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Productivity of open-pollinated white corn (*Zea mays* L.) applied with calcitic lime and zinc

Pabellon, J. M. L.[1*], Gonzaga, N. R.[1], Silverio, B. G. S.[2], Gonzaga A. B. Jr.[1,2], Vergara, J. R. M.[3] and Tuaño, A. P. P.[4]

[1]College of Agriculture, University of Science and Technology of Southern Philippines – Claveria, Misamis Oriental, Philippines; [2]Center for High Value Crops, Research Office, University of Science and Technology of Southern Philippines – Claveria, Misamis Oriental, Philippines; [3]Agricultural Systems Institute, College of Agriculture, University of the Philippines Los Baños; [4]Institute of Chemistry, College of Arts and Sciences, University of the Philippines Los Baños.

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Abstract For agricultural areas where white corn production becomes limited due to an acid soil, establishing a proper nutrient management protocol holds significance to improve maize performance while enhancing its nutritional value. Results revealed that enhanced fertilization which significantly affected the yield performance of OPV white corn in Claveria, Misamis Oriental. The study concluded that applying full RR NPK at 180-90-60 rate + calcitic lime at 70 kg ha^{-1} + Zn at 5 kg ha^{-1} (T5) provided the highest harvest index at 0.32 and subsequently attained higher yield performance of the crop at 5.94 t ha^{-1}. However, the use of half RR NPK with Zn at 5 kg ha^{-1} (T7) accounted higher return by 66.83% per peso from investment as it would be recommended.

Keywords: Acid soil, Calcitic lime, Enhanced fertilization, Food security, Nutritional value, OPV white corn, Productivity, Zinc

Introduction

Maize (*Zea mays* L.) is the Filipinos' second most important cereal crop, next to rice. The crop of its white variety is usually cultivated in rural areas, grown with minimal or no inputs, and primarily consumed as a staple. It is commonly referred to as "poor man's rice" and replaces rice in times of hardship, especially for low-income families. As a staple food, it provides a potential source of human nutrition and health advantage such as avoiding and coping with serious illnesses like diabetes due to its low glycemic index. Hence, white corn is also consumed by health-conscious people. In a tropical country like the Philippines, where production potential is high, local farmers grow more

[*] **Corresponding Author:** Pabellon, J. M. L.; **Email:** judymae.pabellon@ustp.edu.ph

valuable crops, including corn. It has been reported that about 14 million Filipinos prefer white corn as their main staple, mostly families from the islands of Visayas and Mindanao (DA, 2022). Maize is grown under a wide range of environmental conditions. The crop is also utilized as feed for poultry and livestock and processed into high-value products when production exceeds the consumption requirement of every household.

Until recently, traditional maize farmers in the country cultivated white corn on their small farms. Aiming to save money from expensive seeds in the market, Filipino corn growers preferred using open-pollinated white corn varieties (OPV). Seeds from the most desirable ears of the recent harvest are used for subsequent cropping instead of buying pricey commercial seeds. Farmers also prefer OPV to naturally breed existing varieties and produce corn traits with better performance and adaptation to the environment. Claveria, as one of the food baskets in Mindanao and a landlocked municipality of Misamis Oriental, is known as a significant producer of corn in the province. The town has an estimated elevation of 350-950m above sea level, which makes it known for its cooler temperature and adequate rainfall distribution favorable for cultivating valuable commodities (Gonzaga, 2018).

Accordingly, cereal-based foods with low levels of nutrients in the diet are a significant factor in the widespread occurrence of nutrient deficiency in consumers such as humans and animals (Hossain *et al*., 2008). Addressing the challenge of food security and nutritional balance for man and animals, producing healthy and nutritious white corn is significant for local farmers and food nutritionists. Recently, the Institute of Plant Breeding (IPB) of the University of the Philippines Los Baños (UPLB) developed and introduced a white corn variety called IPB Var 6 that is designed for human consumption when processed into grits (Anuada, 2022). The designed variety was reported for its higher protein content involving essential amino acids like lysine and tryptophan and high yielding performance than the other corn (UPLB, 2018).

However, producing greater white corn yield with higher nutrient levels becomes limited due to the acidic, old soils where the town belongs. Research has revealed that acid soils are deficient in macronutrients which Ca is included and micronutrients like Zn. As a secondary staple crop of the region (Calalang *et al.,* 2015), producing corn requires proper soil nutrient management, especially in acid soils like Jasaan clay. Thus, the initiative of establishing a proper soil management standard for white corn production in Claveria, Misamis Oriental through enhanced fertilization involving Ca and micronutrient Zn is perceived to improve the productivity performance of OPV white corn of IPB Var 6 variety and significantly enhance its nutritional quality for human consumption. Thus, the study was conducted.

Materials and methods

Location of the study

The study was conducted at the experimental field of the Research Unit of the University of Science and Technology of Southern Philippines (USTP), Claveria, Misamis Oriental, from October 2022 to February 2023 (dry season) with soil characterized as acid upland soil derived from pyroclastic materials from the mountains of Mat-i, Balatukan, and Sumagaya that are deep and well drained with soil pH level ranging from 5.5 to 6.5 (Sabijon and Sudaria, 2018).

Experimental design and treatments

The experiment was laid out in Randomized Complete Block Design (RCBD) with 11 treatments and three (3) replications. A total of 33 plots were prepared for the study. Each plot has a dimension of 4.5m x 5m (22.5 m2). An alleyway was allocated at 1m distance between treatments and 0.5m between replications. The space gave convenience in all field activities such as applying fertilizer, data gathering, labeling of plots, weeding, harvesting and other activities related to the study. Fertilizer inputs purchased was based on the identified treatments and soil nutrient combinations as follows: T0 – Control; T1 – Full RR; T2 – RR + L1 Calcitic Lime; T3 – RR + L2 Calcitic Lime; T4 – RR + L1 Calcitic Lime + Zn1; T5 – RR + L2 Calcitic Lime + Zn2; T6 – ½ RR; T7 – ½ RR + Zn1; and T8 – ½ RR + Zn2.

The study used the recommended fertilizer rate that was determined through initial soil chemical analysis done at the Analytical Services Laboratory (ASL), ASI, of UPLB. The crops were tested in different fertilizer combinations of identified soil enhancers where the recommended inorganic fertilizer rate (RR) used is 180-90-60 kg of NPK per hectare, 70 kg ha-1 for calcitic lime, and 5 kg ha-1 for Zn. Urea (45-0-0), Solophos (0-18-0) and Muriate of Potash (0-0-60) are the synthetic NPK fertilizers that were used in the study. Nutrient combinations were prepared based on treatments using a weighing scale.

Data gathering

Ear Weight (g) was gathered by weighing the average of sixteen (16) representative samples in the same treatment. Sample was harvested at the center of the microplot measuring 120 cm by 200 cm consisting 16 sample plants.

Ear Diameter (mm) was gathered by measuring the average ear diameter of 16 representative samples in the same treatment using a vernier caliper.

Sample was harvested at the center of the microplot measuring 120 cm by 200 cm consisting 16 sample plants.

Ear Length (cm) was gathered by measuring the length of the ear from tip of the base in the ear up to the top of the ear of the 16 representative samples in the same treatment. Sample was harvested at the center of the microplot measuring 120 cm by 200 cm consisting 16 sample plants.

The number of kernels per ear was determined by counting the number of kernels per ear of sixteen samples in every treatment per replication. The average number of kernels per ear for each treatment per replication was obtained by adding all the numbers divided by sixteen.

Two (2) sample plants at harvest were collected, cut and weighed. Harvest index was computed using the formula:

$$\text{Harvest index} = \frac{\text{Economic Yield}}{\text{Biological Yield}}$$

Weight of Kernels per Ear (g) was taken from sixteen representative ear samples in every treatment per replication. Weight of kernels per ear was measured using a digital weighing scale at harvest.

Weight of 1000 Seeds (g) was taken from 1000 seeds in every treatment per replication. Weight of 1000 seeds was measured using a digital weighing scale at harvest.

Grain Yield was taken by weighing the total grain harvested from the plots after shelling and reported as yield 14% moisture content with a unit of tons/ha.

The cost and return analysis were computed based on the actual records of the cost and the gross sales on the prevailing price of corn in the market. The formula for calculating the Return of Investment is as follows:

$$\text{Return of Investment} = \frac{\text{Net Income}}{\text{Cost of Production}} \quad \text{X } 100$$

Statistical analysis

Significance of the treatments' effect was determined by the analysis of variance (ANOVA) using Statistical Tool for Agricultural Research (STAR). A logarithmic transformation was made on percentage data to meet the assumption of normality. Means was separated by Tukey's Test at $P \leq 0.05$.

Results

Harvest index

The result relative to the harvest index of OPV white corn applied with calcitic lime and zinc is presented in Table 1. The parameter is significant as it determines maize's physiological efficiency and ability to distribute assimilates and convert total biomass expressed in dry matter basis into economic yield. The statistical result shows that treatments used in the study significantly affect the efficiency of the crop to translocate assimilates into plant organs that influence corn productivity and yield performance. Based on the table, plants with the highest harvest index are white corn fed with the recommended rate (RR) of NPK added with half RR of calcitic lime and 2.5kg ha-1 rate of Zn (T5) at 0.32 and is statistically comparable with maize fed with full RR NPK + full RR calcitic lime at 70kg ha-1, and 5kg ha-1 Zn (T4) at 0.28. This means that 32% of the plant's dry matter for T5 was allocated to the marketable plant organ of the crop (ear), while 28% was for T4. The lowest harvest index, on the other hand, was obtained by controlled treatment (T0) at 13%.

Table 1. Harvest index of OPV white corn applied with calcitic lime and zinc

Treatments	Harvest index
T_0 – Control	0.13 [e]
T_1 – Full RR	0.27 [bc]
T_2 – RR + L1 Calcitic Lime	0.25 [bcd]
T_3 – RR + L2 Calcitic Lime	0.23 [cd]
T_4 – RR + L1 Calcitic Lime + Zn1	0.28 [ab]
T_5 – RR + L2 Calcitic Lime + Zn2	0.32 [a]
T_6 – ½ RR	0.24 [bcd]
T_7 – ½ RR + Zn1	0.27 [bc]
T_8 – ½ RR + Zn2	0.21 [d]
F-test	**
CV (%)	6.80

Means in a column with the same letters are not significantly different at 5% level using Tukey's test.
** Significant at a level of 1% of probability ($p < .01$), * Significant at a level of 5% of probability ($.01 =< p < .05$),ns = Not significant ($p >= .05$), RR – Recommended Rate; L1 – Level 1 (Full RR); L2 – Level 2 (Half RR); Mg – Magnesium; Zn - Zinc

Ear weight, ear diameter, ear length, and number of kernels per ear

The ear weight, ear diameter, ear length, and number of kernels per ear of IPB Var 6 white corn applied with calcitic lime and zinc (Table 2). Data showed highly significant differences among treatment means based on recorded data parameters. As presented, the combination of full RR NPK to calcitic lime at 35kg ha^{-1} and zinc at 2.5kg ha^{-1} rate (T_5) was commendable since it obtained the heaviest ear weight by 163.71 g at harvest that is 177.98% heavier than T_0 and was comparable to the rest of the treatments where NPK is amended with lime and Zn. On the other hand, it showed that T_2 attained the greatest ear diameter at 49.34 mm, followed by T_8 at 48.44 mm, T_4 at 48.00 mm, T_3 at 47.98 mm, and T_5 at 47.66 mm, and were still compared to T_1(full RR NPK) and T_7. Results for ear length were also indicated whereby nutrient-applied treatments amended with Ca and Zn of any rate got longer ear lengths at 14.50% to 24.87% higher compared to T_6 and 35.66% to 47.95% longer than T_0. Additionally, the highest number of kernels per ear was observed in T_2 (180-90-60 NPK + 70 kg ha-1 Calcitic Lime) at 400.09 attaining 110.15% greater number of grains than T_0 and was still comparable with other treatments other than T_6 and control respectively. The controlled treatment attained the lowest yield result among the four parameters evaluated, while T_8 remained stable in the middle level regarding yield performance.

Table 2. Weight, diameter, and length of corn ear, and number of kernels per ear of OPV white corn applied with calcitic lime and zinc at harvest

Treatments	Ear weight (g)	Ear diameter (mm)	Ear length (cm)	No. of kernels per ear
T_0 – Control	58.89 ^{d}	41.61 ^{c}	10.01 ^{c}	190.38 ^{c}
T_1 – Full RR	134.53 ^{b}	47.14 ^{ab}	14.69 ^{a}	391.19 ^{a}
T_2 – RR + L1 Calcitic Lime	154.14 ^{ab}	49.34 ^{a}	14.84 ^{a}	400.09 ^{a}
T_3 – RR + L2 Calcitic Lime	141.04 ^{ab}	47.98 ^{a}	13.58 ^{ab}	357.54 ^{ab}
T_4 – RR + L1 Calcitic Lime + Zn1	162.02 ^{a}	48.00 ^{a}	14.58 ^{a}	397.40 ^{a}
T_5 – RR + L2 Calcitic Lime + Zn2	163.71 ^{a}	47.66 ^{a}	14.81 ^{a}	381.23 ^{a}
T_6 – ½ RR	104.05 ^{c}	44.44 ^{bc}	11.86 ^{bc}	325.10 ^{b}
T_7 – ½ RR + Zn1	147.23 ^{ab}	46.83 ^{ab}	14.67 ^{a}	364.19 ^{ab}
T_8 – ½ RR + Zn2	145.35 ^{ab}	48.44 ^{a}	14.12 ^{a}	370.67 ^{a}
F-test	**	**	**	**
CV (%)	6.69	2.28	5.50	4.15

Means in a column with the same letters are not significantly different at 5% level using Tukey's test.
** Significant at a level of 1% of probability ($p < .01$),* Significant at a level of 5% of probability (.01 =p < .05), ns = Not significant (p>= .05), RR – Recommended Rate; L1 – Level 1 (Full RR); L2 – Level 2 (Half RR); Mg – Magnesium; Zn – Zinc

Weight of kernels per ear, weight of 1000 seeds and grain yield

Results on weight of kernels per ear, weight of 1000 seeds, and grain yield applied with calcitic lime and zinc are presented in Table 3. Statistical analysis shows that treatments have significant effects on the parameters evaluated as T_5(180-90-60 NPK + 35 kg ha^{-1} Calcitic lime + 2.5 kg ha^{-1} Zn) and

T_4 (180-90-60 NPK + 70 kg ha^{-1} Calcitic lime + 5 kg ha^{-1} Zn) were recorded to have the highest weight of kernels per ear at 125.89g and 124.11g which are also comparable with the kernel weights of crops under T_2 and T_7. The weight of 1000 seeds were also recorded, whereby T_4 attained the highest weight of 1000 seeds at 304.67 g and is still comparable with other treatments such as T_5, T_8, T_7, T_2, and T_1.

Overall, T_5(RR NPK + ½ RR Calcitic lime + ½ RR Zn) obtained the highest grain yield at 14% moisture content of OPV white corn at 5.94 t ha^{-1} that is 226.37% higher than control and is comparable to T_4 at 5.84 t ha^{-1}, and T_2 at 5.34 t ha^{-1}, respectively, where, the result is higher than the reported average yield of harvested white corn during dry season in Northern Mindanao at 3.29 metric tons ha^{-1} (PSA, 2021). In comparison, results for T_0 are still constant at the lowest level of yield performance based on the parameters evaluated.

Table 3. Weight of kernels per ear, weight of 1000 seeds, and grain yield of OPV white corn applied with calcitic lime and zinc at harves

Treatments	Weight of kernels per ear (g)	Weight of 1000 seeds (g)	Grain yield (t ha^{-1})
T_0 – Control	41.94 ^{e}	121.67 ^{d}	1.82 ^{e}
T_1 – Full RR	98.25 ^{cd}	267.33 ^{abc}	4.38 ^{cd}
T_2 – RR + L1 Calcitic Lime	114.16 ^{abc}	272.67 ^{abc}	5.34 ^{ab}
T_3 – RR + L2 Calcitic Lime	104.41 ^{c}	258.33 ^{bc}	4.77 ^{bc}
T_4 – RR + L1 Calcitic Lime + Zn1	124.11 ^{ab}	304.67 ^{a}	5.84 ^{a}
T_5 – RR + L2 Calcitic Lime + Zn2	125.89 ^{a}	286.33 ^{ab}	5.94 ^{a}
T_6 – ½ RR	87.95 ^{d}	230.67 ^{cd}	4.02 ^{d}
T_7 – ½ RR + Zn1	110.88 ^{abc}	274.00 ^{ab}	5.09 ^{bc}
T_8 – ½ RR + Zn2	108.35 ^{bc}	279.33 ^{ab}	4.90 ^{bc}
F-test	**	**	**
CV (%)	5.52	5.61	5.46

Means in a column with the same letters are not significantly different at 5% level using Tukey's test.
** Significant at a level of 1% of probability (p < .01), * Significant at a level of 5% of probability (.01 =< p < .05), ns = Not significant (p>= .05), RR – Recommended Rate; L1 – Level 1 (Full RR); L2 – Level 2 (Half RR); Zn – Zinc

Return of investment

Cost and return analysis of OPV white corn applied with calcitic lime and zinc is presented in Table 4. Treatment 5 (180-90-60 NPK + 35 kg ha^{-1} Calcitic lime + 2.5 kg ha^{-1} Zn) attained the highest gross income for OPV white corn at 118,843.57 pesos. But considering its higher cost of expenses, T_7 (90-45-30 NPK + 5 kg ha^{-1} Zn) obtained the highest net income at 40,773.35 pesos per hectare, thus, earned 66.83% in every peso invested. On the other hand, T_0 got the lowest income and return due to poor growth and inferior ears harvested resulted to low productivity performance. The analysis reflects that amending Ca and Zn to full RR NPK produces higher yield than the rest of the treatments, however, the application of NPK at lower rate (half RR) amended with Zn provides the highest return of money invested due to lower variable cost.

Table 4. Cost and return analysis of one-hectare production OPV white corn applied with calcitic lime and zinc

Treatments	Gross sales (Php)	Expenses (Php)	Net income (Php)	ROI (%)
T_0 – Control	36448.30	36400.00	48.30	0.13^{f}
T_1 – Full RR	87598.96	78415.22	9183.74	11.71^{ef}
T_2 – RR + L1 Calcitic Lime	106733.20	83415.22	23317.98	27.95^{cde}
T_3 – RR + L2 Calcitic Lime	95299.67	83415.22	11884.45	14.25^{def}
T_4 – RR + L1 Calcitic Lime + Zn1	116883.84	84165.22	32718.62	38.87^{c}
T_5 – RR + L2 Calcitic Lime + Zn2	118843.57	83790.22	35053.35	41.83^{bc}
T_6 – ½ RR	80295.76	61007.61	19288.15	31.62^{cd}
T_7 – ½ RR + Zn1	101780.96	61007.61	40773.35	66.83^{a}
T_8 – ½ RR + Zn2	97984.50	61757.61	36226.89	58.66^{ab}
F-Test				**
CV (%)				20.33

Means in a column with the same letters are not significantly different at 5% level using Tukey's test.
** Significant at a level of 1% of probability ($p < .01$); * Significant at a level of 5% of probability ($.01 =< p < .05$); ns = Not significant ($p >= .05$); RR – Recommended Rate; L1 – Level 1; L2 – Level 2; Mg – Magnesium; Zn - Zinc

Discussion

The result indicates that applying NPK at its standard rate, added with calcium and zinc, produces a higher harvest index and yield in white maize. Department of Agriculture (2019) reported that the average white corn yield in the Philippines as of 2019 is 3.4 t ha^{-1} with a standard harvest index of 0.37 during dry season which is close to the result of the current study presented. A previous study by Khan *et al*. (2017) reported that the application of N fertilizer to maize significantly increased harvest index which is similar to the findings of Kakar *et al.* (2014) that applying NPK at an increased rate improves the harvest index of maize up to 28.2%. On the contrary, a separate experiment concluded that the open-pollinated maize variety (Omankwa) was more efficient in converting total dry matter into grains when grown under zero N fertilization than other plants supplemented with varying rates of N (Ansu *et al*., 2023).

Amending agricultural lime to N increases the harvest index of maize (Victoria *et al*., 2019) since dosing Ca increases the efficiency of maize to recover and absorb N and P and enhances production and translocation of photosynthates for higher yield (Kisinyo *et al*., 2015). Moreover, a conclusion to the experiment conducted by Noreen *et al*. (2021) also agrees with the result since it was found that supplementing Zn increases the harvest index of cereal crops like corn as it helps to enhance the vegetative performance and photosynthetic capacity of plants resulting to an improved distribution of assimilates to form grains over total plant biomass. Hence, when the nutrient is deficient may cause stunted growth, sterility, and inferior quality grains to be harvested (Suganya *et al*., 2020).

The result also supported the findings from the previous experiments that amending Zn at 5.5 kg ha^{-1} (Shahab *et al*., 2016), lime at up to 120 kg ha^{-1} (Alemu *et al*., 2022) to NPK improves ear weight and ear diameter of maize. This is similar to the reports of the previous studies, which cited that the application of N at an increased rate of up to 135 kg ha^{-1} (El-Shahed *et al*., 2017), phosphorus up to 120 kg ha^{-1} (Iqbal *et al*., 2019), and potassium (Kandil *et al*., 2020) increases ear length of maize. Amending lime to NPK in acid soils was also reported to hold importance as it neutralizes soil acidity for better nutrient absorption (Alemu *et al*., 2022) and Zn functions during nitrogen metabolism (Shahab *et al*., 2016).

Interestingly, the findings of Ansu *et al*. (2023) additionally noted a similar result to the current study that supplying an increased rate of N at 150 kg ha^{-1} will result in an increased number of grains compared to zero fertilizer application. A separate study by Adhikary *et al*. (2020) also noted the effectiveness of combining agricultural lime with inorganic fertilizers as it increases kernel number resulting in a higher yield. Further, more of the former experiments also agree with the result shown as conclusions of Liu *et al*. (2020) cited that Zn does the same thing by enhancing the pollen viability of the crop during tasseling stage.

NPK has been known as the primary macronutrient needed by corn to achieve better yields. Hence, applying these nutrients at a standard rate helps farmers attain priority targets of boosting growth and productivity and improving nutrient efficiency (Li *et al*., 2016). The consistently highest result of T4 and T5 by adding calcitic lime and zinc to full RR NPK among the three (3) parameters evaluated in the table agrees with the report of Liu *et al*. (2020) that Zn application to maize increases kernel weight as the micronutrient provides enough carbohydrates to develop corn grains.

The findings of Fontoura *et al*. (2019) also supported to the result shown as calcitic lime has been found to reduce soil acidity and gradually helps to sustain a better soil chemical condition for plant growth. This made nutrients more available for the crop resulting in higher grain yields and enhanced nutritional content.

Moreover, results also agreed with the findings of Martínez-Cuesta *et al*. (2021) that supplementing zinc increases the grain yield of corn by 892 to 2519 kg ha^{-1} while enhancing soil fertility and the nutritional status of corn (Suganya *et al*., 2020). The positive effect of calcitic lime and zinc when added to NPK shows that amending other nutrients like Ca and Zn provides greater chances of producing a higher yield than NPK alone as it attained the highest grain yield of IPB Var 6 white corn in the current study. Thus, combining lime and zinc with NPK enabled the crop to provide a better carbohydrate supply to the developing kernels, thereby enhancing grain yield of corn.

However, in cases where the crop experienced water stress due to erratic rainfall for an extended period, kernel growth and development becomes limited, resulting in a reduced harvest index even supplementing these inorganic fertilizers (Ansu *et al*., 2023). The result brought significant idea as Guerrero and Mouazen (2021) noted that maximizing productivity while minimizing inputs is a way of responding the challenge of reducing the environmental footprints and becoming economically wise. In contrary, the enhancement of nutritional properties of corn to be consumed also holds significance as it helped to improve the health and well-being of every individual consumer (Gibson *et al*., 2010), thus, the application of NPK combine with soil enhancers are still advised.

Based on the above findings, it is concluded that integrating these fertilizers to NPK offered a vast opportunity to enhance the nutritional value of OPV white corn in Claveria, Misamis Oriental, and significantly improves its growth, physiological, and yield performance. Applying full RR NPK added with calcitic lime at 70 kg ha^{-1} and Zn at 5 kg ha^{-1} (T_7) is found to be commendable to boost the growth and yield performance of OPV white corn in the locality while significantly promoting a more nutritious corn staple to consume by a human. However, responding to the challenge of reducing the risks of compromising agricultural sustainability due to excessive fertilizer use, and considering the economic point of view of maximizing returns through a minimal input, the use of half RR NPK and Zn at 5 kg ha^{-1} (T_9) as a result of this study is recommended.

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