16 plots with an area of 16 meters by 12.06 meters were established in an experimental layout of a 1 meter by 0.50-meter factorial experiment arranged in a split plot in three replications.

d. *Field Experimental Layout*
Main plot Treatments:
F_1 – 80% Recommended Rate of Inorganic Fertilizer (RR) based on Soil Analysis
F_2 – 70% Recommended Rate of Inorganic Fertilizer (RR) based on Soil Analysis
F_3 – 60% Recommended Rate of Inorganic Fertilizer (RR) based on Soil Analysis
F_4 – 50% Recommended Rate of Inorganic Fertilizer (RR) based on Soil Analysis
Subplot Treatments:
V1 –Hybrid (GM Cn48)
V2 – Open Pollinated Variety (IES GLUT #7)

F4V2	F3V1	F1V2	F2V2
F4V1	F3V2	F1V1	F2V1
F1V2	F2V1	F4V2	F3V1
F1V1	F2V2	F4V1	F3V2

5. *Crop Care and Maintenance*
   a. *Application of Herbicides.* Isopropyl amine salt glyphosate chemical herbicide was applied for the hybrid corn variety 20 days after planting and before the maturity date to control weeds.

   b. *Manual Weeding.* Manual weeding was done 22 days after planting for the OPV corn variety to control weeds.

   c. *Application of Insecticides.* Cypermethrin chemical insecticides for both varieties were done 15 and 30 days after planting to control insect pests and diseases.

   d. *Application of Inorganic Fertilizer.* Inorganic fertilizers such as 16-20-0, 46-0-0, and 0-0-60 were generally applied 25 days after planting in accordance with various treatments recommended rate (RR).

   e. *Hilling Up.* Hilling up was done 30 days after planting for the OPV corn variety after side-dressing the fertilizer amount percentage recommended to be used in the study.

6. *Data Gathering.* The yield area of 136.59 m^2 has a total of 10 plants in the middle of every subplot. Growth component parameter values were measured or obtained from ten randomly selected plants per treatment. The following data on growth parameters were gathered to assess the effect of different fertilizer rates (80% RR, 70% RR, 60% RR, 50% RR) on the herbage and biomass yield for corn silage production and were subjected to statistical analysis:
   a. *Plant Height.* Plant height was measured from the base of the plant (where the stem emerges from the soil) to the tip of the tallest leaf or the top of the plant. For consistent measurements, a measuring tape or ruler will be

used to measure the height at each growth stage, ensuring that the same point of the plant is used as the reference for each measurement. This should be done at the same time of day to minimize variations due to environmental conditions.

b. *Number of Leaves*. The length of leaves was measured from the base of the leaf blade (where it connects to the stem) to the tip of the leaf. The longest leaf on each plant will be selected and measured using a ruler or measuring tape. For consistency, measurements should be taken on fully expanded leaves, and the same leaf from each plant will be measured throughout the growing season to avoid variations due to leaf age.

c. *Length of Leaves*. The number of leaves was counted starting from the first leaf (V1) to the last fully developed leaf on the plant. This includes counting all leaves visible on the stem at the time of measurement. It is important to note that the count should be done on the main stem, excluding any secondary branches or leaves from tillers, as these are not representative of the plant's main growth.

Establishment and Maintenance of Production Area

1. *Crop Establishment*

a. *Harvesting.* Harvesting was done at the soft dough stage (75 days DAP) based on the Bureau of Agriculture and Fisheries Standards (DA-BAFS), which is the recommended harvesting day in the study. Upon harvesting, the harvested sample plants were labeled to avoid the intermixing of samples. The harvested corn stalk from the production area was brought to the silo for chopping.

b. *Silage Processing.* The chopping of corn stalks was done with the use of a forage chopper. After processing, the collection of herbage yield from the samples was done. Only the whole corn plant was used exclusively for silage production. Each treatment was placed in a plastic bag, and the bag was properly labeled to avoid intermixing of samples.

c. *Storage of Silage in Silo.* A chopped corn stalk was placed in a plastic bag and covered to prevent trapping of air and maintain strict anaerobic conditions. After 21 days of fermentation, the biomass yield from each treatment sample was collected and recorded for data analysis.

2. Data Gathering. The following parameters were gathered to assess the difference in herbage and biomass yield (MT) of OPV and hybrid corn varieties for corn silage and were subjected to statistical analysis:

a. *Herbage Yield* (before ensiling)

b. *Biomass Yield (*after 21 days ensiled). The data for both the growth stage and the ensiling stage was analyzed using ANOVA.

c. *Return on Investment (ROI).* It was gathered to assess the cost and benefit of different fertilizer recommended rates for corn silage. The ROI was computed using a simple economic analysis. The cost of production was based on the prevailing price of farm inputs and labor in the community. The gross income was determined based on the prevailing price of corn silage per kilo in the market. The net income is equal to the gross income minus the cost of production, and the return on investment was computed by dividing the net income by the cost of production multiplied by 100.

B. *Statistical Analysis.* All the collected data was collated and summarized in data form. All data totals and means were computed and subsequently analyzed using the Analysis of Variance (ANOVA) of Split-Plot Design. The Statistical Tool for Agricultural Research (STAR) statistics software was also used for data analysis. The mean differences between treatments were analyzed using the Randomized Complete Block Design (RCBD).

Ethical Considerations

1. *Development and Use of Industrial Synthetic Chemicals. The* researchers were careful in considering the often adverse environmental and social effects of pesticides, coupled with their overall economic benefits.
2. *Public Health.* The researchers considered the toxicity of most modem pesticides used in the study to avoid increasing the potential hazards that lead to poisoning for plant growth and human health.
3. *Environmental Impact.* One of the primary ethical concerns associated with synthetic fertilizers is their potential negative impact on the environment. The researchers considered the negative impact of using fertilizers that often contain high levels of nitrogen, phosphorus, and potassium, which can leach into water bodies and cause pollution.
4. *Health Risks.* Ethical consideration is the potential health risks associated with the use of synthetic fertilizers. The researchers considered the effects of using fertilizers that may contain harmful chemicals, such as heavy metals and pesticides, which can contaminate crops and pose risks to human health.
5. *Responsibility for Openness and Sharing of Data and Material.* The researchers are responsible for ensuring that there is transparency about research findings and in facilitating the sharing of data and material from the experiments.

Results and Discussion

Verification and Assessment of the Effect of Different Fertilizer Rates on the Herbage and Biomass Yield of Corn Silage Production

The statistical analysis of the growth parameters across different fertilizer rates compared the effects of various treatments on plant height, number of leaves, and leaf length in two corn varieties. The results indicated no significant differences among the four treatments for any of the parameters measured.

Conforming to the study result by Bakhtiari (2014), the effects of fertilizer application rates on corn plant height, number of leaves, and leaf length were not significant. The results showed that the effects of fertilization methods on plant height, number of leaves, and length of leaves at 1% and 5% probability levels were not significant. In addition, the effect of fertilizer application rate on plant height, number of leaves, and length of leaves was not significant but was highly significant on the kernel mass. In this study, fertilizer banding on one side of the seedling with 60% nitrogen per hectare applied 10 cm from the seedling at a 5 cm soil depth was selected as the most suitable treatment.

Assessment of the Difference in Herbage Yield and Biomass Yield of OPV and Hybrid Corn Varieties for Corn Silage

The statistical analysis of herbage yields for the two corn varieties under different fertilizer rate treatments showed no significant differences among the treatments. This indicates that any of the applied treatments produced similar herbage yields. Notably, even the lowest fertilizer rate recommended for corn silage achieved the optimum yield.

Consistent with the findings of Cornell University (2010), the study states that corn also requires potassium for sustainably high yields. Since only 20% of the absorbed potassium is stored in the kernels and removed during harvesting, it may not be necessary to offer additional potassium to the crops. In a study by Pau et al. (2023), the research findings support the conclusion that fertilization management has no significant influence on the herbage productivity of corn as influenced by integrated nutrient fertilization. The results of this experiment suggest that optimal nutrient management might be vital for boosting corn yield (both green forage and grain). A higher herbage yield from corn could be obtained by applying the recommended rates of fertilizer during the different growth stages. However, the high herbage yield of forage corn should be supplemented with 60-75% of the recommended amount of fertilizer from the vegetative (seedling stage) to the growth stage (silking stage).

Additionally, according to Cornell University (2010), since only phosphorus is absolutely necessary during the first or vegetative stages of root development, corn producers usually integrate the entire phosphate and some small amounts of nitrogen and potassium as basal fertilization. Applying large amounts of K or N at this stage may result in momentous problems. The amount of nitrogen in the soil should be sufficient for the first stages of corn development. However, corn harvested as a whole plant (silage harvest) would need to apply 60% additional amounts of Nitrogen fertilizer.

The statistical analysis of biomass yield (kg) for different fertilizer rates was used to assess the effects of various treatments on the biomass production of two corn varieties. The results showed no significant differences among the treatments. Consistent with the findings of Hlisnikovsk et al. (2018), increasing doses of applied fertilizer was not connected with higher biomass yield production. The effectiveness of applied fertilizer was higher on soils of the worst quality (sandy loamy, Cambisol, Lukavec), while lower on naturally fertile loamy degraded Chernozem (Ivanovice). This shows the valuable effect of the application of fertilizers. Although the application of excess fertilizers during the growth stages of corn did not affect the increase of corn biomass yield, they had positively affected soil chemical properties.

Additionally, a study conducted by Amanullah et al. (2018) stated that a good corn crop will require commercial (inorganic) fertilizers of 50-60% of phosphate and 60-70% of potash per hectare during growth stages applied to improve their growth and yield since both phosphorus (P) and potassium (K) are required for good corn growth and yields.

Assessment of the Cost and Benefit of Different Fertilizer Recommended Rates for Corn Silage

Tables 1 and 2 show the cost and benefit analysis of different fertilizer recommended rates using V1 hybrid and V2 OPV corn variety in 1 hectare**.** It reveals that Treatment 4 (50% RR) had the lowest production cost of PHP 101,790.00, resulting in a net income of PHP 59, 875.00, and achieved the second-best ROI of 58.82% among the treatments. For the OPV corn variety, on the other side, the same Treatment 4 (50% RR) had the lowest total cost of production with a total of PHP 111,665.00, resulting in a net income of P 24,685.00, and had the second-best ROI among the treatments with a total of 28.38%. Meanwhile, Treatment 3 (60%) attained both highest net income and ROI for the hybrid variety 59.30% and 35.36% for the OPV corn variety.

In a study conducted by Pau et al. (2023), the economic analysis revealed that by growing corn as a dual-purpose (baby corn and green fodder) crop and keeping the crop for 20 more days than a sole green fodder crop, farmers can get a much higher gross income. Since growing corn as a dual-purpose crop is a relatively new practice, more research should be conducted to determine the proper agronomic management practices. The low productivity of corn is attributed to many factors, like the decline of soil fertility, poor agronomic practices, limited use of input, insufficient technology generation, poor seed quality, disease, insects, pests, and weeds. Among the limiting nutrients, nitrogen fertilizer was the most limiting factor in the study.

Additionally, a study conducted in Isabela State University in 2022 claimed that the maximum yield possible is dictated by the genetic potential of the plant and that other growth factors such as sunlight, moisture, etc., are at optimum. If plants are supplied with adequate amounts of all nutrients except one, the growth is proportional to the amount of this limiting element that is added to the soil. Plant growth increases as more of the elements are added, but growth is not directly proportional to the amount of the growth factor added. The total increase in growth became less as increments of the growth factor increased. The principle involved in Mitscherlich's equation is called the Law of Diminishing Return since the increase in yield with each successive addition of the limiting nutrient is progressively smaller. Maintenance of a nutrient in the soil at a level too high above a certain limit is not economical because no appreciable further increase in yield is obtained. This limit corresponds to the yield level of about 99% of the maximum possible yield and is termed the critical level of critical concentration of the nutrient. The value varies with the type of nutrient, crop, types of soil, and other factors.

Table 1. Cost and Benefit Analysis of Different Fertilizer Recommended Rates Using V1 (Hybrid) Variety in One Hectare

Particulars	Volume (Kg)	Gross Income (P)	Price (P/unit)	Product-ion Cost (P)	Net Income (P)	ROI (%)	Cost to Produce 1 Kg
RR (80%)	29,333	5	146,665	106,683	39,902	37.48	3.64
RR (70%)	29,333	5	146,665	101,874	44,791	43.97	3.47
RR (60%)	33,333	5	166,665	104.621	62,044	59.30	3.14
RR (50%)	32,333	5	161,665	101.790	59,875	58.82	3.15

Table 2. Cost and Benefit Analysis of Different Fertilizer Recommended Rates Using V2 (OPV) Variety in One Hectare

Particulars	Volume (Kg)	Gross Income (P)	Price (P/unit)	Product -ion Cost (P)	Net Income (P)	ROI (%)	Cost to Produce 1 Kg
RR (80%)	18,333	5	91,665	97,462	-5.797	-5.95	5.32
RR (70%)	15,667	5	78,335	103,998	-25,663	-24.68	6.64
RR (60%)	24,333	5	121,665	89.880	31,785	35.36	2.69
RR (50%)	22,333	5	111,665	86.980	24,685	28.38	3.89

Conclusion and Future Works

Based on the findings, this study has the following conclusions:

1. The study revealed no significant differences among the growth parameters (plant height, length of leaves, and number of leaves) of different fertilizer rates collected based on the statistical analysis results. However, utilizing 60% of the recommended fertilizer rate lessens the cost of OPV and hybrid production inputs.
2. Each variety received the same herbage and biomass production from any of the treatments. As an outcome, 60% of the required fertilizer rate for corn silage was attained in the ideal OPV and hybrid silage yield.
3. In terms of return on investment of both OPV and hybrid corn varieties, the 60% recommended fertilizer rate produced the highest return on investment for corn silage production. However, in terms of seed cost, OPV corn was more affordable than hybrid corn, making OPV corn more cost-effective and capable of generating higher income compared to hybrid corn.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.