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Characterization of *Citrus aurantifolia* 'Nimas Agrihorti' Cultivar as a Potential Biopharmaceutical Commodity and Its Economic Feasibility in Indonesia

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ABSTRACT

'Nimas Agrihorti' is a citrus cultivar developed to fulfil the increasing domestic demand for biopharmaceutical-grade citrus in Indonesia. Its development aligns with the growing public interest in health-promoting agricultural products. This study aimed to evaluate the morphological characteristics, chemical composition, and economic viability of 'Nimas Agrihorti' as a biopharmaceutical citrus. Field observations were conducted from June 2019 to October 2020 at the Banjarsari Experimental Field, Bayeman Village, Probolinggo, East Java. Morphological assessments followed the Descriptor List for Citrus by IPGRI, and chemical analyses were performed at the Post-Harvest Laboratory of Brawijaya University, Malang. Economic feasibility was assessed by calculating production costs and revenues over a 2-year cultivation cycle. 'Nimas Agrihorti' exhibited favorable morphological traits, including large fruit size (72–82 g), yellow skin, and sweet taste. Chemical analysis revealed vitamin C content of 34.8 mg/100 g and low acidity at 0.45%. The total production cost over 2 years was IDR 42,640,000.00 (equivalent to USD 2,584), with total revenue amounting to IDR 77,360,000.00 (equivalent to USD 4,688), resulting in a Revenue-Cost (R/C) ratio of 2.81. The combination of desirable morphological and chemical characteristics, along with strong economic returns, indicates that 'Nimas Agrihorti' holds significant potential for development as a biopharmaceutical citrus cultivar in Indonesia.

Keywords: citrus, cultivar, biopharmaceutical products, economic feasibility

Introduction

The availability of plant-based biopharmaceutical products for medicinal use in Indonesia has declined over the past few decades. According to BRIN-Indonesia National Research and Innovation Agency (2023), Indonesia remained behind in producing sufficient raw materials for biopharmaceutical drugs, which possessed therapeutic benefits, particularly for enhancing immune function (Annisa et al., 2022). These benefits could be obtained

through direct human consumption or via industrial extraction processes (Fahrurin et al., 2023). However, data from BPS-Statistics Indonesia (2024) indicated a positive trend for citrus as a biopharmaceutical commodity showing increased production in 2021 and 2022, reaching 13,103,964 kg and 25,175,958 kg, respectively.

Citrus fruits are widely appreciated not only for their pleasant flavour but also for their abundance of bioactive compounds and essential nutrients. They are a significant source of phenolic constituents, including flavonoids, phenolic acids, coumarins, terpenoids, limonoids, carotenoids, and pectin (Budiarto et al., 2024). Additionally, citrus is nutritionally rich in compounds such as ascorbic acid (vitamin C), tocopherols and tocotrienols (vitamin E), as well as trace minerals like selenium, zinc, copper, iron, and manganese (Saini et al., 2022). The peel of citrus fruits contains essential oils, carotenoids, flavonoids, and other bioactive molecules known for their potent antioxidant properties. Moreover, citrus seeds offer valuable nutritional components, including essential proteins, ascorbic acid, fatty acids, phytosterols, tocopherols, limonoids, dietary fiber, and flavonoids (Saini et al., 2022).

Citrus is recognized as one of the major fruit sources of carotenoids, compounds known for their potential in cancer prevention. The concentration of carotenoids in citrus fruits can vary depending on environmental and cultivation conditions (Gebregziabher et al., 2023). Citrus extracts are particularly rich in flavanones, with hesperidin identified as the most abundant phenolic compound (Khan et al., 2014; Kumar et al., 2021; Mitra et al., 2022). Phenolic compounds derived from citrus exhibit strong biological activities, including anticarcinogenic, antimutagenic (de Luna et al., 2023), and antitumor properties (Mueed et al., 2023). They have been associated with reducing the risk of colorectal (Gao et al., 2022), esophageal, gastric, and stomach cancers (Tullio et al., 2020), as well as contributing to the prevention of stroke, cholesterol regulation, and exhibiting antioxidant effects (Alaqeel, 2023; Hijaz et al., 2020). Furthermore, these compounds possess anti-inflammatory (Denaro et al., 2021), antifungal, and antithrombotic activities. Hesperidin, in particular, has demonstrated potential in combating coronavirus infections, lowering cholesterol levels, and enhancing bile acid secretion (Saini et al., 2022). Regular consumption of citrus fruits is thus highly beneficial to human health, supported by their rich nutrient profile and palatable taste (Liu et al., 2022).

Extensive research has been conducted on the health benefits of citrus species. For instance, Shafreen et al. (2018) investigated the interaction between lime-derived phenolic compounds and human serum proteins. Shimada et al. (2022) reported the bioactivity of kabosu (*Citrus sphaerocarpa*) in inhibiting angiogenesis and the migration of breast cancer cells. Similarly, Anuchapreeda et al. (2020) highlighted the use of kaffir lime leaves (*Citrus hystrix*) both as a culinary ingredient and in traditional medicine. Additional studies by Prommaban and Chaiyana (2022) demonstrated the anti-aging and anti-melanogenic properties of essential oils extracted from the leaves and peels of *Citrus aurantifolia* (Christm.) Swing and *Citrus reticulata* Blanco cv. Shogun. While numerous studies have explored the bioactive components and therapeutic effects of citrus fruits, relatively few have focused on the development of new cultivars. One such example is the 'Nimas Agrihorti' cultivar, which offers health benefits—particularly for low-fat dietary applications and diabetes management—despite its naturally sweet flavor profile.

The development of new citrus cultivars is anticipated to support initiatives by the Directorate General of Horticulture, Ministry of Agriculture, aimed at reducing

the influx of imported citrus fruits, which are becoming increasingly accessible in Indonesia (Rahayu et al., 2020). Achieving this goal requires efforts to enhance fruit quality, ensure year-round availability, and increase production volume. One approach involves the cultivation of the 'Nimas Agrihorti' citrus cultivar (Figure 1). As a newly introduced cultivar, 'Nimas Agrihorti' citrus developed in 2012 by the Citrus and Subtropical Fruit Research Center has been identified as possessing high nutritional value and the potential for dual use—as a fresh consumption product and as a raw material for biopharmaceutical applications. In addition to its nutritional qualities, 'Nimas Agrihorti' also exhibits favorable productivity and economic value. Besides the advantages of 'Nimas Agrihorti', this study was conducted to evaluate the potential of 'Nimas Agrihorti' as a biopharmaceutical citrus by analyzing its chemical composition and assessing its economic feasibility.

Fig. 1. *Citrus aurantifolia* 'Nimas Agrihorti' fruits in the field. Source: research documentation (2015).

Materials and Methods

The study was conducted on 'Nimas Agrihorti' mother plants aged 2.5 to 3.5 years, with two harvest cycles, grown in an experimental plot of approximately 1,000 m². Field observations were conducted at the Banjarsari Experimental Field, Bayeman Village, Probolinggo, East Java. The site was characterized by alluvial soil, an elevation of 1 m above sea level, an average annual rainfall of 1,200 mm, approximately 90 rainy days per year, a temperature range of 21–28°C, relative humidity of 76%, and soil pH between 6 and 7. Observations and plant identification were carried out from June 2019 to October 2020. Morphological characteristics were evaluated using the Descriptor List for Citrus developed by International Plant Genetic Resources Institute (IPGRI), while analyses of the fruit chemical properties were conducted at the Post-Harvest Laboratory, Brawijaya University, Malang.

Variables of Observation

The qualitative traits assessed in this study included overall plant morphology, such as stem, leaf, and fruit shape and color. Stem shape was evaluated through transverse stem sections, while stem color was visually assessed and confirmed through consensus by five evaluators. Fruit skin color, along with the color of the flesh, leaves, and flowers, was determined by comparing samples to a standardized color chart. Quantitative characteristics encompassed parameters such as plant height, yield (number and weight of fruits), fruit dimensions, vitamin content, stem diameter, leaf size, number of fruit segments, flower count, and fruit count. Additional measurements included total fruit per plant, average fruit weight, fruit length and diameter, sugar content, and results from chemical composition analysis.

Variable of Farm Feasibility

According to Pebrianto et al. (2023), farm feasibility is evaluated using the Revenue-Cost (R/C) ratio. A ratio equal to 1 indicates a break-even point, meaning the capital investment is fully recovered. If the R/C ratio exceeds 1, the farming activity is considered profitable, whereas a ratio below 1 reflects a financial loss.

Results and Discussion

Characteristics of 'Nimas Agrihorti'

'Nimas Agrihorti' was obtained through hybridization between citrus and sweet orange, resulting in distinctive traits such as a plant height ranging from 156 to 214 cm, a shrub-like canopy structure, and stem diameters of 4–6 cm with a greyish coloration. Unlike typical lemon plants, which generally begin fruit production at heights of 3–5 m, 'Nimas Agrihorti' demonstrates precocious fruiting ability at significantly lower plant heights, indicating its early-yielding advantage.

The hybridization between citrus and sweet orange has resulted in the morphological superiority of the 'Nimas Agrihorti' cultivar, particularly in terms of flavor profile, fruit size, and other agronomic traits. The leaf shape of 'Nimas Agrihorti' exhibited an oval shape, with lengths ranging from 7 to 10 cm and widths between 4 and 6 cm. The plant produced compound flowers. Illustrations of the leaf and flower morphology of 'Nimas Agrihorti' are presented in Figure 2.

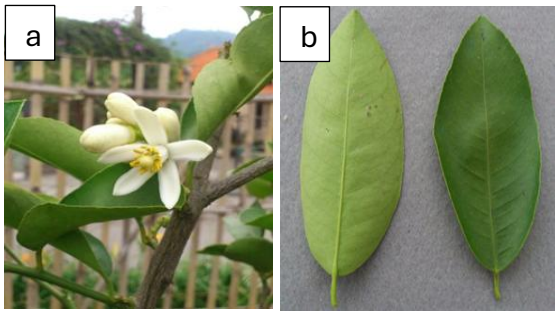

Fig. 2. Flowers (a) dan leaves (b) of *Citrus aurantifolia* 'Nimas Agrihorti'.

The leaf and flower morphology of 'Nimas Agrihorti' resembled that of common citrus species, displaying an oval to elliptical leaf shape (Ernawati et al., 2023). Based on the findings of Adlini et al. (2020), citrus leaves typically ranged from 5.5–13 cm in length and 2–7.5 cm in width, while the Cancer Chemoprevention Research Center reported leaf dimensions of 2.5–9 cm in length and 2–5 cm in width (CCRC UGM, 2008). Compared to these references, the leaf size of 'Nimas Agrihorti' falls within the broader range, classifying it in the large-leaf category. This characteristic is important, as leaf size is known to influence the photosynthetic rate, which is associated with plant productivity (Setyanti et al., 2013; Yustiningsih, 2019; Zulkifli et al., 2022). When compared to other lime cultivars, such as 'Nipis Borneo', 'Nimas Agrihorti' demonstrated superior morphological traits, as summarized in Table 1.

Table 1. Comparative morphological characteristics of *Citrus aurantifolia* 'Nimas Agrihorti' and 'Nipis Borneo' cultivars.

Plant morphology	'Nimas Agrihorti'	'Nipis Borneo'
Canopy shape	Erect	Round
Stem color	Grey	Greenish brown
Leaf shape	Ovate	Elliptic
Leaf color	Green	Green
Flower shape	Compound	Compound
Flower color	Green	Light green
▪ Flower petals	White	White
▪ Stamen	Yellow	Dark yellow
▪ Another	Yellowish green	Light yellow
Flower type	Compound	Compound
Flowering time	Continuously	January, March, July, and November
Harvest time	Continuously	April, June, September, and December
Fruit shape	Ellipsoid	Round
Skin color	Yellow	Yellow
Flesh color	White	White
Flesh taste	Sweet	Sour
Seed shape	Ovoid	Elliptic
Seed color	Cream	White bone

Although both 'Nipis Borneo' and 'Nimas Agrihorti' cultivars shared similar exocarp and pulp coloration, 'Nimas Agrihorti' was notably sweeter in taste. In addition to differences in morphological traits of the tree and fruit, a comparative analysis of their quantitative attributes is presented in Table 2.

The quantitative character indicated that 'Nimas Agrihorti' was a citrus cultivar characterized by high water content (60%) and low acidity (0.45%) (Table 2). Although its sugar content (8.3%) was

lower than that of 'Nipis Borneo' (10.8%), the overall taste profile of 'Nimas Agrihorti' remained favorable. These attributes contribute to its superior sensory qualities compared to other citrus cultivars. Given these compositional advantages, 'Nimas Agrihorti' demonstrated promising potential for development as a biopharmaceutical or medicinal citrus cultivar.

Table 2. Quantitative characterization of *Citrus aurantifolia* 'Nimas Agrihorti' in 2020 and comparative analysis with 'Nipis Borneo'.

Characteristics	'Nimas Agrihorti'	'Nipis Borneo'
Plant height (cm)	156–214	550
Stem diameter (cm)	6.51	13.8–29.0
Leaf size		
▪ Length (cm)	11.48	6.3–8.0
▪ Width (cm)	5.46	2.8–4.1
Fruit size		
▪ Length (cm)	5–6	3.5–4.7
▪ Diameter (cm)	5.65–5.92	3.7–5.1
Thickness of fruit skin (mm)	2.40–3.81	1–2
Water content (%)	60.2	37.25–43.96
Sugar content (%)	8.3	10.2–10.8
Vitamin C content (mg/100 g)	34.8	53.66–55.58
Acid content (%)	0.45	11.86–15.53
Number of segments per fruit	10	10–12
Weight per fruit (g)	72–80	30–70
Fruit number per plant	80–120 (on pot)	3,000–4,000 (in the field)
Percentage of edible fruit part (%)	70–75	71–74
Production per plant (kg)	10–15 (on pot)	220,223 (in the field)
Age of mother plant (years)	11	25

Potentials 'Nimas Agrihorti' as Biopharmaceutical

The fruit production of 'Nimas Agrihorti' began at 2.5 to 3 years after grafting, with each plant yielding approximately 10 kg of fruit. With a planting density of 400–500 trees/ha, the estimated yield reached around 5,000 kg/ha. As the plant matures, its productivity tended to increase, 'Nimas Agrihorti' also showed strong potential for commercial development due to its competitive traits, including large fruit size (72–82 g), yellow exocarp, sweet flavor, a vitamin C content of 34.8 mg/100 g, and low acidity at 0.45%. A summary of its chemical properties relevant to biopharmaceutical development is presented in Table 3.

The extract yield of 'Nimas Agrihorti' was 44.13%, placing it in the moderate category relative to other citrus cultivars. The extract yield was lower than that of 'Sitaya Agrihorti' (59.05%) and 'Krisma Agrihorti' (54.67%), while it was notably higher than 'Nagamik' (14.66%) and 'Sari Agrihorti' (22.88%). This intermediate extract content indicates its suitability as a raw material for citrus-based beverages with competitive functional properties. The sugar content of 'Nimas Agrihorti' was 8.30%, which is comparable to 'Krisma Agrihorti' (8.68%) and 'Chokun' (8.60%), and significantly higher than that of 'Sitaya Agrihorti' (4.21%) and 'Sari Agrihorti' (3.11%). The natural sweetness of 'Nimas Agrihorti' enhanced its appeal to consumers seeking flavorful, yet health-oriented fruit options, positioning it well for fresh consumption or use in functional beverage formulations.

Table 3. Chemical composition analysis of *Citrus aurantifolia* 'Nimas Agrihorti' and other citrus cultivars.

Cultivars	Extract (%)	Sugar (%)	Acid (%)	Vitamin C (mg/100 g)
'Krisma Agrihorti	54.67	8.68	1.85	22.52
'Chokun'	36.16	8.60	0.50	17.98
'Sitaya Agrihorti'	59.05	4.21	0.24	21.55
'Nagamik'	14.66	5.31	13.70	26.17
'Sari Agrihorti'	22.88	3.11	19.16	31.46
'Nimas Agrihorti'	44.13	8.30	0.45	33.47
'Nipis Borneo'	-	8.60	3.392	34.80

One of the distinguishing features of 'Nimas Agrihorti' was its exceptionally low acidity level at 0.45%, the lowest among the citrus cultivars evaluated. This significantly differentiates it from high-acid cultivars such as 'Nagamik' (13.70%) and 'Sari Agrihorti' (19.16%). The mild acidity enhances its palatability and makes it suitable for individuals with dietary limitations, such as those experiencing acid

reflux or gastric sensitivity. Furthermore, the low acid profile expands its potential for use in culinary and industrial products that require low-acid extracts.

In terms of nutritional composition, 'Nimas Agrihorti' had high vitamin C content of 33.47 mg/100 g, closely following 'Nipis Borneo' (34.80 mg/100 g) and exceeding other cultivar such as 'Krisma Agrihorti' (22.52 mg/100 g) and 'Sitaya Agrihorti' (21.55 mg/100 g). This substantial vitamin C concentration supports its use as a functional food with antioxidant properties, contributing to immune function, reduction of oxidative stress, and collagen and carnitine biosynthesis—factors critical to maintaining overall health and body resistance (Ivakdalam & Rehena, 2020; Yulianto et al., 2022). The increasing global consumption of citrus extracts reflects rising awareness of the health benefits associated with their bioactive components (Ali Abadi et al., 2022; Shafiee & Minaei, 2018).

'Nimas Agrihorti' also demonstrated a rich profile of phenolic compounds, particularly unique flavonoids such as methoxyflavones (MFs), coumarins (Cs), and furanocoumarins (FCs), known to enhance antioxidant activity (Li et al., 2021; da Silva et al., 2013). The extract is especially abundant in hesperidin—a dominant flavanone—followed by narirutin, commonly found in citrus species. These phenolic compounds were reported to exhibit potent bioactivity, including anticarcinogenic, antitumor, antimutagenic effects, and the ability to lower risks associated with colorectal, esophageal, gastric, and stomach cancers, as well as stroke (Gao et al., 2022).

Economic Potential Based on Feasibility of 'Nimas Agrihorti' Cultivation

The assessment of farm feasibility for newly developed citrus cultivars offers valuable insights into their economic viability and sustainability. 'Nimas Agrihorti' presents strong commercial potential due to its favorable combination of sweetness and elevated vitamin C content. These traits make it suitable for fresh consumption, and it is also well-positioned for use in functional food, pharmaceutical, and nutraceutical product development. As a result, it holds promise as a high-value commodity and a multifunctional ingredient across various industries.

The morphological characteristics of 'Nimas Agrihorti', as described in section 3.1, demonstrated superiority compared to other citrus types. The introduction and promotion of new cultivars were also assessed through their economic viability, which serves as a key consideration for growers in determining the sustainability of continued cultivation. The economic performance of 'Nimas Agrihorti' was analyzed in the following section.

The cultivation of the 'Nimas Agrihorti' citrus cultivar demonstrated strong economic feasibility, with a total production cost of IDR 42,640,000.00/ha (Table 4). The most substantial expenditure was land rental, comprising nearly half of the total cost, followed by key inputs such as seedlings, labor, fertilizers, pesticides, and organic manure. These factors collectively shaped the production expenses, which remained manageable and suggested the cultivar suitability for efficient cultivation. Over 2-year cultivation cycle, 'Nimas Agrihorti' achieved a cumulative yield of 12,000 kg, reflecting an increasing trend in productivity. The first year produced 3,000 kg with a revenue of IDR 30,000,000.00, while the second year yielded 9,000 kg, generating IDR 90,000,000.00. This upward trend indicates the plant's enhanced productivity as it matures, emphasizing its performance under optimal agronomic practices.

With total revenue reaching IDR 120,000,000.00 and net income at IDR 77,360,000.00, the farming of 'Nimas Agrihorti' proved to be highly profitable.

The R/C ratio of 2.81 further confirmed the economic sustainability of this cultivation. Efficient resource management enhanced the cost-benefit ratio, and the productivity gains in the second year reinforced the long-term potential of this citrus cultivar. Taken together, the agronomic strengths and economic returns position 'Nimas Agrihorti' as a promising commodity for both smallholder and commercial farming operations.

Table 4. Farm feasibility of *Citrus aurantifolia* 'Nimas Agrihorti'.

No.	Item	Unit	Quantity	Price (IDR)	Total (IDR)
1	Land rent	ha	1	20,000,000	20,000,000
2	Seeds	Trees	600	15,000	9,000,000
3	Manure	Sacks	150	15,000	2,250,000
4	NPK fertilizer	kg	200	12,000	2,400,000
5	Pesticides	Package	1	2,000,000	2,000,000
6	Labour wages	Person per day	2	50,000	7,000,000
Total cost					42,640,000
1	'Nimas'	kg	3,000	10,000	30,000,000
2	'Agrihorti citrus'	kg	9,000	10,000	90,000,000
Total revenue					120,000,000
Total income					77,360,000
R/C					2.81

Conclusion

'Nimas Agrihorti' is recognized as a promising citrus cultivar with significant potential for development as a biopharmaceutical product. Its morphological traits contributed to enhanced productivity under optimal agronomic conditions. Despite its relatively low sugar and acid levels, the fruit offered a mildly sweet flavor and contains a high concentration of vitamin C, supporting its classification as a source of bioactive compounds for therapeutic applications. The economic analysis reinforced its potential, with a favorable R/C ratio of 2.81, indicating high profitability. These attributes aligned well with the increasing demand for biopharmaceutical and functional food products in both domestic and international markets. Therefore, 'Nimas Agrihorti' represents a strong candidate for advancement as a medicinal plant and high-value agricultural commodity.

Conflict of Interest

All authors have no conflicts of interest to disclose.

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