

# Factors Influencing Biofortified Inpari IR Nutri Zinc Rice Production in Margatiga, East Lampung, Indonesia

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## Abstract

**Purpose:** This study examines the production factors that determine the output of Inpari IR Nutri Zinc, a zinc-biofortified rice variety cultivated by smallholder farmers in Jayaguna and Negeri Tua villages, Margatiga Subdistrict, East Lampung Regency, Indonesia, and evaluates the extent to which these factors jointly explain variation in farm-level rice output.

**Methodology:** A quantitative explanatory survey design was applied to fifteen farmers selected through simple random sampling from a population of 104 registered Inpari Nutri Zinc growers. Primary data on land area, seed quantity, urea and NPK Phonska fertilizer use, herbicide, fungicide, rodenticide, and insecticide application, and labor input were collected through structured interviews and analyzed using multiple linear regression in SPSS.

**Results:** The regression model produced a coefficient of determination of 0.949 and an F-statistic of 90.012 at a significance level below 0.05, indicating that the nine production factors jointly explain 94.9% of the variance in rice output, with land area and urea fertilizer emerging as the most influential partial predictors.

**Conclusions:** Land expansion and balanced fertilization remain the principal levers for raising Inpari Nutri Zinc productivity in the study area.

**Limitations:** The small sample size and single-season cross-sectional design constrain the generalizability of the coefficients.

**Contributions:** The study offers empirically grounded guidance for extension planning and input allocation policy supporting biofortified rice diffusion in stunting-prone regions of Lampung Province.

**Keywords:** *Fertilizer Use, Inpari Nutri Zinc, Land Area, Rice Production, Smallholder Farmers*

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## 1. Introduction

Rice remains the principal staple food of the Indonesian population, and sustaining domestic production is central to the nation's food security agenda. Despite decades of policy attention, domestic paddy output has repeatedly fallen short of consumption needs, forcing periodic reliance on imports and exposing the vulnerability of the rice subsector to price volatility and supply disruption (Fisher, 2025). Within this policy landscape, the government has pursued not only volumetric self-sufficiency but also nutritional adequacy, recognizing that the quality of staple food consumption is as

consequential for public health as its quantity. Biofortification, the process of enhancing the micronutrient density of staple crops through conventional breeding, has emerged as one of the more cost-effective interventions available to policymakers seeking to address widespread micronutrient deficiency without altering established dietary patterns ([Luna & Suryana, 2024](#)).

Inpari IR Nutri Zinc is Indonesia flagship biofortified rice cultivar, officially released by the Ministry of Agriculture in 2019 through the Indonesian Center for Rice Research. The variety was developed specifically to elevate the zinc content of milled rice, a micronutrient that functions as a cofactor in several hundred enzymatic reactions governing cellular metabolism, immune competence, and tissue repair in the human body. Zinc deficiency, sometimes described as hypozincemia, has been linked in the clinical literature to stunted linear growth in children, impaired cognitive development, dermatological abnormalities, and weakened immune response, and it interacts closely with the broader burden of childhood undernutrition that continues to affect a substantial share of Indonesian children under five years of age ([Ernawati, Syaquy, Arifin, Soekatri, & Sandjaja, 2021](#)). Field assays conducted by the Indonesian Center for Rice Research indicate that Inpari IR Nutri Zinc carries a zinc concentration in the range of 29 to 34 parts per million, appreciably higher than conventional cultivars such as Ciherang, whose zinc content typically remains below 25 parts per million ([Damayanthi, Nurjanah, & Navratilova, 2023](#)). Beyond its nutritional profile, the variety has demonstrated favorable agronomic characteristics, including tolerance to brown planthopper infestation and moderate resistance to blast and tungro disease, alongside grain quality traits that Indonesian consumers generally find acceptable in terms of texture and aroma ([Mamoriska, Hidayat, Magda, Yulianti, & Damayanthi, 2022](#)).

The diffusion of Inpari IR Nutri Zinc across Indonesia has proceeded unevenly. National programs coordinated through the Directorate General of Food expanded cultivated area from roughly ten thousand hectares in 2020 to more than two hundred thousand hectares by 2024, with participating regions increasing correspondingly, and independent evaluations associate the scale-up with a measurable decline in national stunting prevalence over the same period ([CGIAR, 2025](#)). In Lampung Province, adoption has concentrated in a handful of regencies, including East Lampung, where local seed multiplication units under the Institute for Agricultural Technology have supported distribution to farmer groups since 2020. East Lampung Regency, and Margatiga Subdistrict in particular, presents a compelling site for closer investigation because it combines an active biofortification program with a persistent local nutrition burden, a pairing that raises the practical question of whether the agronomic potential of the variety is being realized at the farm level or whether production constraints are limiting the volume of biofortified rice reaching local consumers.

Farm-level rice production is a function of the interaction among several categories of input, commonly grouped into land, seed, fertilizer, crop protection chemicals, and labor. A substantial body of empirical work employing Cobb-Douglas or linear regression specifications has confirmed that land area and fertilizer application tend to exert the strongest positive influence on paddy output across diverse agroecological settings, while the marginal contribution of seed quantity, pesticide use, and labor is more variable and often conditioned on how closely farmers adhere to recommended technical packages ([Dait, 2023](#); [Salam, Anshori, Achmad, & Yusuf, 2024](#)). In Indonesia specifically, studies on irrigated lowland rice systems have generally corroborated the dominant role of land and balanced fertilization, while also documenting that overuse or misapplication of crop protection inputs can depress rather than enhance output, a pattern attributed to farmers deviating from recommended dosages ([Ginting, & Andari, 2021](#); [Oktisia, 2023](#)). Whether these general patterns hold for a biofortified variety cultivated by a small group of farmers in a specific agroecosystem such as Margatiga has not, to the knowledge of the present author, been directly examined, and this gap motivates the present study.

Preliminary field observation in Jayaguna and Negeri Tua villages revealed that although a cohesive farmer group has cultivated Inpari IR Nutri Zinc since 2023, yields have varied considerably across plots of comparable size, suggesting that factors beyond land endowment are shaping output. Anecdotal reports from farmer group leaders pointed to inconsistent fertilizer timing, variable

pesticide practices, and differences in labor deployment across the cropping calendar as plausible contributors to this variation. These field impressions are consistent with previous studies showing that production inputs such as land area, seed use, fertilizer application, pesticides, and labor allocation significantly affect rice productivity, although the magnitude and direction of their effects may differ across locations and farming systems ([Mardiasmo, 2018](#); [Alamri, Rauf, & Saleh, 2022](#); [Marwanti, Saptana, & Ashari, 2023](#)).

The problems this research seeks to identify begin with the observation that nutritional deficiency indicators persist in Margatiga Subdistrict notwithstanding an active biofortified rice program, that previous studies elsewhere report favorable productivity for improved rice varieties without clarifying which specific inputs drive that performance locally, that the variety continues to require active socialization and further development within the district, that a wide array of candidate production factors has not yet been jointly tested for the local farming system, and that ongoing monitoring of productivity is warranted given the strategic role the crop plays in local food and nutrition security. Previous research has demonstrated that land area, fertilizer use, labor, seed quality, and pest management remain key determinants of rice production, although their significance varies according to local agroecological and socioeconomic conditions ([Modjo, Dunggjo, & Rahim, 2025](#); [Muttaqin, & Suman, 2023](#); [Rahman, & Sangeran, 2022](#)).

## **2. Literature Review and Hypothesis/es Development**

### ***2.1 The Concept and Strategic Role of Biofortified Rice***

Biofortification differs fundamentally from post-harvest fortification in that the nutrient enhancement is embedded in the plant genome through breeding rather than added during processing, which lowers the recurrent cost of nutrient delivery and integrates naturally into existing dietary habits ([Luna & Suryana, 2024](#)). Inpari IR Nutri Zinc was bred specifically to address zinc deficiency, a micronutrient gap that has proven persistent in Indonesia despite broader improvements in caloric sufficiency. Comparative characterization studies confirm that the zinc content of Inpari IR Nutri Zinc is concentrated largely in the aleurone layer of the grain, meaning that milling intensity and post-harvest handling can materially affect the nutrient that ultimately reaches the consumer's plate ([Mamoriska et al., 2022](#)). This finding carries direct implications for downstream policy, since promoting the variety without attention to milling practices could dilute its intended nutritional benefit.

### ***2.2 Zinc Deficiency, Stunting, and Nutritional Justification***

The public health rationale for biofortification rests on well-documented associations between micronutrient inadequacy and child growth outcomes. National-level surveys of Indonesian children have repeatedly found that stunted children exhibit significantly lower serum zinc concentrations than their non-stunted peers, alongside weaker correlations between zinc status and standard anthropometric z-scores ([Ernawati et al., 2023](#)). Related work examining socioeconomic gradients in micronutrient status among children under five has shown that stunting and related deficiencies cluster disproportionately among households of lower socioeconomic standing, reinforcing the argument that a staple-food intervention such as biofortified rice, which does not depend on discretionary purchasing power in the way supplements or fortified snacks do, has particular relevance for equity-oriented nutrition policy ([Ernawati et al., 2021](#)). These findings collectively situate Inpari IR Nutri Zinc within a broader portfolio of interventions aimed at closing Indonesia's persistent stunting gap, a portfolio that also includes fortified rice distributed through the national food logistics agency ([Mamoriska et al., 2022](#)).

### ***2.3 Determinants of Rice Production: International and National Evidence***

The empirical literature on rice production functions is extensive and generally converges on a small set of recurring findings. Land area is the most consistently significant positive determinant of output across studies conducted in the Philippines, Bangladesh, Pakistan, and multiple Indonesian regencies, reflecting the straightforward agronomic logic that a larger cultivated area, holding other inputs constant, permits a larger harvestable crop ([Dait, 2023](#)). Fertilizer application, particularly of urea and compound NPK formulations, is the second most frequently significant factor, with several studies reporting that fertilizer elasticities of production are comparable in magnitude to those of land,

provided that application follows recommended dosage and timing ([Ginting & Andari, 2021](#); [Nasrin et al., 2022](#)). Seed quantity shows a more ambiguous relationship with output; some studies report a significant positive elasticity, while others find that once farmers have adopted a locally recommended seeding rate, further increases in seed volume no longer translate into proportional yield gains, a pattern consistent with diminishing marginal returns once the optimal plant population density has been reached ([Kurniawati et al., 2022](#)).

Labor input has likewise generated mixed findings. Cross-country evidence from irrigated systems in Cambodia and the Philippines associates greater labor input, particularly hired labor deployed at critical crop stages, with modest but statistically significant yield gains, attributable to more timely weeding, transplanting, and harvesting ([Dait, 2023](#)). In smaller-scale Indonesian farming systems, however, labor elasticities are frequently insignificant, which several authors interpret as evidence that labor supply in smallholder rice farming is rarely the binding constraint, since most tasks are performed by family members regardless of marginal productivity considerations ([Oktisia, 2023](#)). Crop protection inputs, comprising herbicides, fungicides, rodenticides, and insecticides, present the most heterogeneous pattern of all. Multiple studies from East and Southeast Asia report that pesticide and herbicide application enters the production function with a significant positive coefficient when farmers follow calibrated dosing protocols, yet an equal number of studies report null or even negative coefficients when application deviates from technical recommendations, since excessive dosing can damage the crop canopy, disturb beneficial soil organisms, and elevate production costs without a corresponding yield benefit ([Suretno et al., 2021](#)). A recent regression-based study of rice farmers in Bantaeng Regency, Indonesia, using logistic estimation similarly found that herbicide use failed to register as a significant determinant of production once other inputs were controlled for, a result the authors attributed to inconsistent adherence to recommended application rates among smallholders ([Salam et al., 2024](#)).

Beyond the technical input categories, several studies have incorporated farmer and household characteristics, including age, education, and farming experience, into the production function, generally finding that these variables operate indirectly, by shaping the efficiency with which technical inputs are converted into output, rather than entering the model as a direct production factor with a large marginal effect of its own ([Ali et al., 2022](#)). Education level, in particular, has been associated with faster and more consistent adoption of recommended dosing schedules, which in turn interacts with the fertilizer and pesticide coefficients described above ([Ali et al., 2022](#)).

#### **2.4 Institutional and Policy Context in Indonesia**

Government fertilizer subsidy policy has historically underpinned Indonesia's pursuit of rice self-sufficiency, and empirical assessments of subsidy programs in comparable Southeast Asian settings confirm that price support for fertilizer meaningfully increases the probability of adequate and timely application among smallholders, thereby reinforcing the productivity gains associated with fertilizer use documented in the agronomic literature ([Nasrin et al., 2022](#)). At the same time, comparative policy analysis across rice-dependent developing countries cautions that the pursuit of volumetric self-sufficiency can crowd out attention to nutritional quality unless deliberately paired with interventions such as biofortification, underscoring the complementary rather than substitutive relationship between productivity-oriented and nutrition-oriented rice policy ([Fisher, 2025](#)).

#### **2.5 Prior Findings on Inpari IR Nutri Zinc Performance**

Several field-based studies conducted since the variety's release provide useful comparative benchmarks for the productivity figures examined in this study. Research conducted in Kutai Kartanegara, East Kalimantan Province, found that Inpari IR Nutri Zinc achieved a harvested yield of 6.91 tons per hectare of harvested dry paddy, outperforming both Inpari 32 and a resistant Bioni cultivar under comparable growing conditions, a result the authors attributed to the variety's favorable adaptability across differing soil types ([Pebriandi et al., 2021](#)). A separate assessment conducted in North Sumatra Province, focusing on the institutional and market dimensions of scaling up the variety, reported that although Inpari IR Nutri Zinc carries strong agronomic potential, its wider diffusion has been constrained by limited farmer familiarity with the cultivar, insufficient access to capital among

prospective adopters, and an underdeveloped downstream processing sector capable of capturing and communicating the variety's zinc premium to consumers (Chairuman et al., 2022). A comparative agronomic trial conducted more recently found that Inpari IR Nutri Zinc, alongside the related Inpari 42 cultivar, exhibited a comparatively short plant stature and produced 7.0 tons per hectare of harvested dry paddy, a level of performance the study characterized as competitive with, though somewhat below, the highest-yielding comparison variety in the trial (Suparwoto et al., 2023). At the varietal breeding level, screening work conducted at the Indonesian Center for Rice Research on nearly a thousand biofortification breeding lines confirmed that zinc concentration varies systematically with grain pericarp color, with white-grained lines exhibiting the widest range of zinc content, a finding that helps explain some of the variability in nutrient outcomes reported across different Inpari Nutri Zinc growing regions even when agronomic management is broadly similar (Rohaeni, 2023). Collectively, these prior studies suggest that the productivity ceiling for Inpari IR Nutri Zinc under favorable management is close to seven tons per hectare, a benchmark against which the performance of farmers in Margatiga Subdistrict can usefully be compared, and they reinforce the observation that institutional constraints, rather than purely agronomic ones, may be equally important in explaining why realized yields at any given location fall short of the variety's demonstrated potential.

### ***2.6 Conceptual Framework and Hypotheses***

Synthesizing the theoretical and empirical literature reviewed above, the production of Inpari IR Nutri Zinc rice in the study area is conceptualized as a function of nine measurable inputs: land area, seed quantity, urea fertilizer, NPK Phonska fertilizer, herbicide, fungicide, rodenticide, insecticide, and labor. These inputs are hypothesized to jointly and significantly determine paddy output, consistent with the broad pattern established in the international and national literature reviewed in the preceding sections, while their individual partial effects are expected to vary in both magnitude and statistical significance depending on how consistently local farmers apply each input relative to recommended technical guidance. This framework directly informs the two hypotheses tested in the present study, namely that indicators of successful production include timely harvest, appropriate fertilizer type, favorable price, adequate harvest volume, assured quality, and suitable market placement, and that the factors influencing Inpari Nutri Zinc production in Margatiga Subdistrict can be grouped broadly into production factors and environmental factors.

## **3. Methodology**

### ***3.1 Research Design and Location***

This study adopted a quantitative explanatory survey design intended to test the strength and direction of association between a defined set of independent production variables and rice output as the dependent variable. The research was conducted in Jayaguna and Negeri Tua villages, Margatiga Subdistrict, East Lampung Regency, Lampung Province, Indonesia. These two villages were purposively selected because they host an established and well-organized Inpari IR Nutri Zinc farmer group with a multi-year cultivation history, situated within a subdistrict that the provincial food security agency has formally designated as a biofortified rice development area. Margatiga Subdistrict comprises thirteen villages with a combined population of approximately 46,885 residents as of the 2020 population census, and agriculture, together with smallholder livestock keeping, constitutes the dominant livelihood activity, accounting for the large majority of household income in Jayaguna and Negeri Tua.

### ***3.2 Population and Sample***

The population for this study consisted of all registered Inpari IR Nutri Zinc farmers in the two study villages, numbering 104 individuals according to farmer group records maintained by the local extension office. Sample size was determined using the simple random sampling procedure recommended for populations of this scale, following the guidance that a sampling fraction of approximately 15 to 25 percent of the population is appropriate once the population exceeds a size that would otherwise justify a full census (Arikunto, 2006). Applying a sampling fraction of 15 percent to the population of 104 yielded a target sample of fifteen farmers, who were then selected at random without regard to subgroup stratification, ensuring that each registered farmer had an equal

probability of selection. While a sample of this size is modest in absolute terms, it corresponds closely to the entire population of farmers actively cultivating the variety within the two focal villages during the reference cropping season, which mitigates, though does not eliminate, the statistical power limitations that a small sample would otherwise impose.

### **3.3 Data and Sources**

Two categories of data informed the analysis. Primary data were obtained directly from sampled farmers and covered land area planted, seed quantity used, quantities of urea and NPK Phonska fertilizer applied, quantities of herbicide, fungicide, rodenticide, and insecticide used, labor days deployed across the cropping cycle, and total harvested output measured in kilograms of dry unhulled paddy. Secondary data were drawn from the East Lampung Regency Food Security, Agriculture, and Horticulture Office, from village administrative records in Jayaguna and Negeri Tua, and from the 2020 population census published by the Central Statistics Agency of East Lampung Regency, and were used primarily to characterize the study area and to validate the population figures underlying the sampling procedure.

### **3.4 Data Collection Techniques**

Data were collected through a combination of structured in-depth interviews, direct field observation, and documentation review. Interviews followed a prepared guide covering each production input category and were conducted individually with each of the fifteen sampled farmers outside of their routine farming hours to minimize disruption to their livelihood activities, with responses recorded using a digital voice recorder to preserve accuracy. Field observation was carried out within the farmer group's cultivation plots to corroborate self-reported input use and to record contextual information on cropping calendar and irrigation practice. Documentation review drew on farmer group records, village office statistics, and relevant secondary reports to supplement and cross-check the primary interview data.

### **3.5 Analytical Method**

Data were compiled and organized using Microsoft Excel, after which multiple linear regression analysis was performed in SPSS to estimate the relationship between rice production, treated as the dependent variable, and the nine independent production variables described above. Multiple linear regression was selected because it permits simultaneous estimation of the partial contribution of several inputs while controlling for the influence of the others, in keeping with standard practice in the empirical rice production literature reviewed in Section 2 (Dait, 2023; Salam et al., 2024). The general form of the estimated model is expressed as follows, where  $Y$  denotes rice production,  $X_1$  through  $X_9$  denote land area, seed quantity, urea fertilizer, NPK Phonska fertilizer, herbicide, fungicide, rodenticide, insecticide, and labor respectively,  $b_0$  denotes the regression constant,  $b_1$  through  $b_9$  denote the partial regression coefficients associated with each input, and  $e$  denotes the error term capturing unobserved influences on production.

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + e \quad (1)$$

Formula 1 model adequacy was assessed through the coefficient of determination, which indicates the proportion of variance in production explained jointly by the nine predictors, and through the F-statistic, which tests the null hypothesis that none of the predictors is jointly related to production. The statistical significance of each individual predictor was assessed through its associated t-statistic and probability value at a conventional significance threshold of 0.05, consistent with the threshold applied throughout the comparable literature discussed in Section 2.

## **4. Results and Discussion**

### **4.1 Overview of the Study Area**

Margatiga Subdistrict is an agrarian district in which agriculture and smallholder livestock keeping together account for approximately 79% of household livelihoods, based on village office records for Jayaguna and Negeri Tua. The district's terrain includes two low hills reaching between 100 and 250

meters in elevation and two principal rivers, the Way Sekampung and the Way Capang, which together support the irrigated lowland rice systems on which the local farming population depends. This agroecological profile is broadly consistent with the conditions under which Inpari IR Nutri Zinc has performed well in other parts of Indonesia, since the variety was bred for irrigated lowland cultivation up to 600 meters above sea level with moderate tolerance to brown planthopper and blast disease ([Balai Besar Penelitian Tanaman Padi, 2019](#)).

#### 4.2 Characteristics of Sampled Farmers

The fifteen sampled farmers displayed characteristics broadly typical of smallholder rice cultivation in rural Lampung. Table 1 summarizes the age distribution of respondents, showing that the majority, eleven farmers, fell within the 41 to 60 year age bracket, while the remaining four farmers were between 21 and 40 years of age, with no respondents older than 60. This age profile suggests a farming population still within a physically productive stage of life, a factor that several studies identify as indirectly supportive of consistent and timely input application ([Ali et al., 2022](#)).

Table 1. Age distribution of sampled farmers

Age Group (Years)	Number of Farmers	Percentage (%)
21 to 40	4	26.6
41 to 60	11	73.4
61 to 80	0	0.0
Total	15	100.0

Table 1 is a frequency distribution derived from primary interview data collected in 2024, and it indicates that the sampled farmer group is concentrated in middle adulthood, a stage of the life course generally associated in the literature with a favorable balance between physical capacity and accumulated farming experience.

With respect to gender, twelve of the fifteen respondents, or 80%, were male, while three, or 20%, were female, a pattern consistent with the broader division of agricultural labor in rural Indonesia in which men more often assume the primary cultivator role while women contribute substantially to supporting tasks and household-level food processing. Educational attainment among respondents skewed toward lower secondary schooling, with seven farmers, or 46.6%, having completed junior secondary education, four having completed senior secondary education, two having completed only primary education, and one each holding a diploma or bachelor's degree. Landholding size was similarly modest, with eleven farmers, or 73.3%, cultivating between 0.20 and 0.50 hectares, and the remaining four cultivating between 0.51 and 0.90 hectares, confirming that smallholder fragmentation, rather than large-scale commercial farming, characterizes Inpari IR Nutri Zinc cultivation in the study villages.

#### 4.3 Input Utilization Patterns

Seed use among the fifteen sampled farmers averaged 13.53 kilograms per farmer, with total seed consumption across the sample reaching 203 kilograms. Urea fertilizer use totaled 1,450 kilograms across the sample, averaging roughly 100 kilograms per farmer, while NPK Phonska fertilizer use totaled 1,500 kilograms, also averaging roughly 100 kilograms per farmer. These application rates are broadly comparable to the technical packages recommended for irrigated Inpari cultivars elsewhere in Indonesia, in which balanced urea and NPK application at moderate rates per hectare has been shown to sustain productivity without inducing the diminishing or negative returns associated with overapplication ([Ginting & Andari, 2021](#)). Crop protection input use was considerably more limited and uneven: only four of the fifteen farmers applied herbicide, relying instead on manual weeding, only two applied fungicide, and only three applied rodenticide, while insecticide was the most widely used crop protection input among the sample, applied as a last resort once pest pressure could no longer be managed manually. Labor input averaged between eleven and twelve worker-days per farmer across the full cropping cycle from land preparation through harvest, a relatively modest labor intensity that is consistent with the small landholding sizes reported above.

#### 4.4 Regression Results

$$Y = -1.786 + 2.444X_1 + 1.229X_2 + 2.877X_3 + 1.826X_4 + 0.985X_5 - 0.408X_6 + 0.588X_7 + 0.446X_8 + 0.491X_9$$

The multiple linear regression analysis produced the estimated model presented below, in which the dependent variable Y represents rice production in kilograms and the independent variables X1 through X9 correspond respectively to land area, seed quantity, urea fertilizer, NPK Phonska fertilizer, herbicide, fungicide, rodenticide, insecticide, and labor. as can be seen in Formula 2.

Table 2. Summary of multiple linear regression results

Variable	Unstandardized Coefficient (B)	Standardized Coefficient (Beta)	t-value	Significance
Constant	-1.786	-	-3.000	0.030
Land Area ( $X_1$ )	2.444	0.584	2.444	0.058
Seed Quantity ( $X_2$ )	1.229	0.239	1.229	0.274
Urea Fertilizer ( $X_3$ )	2.877	0.177	2.877	0.035
NPK Phonska Fertilizer ( $X_4$ )	1.826	0.119	1.826	0.127
Herbicide ( $X_5$ )	0.985	-	-	-
Fungicide ( $X_6$ )	-0.408	-	-	-
Rodenticide ( $X_7$ )	0.588	-	-	-
Insecticide ( $X_8$ )	0.446	-	-	-
Labor ( $X_9$ )	0.491	-	-	-

Table 2 summarizes the standardized and unstandardized regression coefficients together with the associated t-statistics and significance values for each predictor. Table 2 reports the coefficients estimated from the SPSS output based on primary data collected in 2024, and it is intended to convey both the direction and, where applicable, the statistical significance of each production factor's partial relationship with rice output. The model as a whole achieved a coefficient of determination of 0.949, meaning that the nine independent variables jointly explain 94.9% of the variation in Inpari IR Nutri Zinc production observed among the sampled farmers, while the remaining 5.1% is attributable to factors outside the specified model, such as soil fertility heterogeneity, microclimatic variation, or unmeasured management practices. The F-statistic for the overall model was 90.012, significant at a probability value below 0.001, confirming that the null hypothesis of no joint relationship between the predictors and production can be confidently rejected.

#### 4.5 Discussion of Individual Production Factors

Land area emerged as the input with the largest standardized coefficient in the model, corroborating the near-universal finding in the international literature that cultivated area is the single strongest predictor of rice output, since a larger plot mechanically accommodates a larger plant population and, correspondingly, a larger potential harvest (Dait, 2023; Joseph et al., 2023). Although the significance value for land area in the present sample narrowly exceeded the conventional 0.05 threshold, its substantially larger standardized coefficient relative to every other variable indicates that land remains the dominant lever available to farmers seeking to expand output, a conclusion that aligns closely with comparable Indonesian and Southeast Asian evidence (Oktisia, 2023; Suretno et al., 2021).

Urea fertilizer was the only input to register statistical significance at the conventional threshold, with a positive coefficient indicating that increased urea application is associated with higher production. This finding is consistent with the well-established agronomic role of nitrogen in vegetative growth and grain filling, and it echoes evidence from other Indonesian rice-producing regions in which urea application, when aligned with recommended dosing, consistently ranks among the most productive investments a smallholder can make (Ginting & Andari, 2021; Nasrin et al., 2022). NPK Phonska fertilizer likewise carried a positive coefficient, suggesting a complementary role in supplying

phosphorus and potassium alongside the nitrogen delivered through urea, although its effect fell short of conventional statistical significance in this sample, plausibly reflecting the more variable application rates reported among respondents.

Seed quantity carried a positive but statistically insignificant coefficient, a result that mirrors findings from other studies in which farmers who have already adopted a locally appropriate seeding rate see limited additional benefit from further increases in seed volume, since plant population density beyond an agronomic optimum tends to induce intraspecific competition rather than proportional yield gains ([Kurniawati et al., 2022](#)). Labor similarly showed a positive but non-significant relationship with production, in line with evidence from smallholder Indonesian rice systems suggesting that labor supply, given the predominance of family labor in small operations of the kind observed in this sample, is rarely the binding constraint on output ([Ali et al., 2022](#); [Oktisia, 2023](#)).

The crop protection inputs produced the most heterogeneous pattern of results. Herbicide, rodenticide, and insecticide each carried positive though non-significant coefficients, while fungicide alone showed a negative coefficient. Field observation and farmer interviews suggest that this divergence reflects inconsistent adherence to recommended dosing among the small number of farmers who applied these inputs at all, a pattern documented previously among Indonesian rice farmers where excessive or poorly timed application of crop protection chemicals can damage the crop and depress yields rather than protect them ([Suretno et al., 2021](#)). This interpretation aligns closely with the Bantaeng Regency findings, in which herbicide use similarly failed to register as a significant positive determinant of production once other inputs were accounted for, reinforcing the broader conclusion that the productivity payoff from crop protection inputs in smallholder Indonesian rice systems is conditional on technical compliance rather than being an automatic function of quantity applied ([Salam et al., 2024](#)).

#### **4.6 Synthesis**

Taken together, the regression results indicate that Inpari IR Nutri Zinc production in Margatiga Subdistrict is overwhelmingly shaped by land area and by nitrogen-based fertilization, a pattern that is broadly consistent with the international and national literature on rice production functions summarized in Section 2, while the remaining inputs, particularly the various crop protection chemicals, contribute more variably and appear to depend heavily on whether farmers are applying them according to recommended technical guidance. These findings suggest that extension interventions in the study area would likely yield the greatest marginal benefit if they focused on consolidating or expanding cultivable land where feasible, reinforcing correct urea dosing and timing, and improving farmer compliance with recommended crop protection protocols rather than simply promoting greater volumes of chemical input use.

Comparing the productivity levels observed among the fifteen sampled farmers against the benchmarks established in Section 2.5 also offers a useful diagnostic. Given that comparable field trials elsewhere in Indonesia have reported Inpari IR Nutri Zinc yields ranging from approximately 6.9 to 7.0 tons per hectare of harvested dry paddy under favorable management ([Pebriandi et al., 2021](#); [Suparwoto et al., 2023](#)), the variation in per-hectare output observed across sampled plots in Jayaguna and Negeri Tua appears attributable less to any inherent limitation of the cultivar itself and more to the unevenness in fertilizer and crop protection practice documented above. This interpretation is consistent with the institutional diagnosis offered for North Sumatra, where limited farmer familiarity with the variety's specific management requirements, rather than any agronomic shortcoming, was identified as the principal constraint on realizing the cultivar's full potential ([Chairuman et al., 2022](#)). It follows that closing the observed productivity gap in Margatiga Subdistrict is likely to depend as much on strengthening extension delivery and farmer training as on any further input intensification, a conclusion with direct relevance for the local food security agency and farmer group leadership responsible for sustaining the biofortification program in the district. Broader agricultural extension experience from other smallholder cropping systems in Indonesia, including community-based vegetable cultivation programs, similarly demonstrates that consistent technical guidance and group-based learning are frequently more decisive for closing yield gaps than

the sheer availability of inputs alone ([Mujiwati et al., 2020](#); [Mulyanti & Supandi, 2022](#)). A pattern that appears equally applicable to the biofortified rice system examined in this study.

## **5. Conclusions**

### **5.1 Conclusion**

This study set out to identify the factors influencing the production of Inpari IR Nutri Zinc rice among smallholder farmers in Jayaguna and Negeri Tua villages, Margatiga Subdistrict, East Lampung Regency, and to assess the level of productivity achieved under current cultivation practices. The multiple linear regression analysis, drawing on primary data from fifteen sampled farmers, found that land area, urea fertilizer, and NPK Phonska fertilizer exerted a positive influence on rice production, while seed quantity, fungicide, rodenticide, insecticide, and labor did not exert a statistically significant partial influence, though several nonetheless carried a positive sign. Collectively, the nine production factors explained 94.9 percent of the variation in rice production among the sampled farmers, with the overall regression model confirmed as highly significant. The productivity of Inpari Nutri Zinc rice in the study area can be increased through targeted improvement in the factors shown to matter most, particularly through expanding effective land use and through more consistent and technically appropriate fertilizer application.

### **5.2 Research Limitations**

Several limitations qualify the conclusions drawn from this study. The sample of fifteen farmers, while representing nearly the entire population of active Inpari IR Nutri Zinc growers in the two focal villages during the study period, is small in absolute statistical terms, which constrains the precision of the estimated coefficients and limits the power to detect significance for inputs with smaller true effect sizes. The cross-sectional, single-season design captures conditions during one cropping cycle and cannot account for seasonal or year-to-year variation in rainfall, pest pressure, or market prices that might alter the relative importance of the production factors examined. The study also relied substantially on farmer self-report for input quantities, which, despite corroboration through field observation, may be subject to recall or reporting imprecision. Finally, the geographic scope was confined to two villages within a single subdistrict, which limits the extent to which the findings can be generalized to Inpari IR Nutri Zinc cultivation in other agroecological zones of Lampung Province or elsewhere in Indonesia.

### **5.3 Suggestions and Directions for Future Research**

Future research would benefit from a larger, multi-season panel of farmers spanning several subdistricts within East Lampung and neighboring regencies, which would permit more robust estimation of input elasticities and allow researchers to test whether the dominance of land and urea fertilizer observed in this study holds across a wider range of agroecological conditions. Subsequent studies might also incorporate direct measurement of soil fertility and irrigation water availability as additional explanatory variables, given that these factors were identified qualitatively during fieldwork as plausible sources of unexplained variance in output. Further investigation into the relationship between farmer compliance with recommended crop protection dosing and realized yield, potentially through a dedicated dosage-tracking instrument rather than aggregate quantity alone, would help clarify the ambiguous results obtained for herbicide, fungicide, rodenticide, and insecticide in the present analysis. Finally, given the nutritional rationale underlying the promotion of Inpari IR Nutri Zinc, future work should consider linking farm-level production data with household-level zinc intake and child anthropometric outcomes to evaluate whether productivity gains at the farm level are translating into measurable nutritional benefits within the communities that grow this variety.

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## Author Contributions

SI, NI, and NN contributed equally to this study. SI was responsible for conceptualization, research design, and development of the analytical framework. NI contributed to data collection, field survey implementation, and literature review. NN was involved in data analysis, interpretation of results, and drafting the manuscript. All authors jointly participated in revising the manuscript critically and approved the final version for submission.

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