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RESEARCH ARTICLE
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The Role of DNA Testing in Measuring Oil Palm Seed Purity for Quality Assurance: a Case Study in Indonesia

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ABSTRACT

Palm oil belongs to important commodities to support food and energy security, especially for some tropical countries. To increase productivity, quality and sustainability of palm seed production, quality is an important key factor. Various tests of seed purity levels can support this effort. One of them is DNA testing which has recently been widely developed. However, in its implementation, it still faces challenges regarding when the test should be used and at what stage in the supply chain. The application of effective DNA testing is intended to provide a solution to ensure the purity of oil palm seeds and seedlings. The characteristics that determine high-quality and cheap oil palm seeds are found using descriptive analysis of field survey data and questionnaires. In oil palm nurseries, DNA testing application models can be used and have high accuracy. This paper conducts a study related to accuracy, effectiveness and weaknesses that must be improved.

Keywords: Oil palm seed, Genetic testing, Purity-quality, National standards, Nurseries

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INTRODUCTION

Oil palm is a plantation crop that is widely cultivated in various tropical countries and is an important commodity due to its wide use in the food industry, energy and various other industrial derivative products. From 1997 to 2018, global oil palm production increased from 100 million metric tons to 300 million metric tons and expanded to 21 Mha in 2018 (FAO, 2018; Xu et al., 2023). Currently the top 5 world biggest producers are Indonesia 59%, followed by Malaysia 24%, Thailand 4%, Colombia 2% and Nigeria 2% (USDA, 2023).

Commercial cultivation of palm oil began in 1911 in Indonesia and 1917 in Malaysia. Today, it has become the most widely consumed edible oil globally. Indonesia and Malaysia currently dominate the palm oil export market, jointly accounting for approximately 86% of the world's total production. Oil palm plays a vital role in the economies of several countries, particularly Indonesia, which export significant amounts of its products, including oil, meal, and various derivatives (Murphy et al., 2021). In Indonesia, oil palm plantations are categorized as small holder plantations (PR), and large plantations. For large plantations, they are owned by state and private plantation companies (PBN and PBS). Recently, the Minister of Agriculture set the area of oil palm plantations to reach 16,381 million hectares spread across 26 provinces in Indonesia (MOA, 2019). The recent official number indicated the rapid expansion of oil palm plantation and the growing population of people depending on palm oil industry directly and indirectly.

With the trend of world fossil oil production, the role of palm oil for fuel and chemical raw materials (oleochemicals) for the manufacturing industry will increase, although the development of electrical vehicles (EVs) will slow the rate of increase in vegetable oil consumption. On the other hand, palm oil is also one of the country's most important industrial commodities. This commodity earns significant foreign exchange, contributes to the regional economy, creates jobs and reduces poverty, and can help reduce emissions by exploiting underutilized and degraded land (Goenadi, 2008). To boost product output, oil palm plantation needs high yielding Tenera hybrid seeds (Rethinam & Murugesan, 2022). The national palm oil productivity is approximately 4 tons of oil per hectare per year. This Fig. falls short of the Indonesian National Standard (SNI), which is set at 6 tons of oil per hectare per year. PBS had the highest productivity, with roughly 4.5 tons of oil per acre, followed by PBN with 4.1 tons.

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PR is considerably lower, with only 3.4 tons of oil per hectare (Tasma, 2016). Meanwhile, with optimal productivity conditions, the predicted potential is 18.5 tons of oil/ha/year (Corley & Tinker, 2008).

To boost the production, oil palm plantations require high-yielding Tenera hybrid seeds (Rethinam & Murugesan, 2022). National oil palm productivity is around 4 tons of oil per hectare per year. This Fig. is still below the Indonesian National Standard (SNI) which is set at 6 tons of oil per hectare per year. PBS has the highest productivity, which is around 4.5 tons of oil per hectare, followed by PBN at 4.1 tons. PR is much lower, which is only 3.4 tons of oil per hectare (Tasma, 2016). Meanwhile, with optimal productivity conditions, the predicted potential reaches 18.5 tons of oil/ha/year (Corley & Tinker, 2008).

Currently, the Indonesian Government has launched a smallholder oil palm rejuvenation program (PSR) to encourage increased production, capacity, and capability of farmers through the Regulation of the Minister of Agriculture No. 18/Permentan/KB.330/5/2016 and the National Action Plan for Sustainable Oil Palm Plantations 2019-2024 through Presidential Instruction No. 6 of 2019. One of the programs to increase productivity and sustainability is Rejuvenation of Smallholder Oil Palm Plantations, which called "Peremajaan Kelapa Sawit Rakyat (PSR)" (Ardana et al., 2022). The crucial problem in this program is the needs of a supporting system for ensure the circulation of standardized seeds, especially for small plantations, because there is a circulation of low quality or substandard seeds in the and supply chain, especially for small plantations (Prasetya et al., 2025). To mitigate the circulation of low-quality seeds, a sustainable certification system has been developed to guarantee the circulation of standardized seeds through government regulations (MOA, 2020). To support this program, testing the purity of seeds with high accuracy and easy to apply plays an important role.

The availability of superior oil palm seeds is primarily to support the community oil palm rejuvenation program. This program is also to increase the productivity of plantations, especially those that are over 25 years old and very unproductive because they are only able to produce less than 10 tons of fresh fruit bunches (FFB) per hectare per year (MOA, 2023). The use of superior oil palm seeds is very important for the success of the oil palm plantation rejuvenation program. This program is also an important alternative to reduce the expansion of plantation areas and can support environmental protection and preservation. Based on experience in several countries, success in developing sustainable oil palm plantations by implementing technical standards for seed standards (Corley & Tinker, 2008; Brandi et al., 2013). In Indonesia, the oil palm plantation rejuvenation program targets to achieve a productivity of 60 million tons of CPO per year by 2045 without land expansion (Permatasari et al., 2024).

Standardized Oil Palm Seed and Certification

Ensuring the use of quality oil palm seeds is a key factor for the success of the oil palm plantation replanting program. The implementation of standards and certification by providing labels (blue labels) has been carried out based on the regulation from the Ministry of Agriculture No. 436/Kpts/LB.320/7/2004. This is supported by the implementation of the National Standard SNI 8211:2015 (Table 1; Table 2). This standard stipulates the quality requirements for oil palm seed production, germination requirements, technical packaging requirements, growth requirements, and after-sales services. The quality requirements in this standard are used as an effort to improve the quality assurance of oil palm seeds (Issaoui & Delgado, 2019). Oil palm seed germination greatly affects the productivity of oil palm plantations (Herdiansyah et al., 2020).

Ideal palms should contain at least the following characteristics: CPO yield of 8-9 tons/ha, resistance to diseases, amenable to mechanized harvest, slow increment of trunk height/vertical growth (< 35cm/year), longer usable time (e.g., > 30 years), tolerance to biotic (e.g., drought) and abiotic stress, efficient use and conversion of fertilizers, better fatty acid profile for cooking, and ideal fatty acid profile for human consumption (Yue et al., 2021). Palm oil with all the above properties is very difficult to find. The genetic approach allows us to gain knowledge about the genetic composition of important traits in oil palm. Thus, there is an opportunity to improve palm oil yields through plant breeding (Yue et al., 2020). The sequencing of the oil palm genome provides an important resource for rapid

Table 1: Requirements for technical procedure breeding according to national standard SNI 8211-2015

No	Benchmark	Requirements
1	Population base Dura and population base Tenera or Pisifera	Own information family tree complete and documented lineage _ with Good
2	Method selection	Through progeny testing with method that has tested in a manner scientific
3	Testing Progeny	
	a. Test location	Specification pedo-agroclimatic certain
	b. Plan cross	Fulfil rule knowledge breeding and standard statistics
	c. Draft test	Fulfil rule knowledge breeding and standard statistics, at least have One cross standard and/ or every tested cross can connected One with other
	d. Vegetative observation	At least twice during testing
	e. Observation production	Average from at least four observations year harvest consecutive
	f. Bunch analysis	Analysis equal oil with method *Soxhlet*, by the time the bunch is already develop perfect at least 4 takes a sample at 6-month intervals
	g. Results data testing	Documented with Good
4	Criteria Selection Cross	
	a. Production of fresh fruit bunches (FFB)	≥ 175kg/tree/year
	b. Palm products (crude palm oil [CPO] + palm kernel oil [PKO])	≥ 6tons/Ha/year
	c. yield factory (yield laboratory x 0.855) equivalent with method *Soxhlet*	≥ 23%
	d. Growth rise (measured after plant 6 years old after plant)	≤ 80cm/year
5	Method Inspection	Appendix A

Sources: (BSN, 2023).

Table 2: Requirements quality sprouts according to national standard SNI 8211-2015

No	Benchmark		Requirements
1	Quality genetics		
	a.	Origin material plant	Garden seeds that have set by the authorities competent on the name of the Minister of Agriculture
	b.	variety	Seed superior plant plantation
	c.	Purity	No not enough of 98% sprouts produce coconut palm type Tenera based on pollination blank
2	Quality pathological		OPT free
3	Quality physique		
	a.	Weight seed	Minimum 0.8g
	b.	Radicle and Plumula	
	-	Long	The radicle is at least 0.3cm, and The plumule is at least 0.3 cm
	-	Colour	White yellowish
	-	Direction grow	opposite direction
	-	appearance	Can be distinguished clearly

Sources: (BSN, 2023).

genetic improvement of complex traits, thereby helping to achieve the sustainability of palm oil (Ithnin & Kushairi, 2020; Ong et al., 2020). The best quality seeds are then marked using labels or laser marking depending on the technology applied to the seed producer (Prasetya et al., 2025).

To ensure the oil palm industry's optimum oil yield in the future, both genetic purity and sound farming methods are equally important. (Teh et al., 2019). Monitoring the purity of oil palm seeds can also reduce the risk of failure after replanting. (Ardana et al., 2024). This research aims to investigate the role of DNA testing in assessing oil palm seed purity as a key aspect of quality assurance, focusing on a case study in Indonesia. The study will explore the efficiency of DNA testing in seed certification and its contribution to improving productivity and sustainability in the country's palm oil sector.

To identify superior seeds, there are two aspects that must be considered, namely conformity with the type and purity of superior seeds. Both parameters and criteria are described in the regulations and national standard of Indonesia (SNI standards). Several testing methodologies have been developed, but they cannot always be applied because they are considered ineffective and very costly and often unproven (Heidt et al., 2020). The developed methodology must be able to face these challenges and can be applied in line with the sustainable new plantation planting program. The methodology must be able to support testing parameters that comply with purity standards for the quality requirements of germinating seeds and seedlings in the National SNI 8211: 2015 standard (Wahono et al., 2023; Isharyadi et al., 2024). Testing that previously relied on physical observations of plants was considered to have low accuracy. Based on the regulation of Ministry of Agriculture (MOA) "Kementan No. 321 / Kpts / KB.020 / 10/2015 and No. 76 / Kpts / KB.020 / 10/2017), permits to release superior seeds using blue labels must be supported by the right methodology. DNA testing methods are rapidly developing, and their costs are very low, making them a good choice for determining the purity of oil palm seeds. The success of the purity determination method at the beginning of planting is very helpful for small plantations to ensure the quality of the oil palm seedlings planted. The old practice that for small plantations to know whether the planted seedlings are superior or not after the plants are 3 or 4 years old is very detrimental to farmers because they have spent resources and costs for land preparation, fertilizers, pesticides, labor wages, and investment capital) are wasted, and most importantly is the time that is lost when the planted seedlings are inferior Tenera seeds.

Genomic Technology Innovation

Genomic technology is being used to boost oil palm productivity. Reference genome maps for two oil palm species have been created using genomic technologies (*Elaeisguineensis* and *Elaeis oleifera*) (Seyum et al., 2021). Shell gene (Sh) is a gene that regulates oil yield heterosis and the formation of mantle fruit. This gene specifies the thickness of the lignin layer in the seed shell, which is used to identify the kind of oil palm based on the thickness of the fruit shell (Purba et al., 2001). Because of a cross between the dura and Pisifera kinds, Tenera was created (Singh et al., 2013; Corley & Tinker, 2015; Bilska & Szczecinska, 2016). Fig. 1 shows the cross section of varies oil palm seed type Dura, Tenera and Pisifera. Genomic technology's capacity to identify molecular markers of the Sh gene aids in precisely distinguishing non-Tenera oil palm seeds from oil palm seeds or seeds in the plantation at an early stage, preventing planter losses and ensuring high output (Singh et al., 2013). By finding superior Tenera seeds quicker and at a lesser cost than waiting for the plant to produce, this technical innovation boosts efficiency and efficacy. DNA testing technology can determine various types of mutations, which will accurately determine the type of seed and its purity. Whenever DNA testing technology does not detect multiple types of mutations at the same time, the inaccuracy can be catastrophic; for example, Dura can be mistaken for Tenera, and even Pisifera can be mistaken for Tenera. It's crucial because the country's palm oil business has released around 53 varieties of superior Tenera Hybrid since 1984.DNA testing can also be implemented on plantations resulted from the PSR program, as part of the monitoring and assessment of finished replanting to help support the program. Marker-assisted selection (MAS) has the potential to accelerate genetic improvement (Ruane et al., 2007; Bai et al., 2017). Utilization of genome sequence for charaterisation and variety development haben been also open various achivemen of improvemen of quality of palm oil seeds (Singh et al., 2022; Ooi et al., 2023; Xu et al., 2024).

DNA Test at the Nursery Stage

In the nursery, grown seed testing is generally carried out to ensure seed purity at the nursery stage (Pedrini & Dixon, 2020). In general, in nurseries, germinated seeds obtained from seed sources will go through two stages: the pre-nursery stage (1-3 months) and the main nursery stage

(3-12 months). In nurseries, DNA testing is carried out by sampling at a depth of 10% to represent seed purity. To assist DNA testing in large nurseries that grow ten or one hundred thousand seedlings, seedlings are arranged into groups of 1,000 seedlings because seedlings from crosses or the same genetic background are also maintained in nurseries (Ram et al., 2022). Population labels will be attached to each seedling from each group of 1000 seedlings, and 100 seedlings will be randomly selected for leaf sampling and DNA testing. Furthermore, the purity level of Tenera seedlings per group can be determined after testing on the SHELL. The cost of testing per seedling is IDR 4,290, and it relies on a 10% sampling approach. The cost of DNA testing for one hectare is IDR 643,500 (15 x IDR 42,900 every DNA test). There is an additional cost associated with DNA testing, such as the sample collection fee (IDR 2,574 per seedling) and the population labelling costs with plastic labels in this experiment.

Fig. 1: Cross section of varies oil palm seed type Dura, Tenera and Pisifera (Disbunkaltim, 2025).

MATERIALS & METHODS

As previously stated, the purity of superior palm seeds plays an important role in producing palm oil productivity and quality. Purity testing available at companies varies. This study relies heavily on data and information obtained from seed producing companies (seed sources) and nursery owners, as business actors who produce oil palm seeds and seedlings and are legally registered with the Ministry of Agriculture and will test their products using DNA testing. The descriptive analysis method is used in this study. Quantitative and qualitative data are used in data analysis. The statistical average or mode was also used in this study to determine the data representation of seed sources and nurse owners. Questionnaires and field surveys were used to collect data on the elements that influence the growth of oil palm seeds and seedlings as well as situations or phenomena seen in the field, such as genetic abnormalities (Mardalis, 2008; Nazir, 2013; Nchu & Koona, 2020; Defitri & Marcelian, 2023). The respondents of this study are seed sources and nursery owners, officially registered with the Ministry of Agriculture. Based on data from the Directorate General of Plantations, there are 19 seed sources and 123 nursery companies. And all seed source companies act as oil palm nursery owners. Field surveys were also carried out in following Riau Province, West Java Province, South Sumatra Province and North Sumatra Province.

A simple cost-benefit analysis based on the lowest total cost vs the number of improved seeds obtained was used to establish the usefulness of DNA testing (Bekele et al., 2019). The costs incurred by oil palm seed sources and nursery owners are the average anticipated costs, omitting land leasing costs, material or material inflation values, and depreciation of machinery or tools employed throughout the development process. These expenses will be used to determine the lowest overall expenditures that must be incurred to ensure superior oil palm seedlings, such as the cost of germinated seeds, equipment, fertilizers, pesticides, and labour wages, among other things. As a result, the cost-benefit analysis is strongly linked to making judgments about assuring better seedlings by DNA testing at the four stages of oil palm seedings development, including before germination, Pre-Nursery, Main-Nursery, and ready-to-plant seedlings.

RESULTS & DISCUSSION

To produce oil palm seeds, all the requirements outlined in national standards and regulations are used as references by producers, although there are still many sub-standard seed trades and various possible causes, including the most important one is the absence of labels and certificates on the traded products (Prasetya et al., 2025). Requirements for the level of seed purity for national standards: no less than 98 percent of germinated seeds must be from Tenera, and less than 5% Dura contamination must be present for regulations. However, it is not possible to determine the purity of the sprouts because there are no good and easy-to-implement test facilities. Based on these field facts, it is recommended to use DNA testing to determine the level of purity of oil palm seeds to comply with national standards.

Superior Seed Production Activities

Based on the oil palm seed regulation, all business actors in the oil palm industry are required to conduct DNA testing to ensure that there are no oil palm plants with productivity of less than or equal to 10 tons of FFB per hectare per year. The genotype of the parent plant will affect the viability of the seeds produced. In addition, the variety or genotype of the hybrid coconut parent plant also affects the success rate of seed production from crossbreeding. All producers are required to carry out class readiness related to facilities and cost analysis. Field surveys are used to determine the costs incurred during the seed nursery process. Materials and tools, as well as labour wages for activities, are two main cost groups. Companies can identify wage information although these wages vary depending on the minimum wage in each region, they are not included in the data so that the total predicted data per stage and seed purchase costs can be presented. The following table shows a list of cost items recognized by producer and breeder businesses (Table 3).

Table 3: Identification of costs on seed production activities

No	Group	Sub-group	Cost items
A	Materials and tools	Tools	Hoes, shovels, water pump, sprayer knapsack, plastic bucket, plastic hose ¾ inch, small polybag 14cmx23cmx0,1mm, and big polybag 30cmx30cm
		Seed	Seed, and seed escort
		Fertilizer and pesticides	Urea, NPK, organic fertilizer, herbicide, insecticide, and fungicide
B	Labour by activities	Sprouts and Pre-Nursery	Polybag filling, planting, sprinkling, fertilization, and security of seeds
		Main-Nursery and ready-to-plant seeds	Sprinkling, fertilization, pest control, weed control, security of seeds, and packaging of seeds

The average number of seeds produced by one parent tree per cross was 1,292 germinated seeds, according to the questionnaire. The interquartile range (IQR) using the inner quartile range of the data on the average number of seed production from producing companies is 1,100-1,439 germinated seeds, as indicated by the field that presents the IQR using the inner quartile range of the data on the average number of seed production from producing companies. The number of seeds generated from each cross is known to be dependent on the age of the mother plant, according to the site survey. The quality of the seeds is also influenced by environmental factors such as the age of harvest, environmental conditions, the effectiveness of pollination, and the maturity level of male and female flowers (Low et al., 2020). One outlier or data with an extreme value (2.100) was detected in the data distribution (skewness), as indicated in the Boxplot image (Fig. 2).

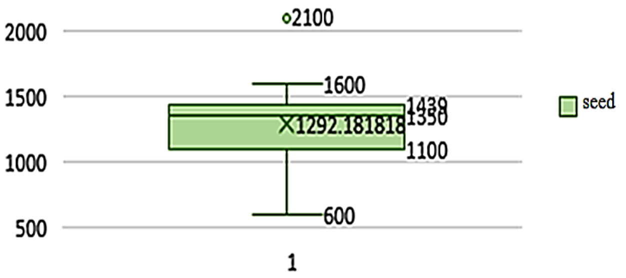

Fig. 2: Boxplot data on the amount of seed production in one cross.

Seed Producer Facilities and Capabilities

The level of attention from business actors for seedlings research initiatives is relatively high. The percentage of questionnaire responses from seed producing entities reached 58 percent of the total seed sources and nursery owners. The first question, which was directed at seed production businesses, concerned the company's facilities and ability to do DNA testing. The following diagram in Fig. 3 shows the company's response to the question related to the availability of DNA testing. Panel A indicates the availability of manufacturer's facilities for DNA testing, Panel B. Experience of manufacturers conducting DNA testing, and Panel C. Ability of producers to perform DNA testing. Panel A shows that 69% of businesses have available facilities for DNA testing, while 31% do not. Panel B highlights the experience of manufacturers, with 50% having experience conducting DNA testing and 50% not engaging in such practices. Lastly, Panel C indicates that 69% of producers can perform DNA testing, while 31% are not. This data reflects the varied capabilities of businesses in the seedling production industry regarding DNA testing, suggesting both opportunities for improvement and challenges in accessibility.

Based on field surveys and information gathered from seed producers, many companies have the equipment and capabilities to conduct DNA testing, but they do not carry out them for on germinating seeds or seedlings ready for planting. They prefer to use DNA testing for marking parent trees with the main aim of identifying soil that is resistant to diseases, especially those caused by the fungus Ganoderma sp. As it is known that the threat of this disease is very difficult to control, many producers carry out mitigation as early as possible (Anuar et al., 2024; Hussain et al., 2025). One of the reasons for this marking is to facilitate the marketing of seeds and producers will gain profits faster. There are several companies that do not have DNA testing facilities for detection related to the existence of Ganoderma disease, they must conduct testing in external labs in the area that are not available, so they have to send samples for this test abroad and it will cost much more. In addition, there are only a few companies that sell DNA testing services on an international scale.

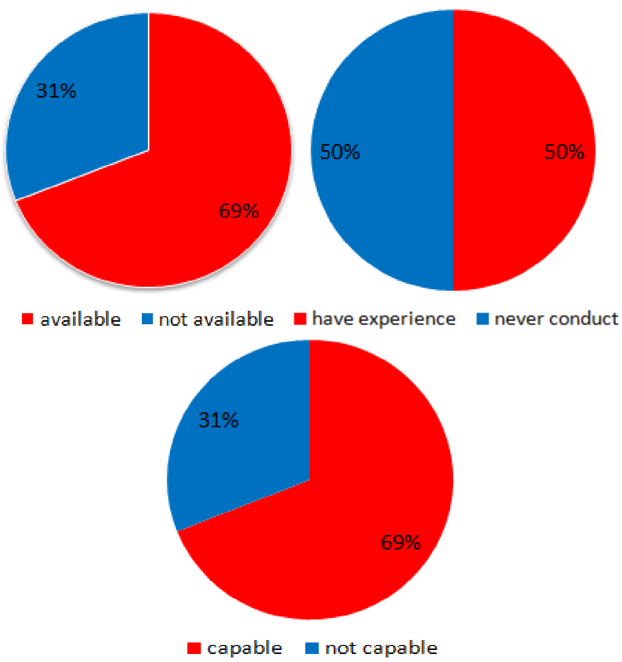

Fig. 3: Seed producer facilities and capabilities for DNA testing.

Minimum Sales of Seeds and Prices

DNA testing is closely related to the number of samples to be tested, which depends on the marketing volume. Most producers have a minimum order of 100, 200, or 500 germinated seeds. Only one producer requires a minimum purchase of 150 germinated seeds (Fig. 4). In addition to the average number of seeds mentioned above, the average selling price of germinated seeds from producers to nursery owners, plantation business actors, or smallholders is IDR 8,927. Meanwhile, the selling price range for oil palm seeds ranges from IDR 8,000 - 9,500 and the lowest is IDR 7,500.

In general, the price of oil palm seeds does not differ much between producers. The price of oil palm seeds tends to be stable, except when the demand for seeds is very high due to high palm oil prices, as happened several years ago. The price of seeds in that year increased sharply along with the increase in the number of seed requests in the same year, as an impact of the increase in palm oil prices (Bai et al., 2017). On the other hand, some vendors sell seeds in foreign currency for USD 0.85 (around IDR 12,300), an outlier in the data distribution (Fig. 4). Furthermore, some businesses offer small farmers, and community's discounts or subsidies ranging from 5% to 10%. Meanwhile, producers offer higher prices to corporations. For ready-to-plant seedlings, producer companies sell for around IDR 40,000 per seedling and this is among the lowest prices. Some producers sell for IDR 42,000 per seedling.

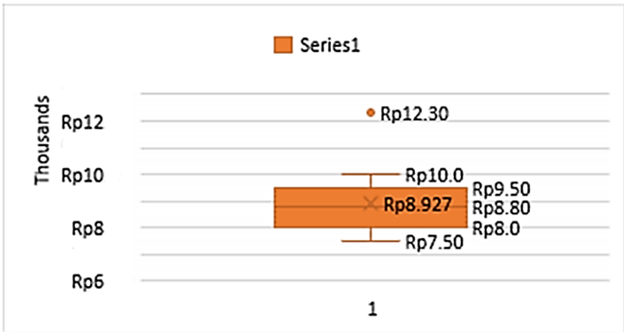

Fig. 4: Boxplot producer selling price data per sprout.

Diseases and Losses

As found in other plantation crops, oil palm plantations are inevitably threatened by pests and diseases that can cause yield losses (Hussain et al. 2025). Several diseases that commonly attack oil palm seeds in the seed production process were found during the site survey. Genetic abnormalities are responsible for various phenotypes, including rolled leaves, crown disease, rotating leaves, yellow thrips leaves (*Chimaera*), barren/bald, narrow leaflets, wrinkled leaves, and others. In addition to genetics, diseases caused by fungi are also found, including leaf spot disease caused by the fungus *Culvularia sp*.; blast disease caused by the fungus *Rhizoctonia lamellifera* and *Phytiumsp* and others. For seedlings affected by abnormalities, they are usually discarded or destroyed. However, fungal seeds can be controlled in several ways, such as using insecticides or pruning diseased leaves and isolating seeds from other plants (Liwang et al., 2012; Rahmi, 2015). Another technology that is still being developed is the detection of the ability of plants to produce lignin because it is assumed that the higher the lignin content, the higher the degree of resistance to Ganoderma (Sharma & Tan, 1997). Based on the results of field inspections and questionnaires from producers and breeders, several types of diseases or abnormalities have been found in the pre-nursery and main nursery stages. Furthermore, the rate of los or reduction in the number of seedlings was measured at each stage of the superior nursery production process. The average loss in the number of seedlings was 6.03 percent for pre-nursery, 6.03 percent for main-nursery, and 3.05 percent for ready-to-plant seedlings, according to data from the questionnaire (Table 4). Pre-nursery oil palm nurseries losses by 2.5%-10%, main-nursery oil palm seedlings shrank by 2%-10%, and ready-to-plant oil palm seedlings shrank by 1%-5%. The average standard deviation for each step produced a wide range of values (3.58). This is influenced by the location of the land, land conditions, and the size of the seed producer or breeder companies.

Table 4: Identification of disease and rate of seed losses

No	Stage	Disease	Seed los rate	
			Site survey	Questionnaire
1.	Pre-Nursery	Genetics		
		• Grass leaf		
		• Rolled leaf		
		• Chimera	5%	6%
		Fungus		
		• Anthracnose	(1-3 months)	(1-3 months)
2.	Main-Nursery	Genetics		
		• Crown disease		
		• Narrow pinnate		
		• Stunted		
		• Sterile/Baren		
		• Short internode	10%	6%
		• Wide internode		
		• Etiolation	(3-18 months)	(3-12 months)
		Fungus		
		• Leaf spots disease		
		• Gray spots disease		
3	Ready-to-plant seeds	Genetics		
		• Crown disease		3%
		• Narrow pinnate		(12-24 months)
		• Stunted		
		Fungus		
		• Bud rot		
		• Marchitez disease		

Effectiveness of DNA Test Implementation for Providing Superior Seed

As mentioned before the importance of risk mitigation lead many activities as efforts to avoid a sub-standard seed with poor productivity. On other hand, the best quality or superior seeds that are healthy (parents are free of genetic disease), correct (varieties have been registered), and pure must be used in appropriate acts (meets the maximum requirements for Dura contamination). DNA testing is projected to be the primary determinant and "guarantee" of high-quality seeds. Although the success of high oil palm productivity is also determined by good agricultural practices. However, considering the oil palm has a 25-year economic life, it is critical to cultivate the correct high-yielding seeds. Allowing errors upstream will have a negative impact on the entire value chain. DNA testing on seeds utilizes destructive methods, and seeds examined are no longer usable. A molecular approach that can be used to test the purity of oil palm through DNA fingerprint analysis is the Simple Sequence Repeat (SSR) technique (Okoye et al., 2016). This method can identify the purity of offspring based on information from both parents. The advantages of the SSR technique are that it has high polymorphism, is codominance, and is effective for distinguishing populations that are not affected by genotype interactions with the environment (Salomon-Torres et al., 2017). A seed is declared pure if the genotype possessed by the individuals in the offspring shows a pattern of inheritance of alleles from their parents based on Mendel's law of segregation (Dhulgande, 2023). However, if there is one individual who has an allele that does not match the parental allele information on 1 or 2 markers that are different from other markers, then the assumption is that a mutation has occurred in that individual.

In the production planning, it is in general, before calculating the cost of seed production, it is necessary to describe the average estimated total cost incurred per 1,000 seeds by the breeding company based on the questionnaire. The average purchase price of sprouted seeds is IDR 8,729. This price is slightly lower than the average selling price of sprouted seed producers (IDR 8,927). This shows that most of the breeding companies prefer the cheaper price of sprouted seeds from producers registered with the DITJENBUN. Considering the process of breeding is mostly done by breeding companies, the purchase seed price of IDR 8,729 becomes the calculation price. For the pre-nursery stage, the average total cost incurred by the breeder is IDR 5,136 per item, where the estimated range for the total cost incurred by the nursery company at this stage is between IDR 2,625 and IDR 6,425. Even though at this stage there are data including outliers with a breeder expenditure of IDR 12,500. The biggest cost in the main-nursery stage, the average total cost incurred by the breeder is IDR 12,259 per item, where the estimated range of total costs incurred by the company at this stage is between IDR 8,500 and IDR 15,954. At the ready-to-plant stage, the average total cost is IDR 4,835 per seedling, where the estimated range of total costs incurred by the nursery company at this stage is between IDR 2,523 and IDR 5,750. At this stage, there are also extreme data with an expenditure of IDR 11.250 (Fig. 5).

Considering the germination test is carried out by seed producers and the average number of seeds produced from one parent tree in one cross (1,292 sprouts), the value of 1290 becomes the basis for the calculation. Data on seed number reduction to genetic diseases have been identified by nursery companies. In this study, seed number reduction due to fungi/fungi or non-genetic diseases was not considered or assumed to be controllable or curable. Based on the data above, the effectiveness of DNA testing on oil palm seeds has been calculated in the following table (Table 5).

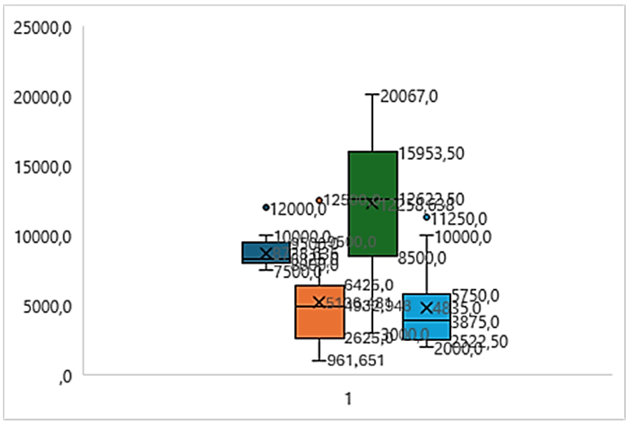

Fig. 5: Boxplot data on average breeder costs at each seed stage.

Based on the estimated PSR area by the Directorate General of Plantation (2018), e.g., oil palm planted in 1994 and 1995 must be replanted in 2020 and 2021 to reach 70,212 hectares and 85,992 hectares, respectively. For smallholders alone, 10.53 million ready-to-plant seeds are needed for 2020 and 12.90 million seeds for 2021. For 2021, model 4 requires 1.29 million times DNA tests (10%) and model 1 requires 10,000times DNA tests (average number of seeds produced). So, based on the superior seeds produced by Model 1 and Model 4, there is a difference of 2.71 million seeds as gab to meet the needs. Other than wasting time, cost efficiency has shown that the average difference in the cost of ready-to-plant seeds between both models is IDR 434. So, for 2021 seed needs, the cost efficiency is IDR 5,6 billion. This value does not include additional costs for 2,658 times DNA tests of preheated seeds.

Table 5: DNA test model in seed nurseries

Model	Item	preheated seeds	pre-nursery	main nursery	ready-to-plant	Total	number
First	cost	10133.947	5963.455	13374.005	4956.665		1.019
	test fee	4800.000					
	(-) broken test	872.864					
	(-) genetic disorder		626.390	588.895	279.521		
	sum	15806.941	6589.845	13962.900	5236.186	41595.741	40.830
Second	cost	11259.941	6626.061	14.859.554	5.507.405		1.104
	test fee		5200.367				
	(-) broken test						
	(-) genetic disorder		679.028	638.382	303.010		
	sum	11259.941	12505.456	15497.935	5810.416	45073.748	40.815
Third	cost	11259.941	6626.061	14860.005	5507.405		1.104
	test fee			4886.612			
	(-) broken test						
	(-) genetic disorder		679.028	638.382	303.010		
	sum	11259.941	7305.089	20384.999	5810.416	44760.444	40.531
Fourth	cost	11259.941	6626.061	14860.005	5507.405		1.104
	test fee				4737.687		
	(-) broken test						
	(-) genetic disorder		679.028	638.382	303.010		
	sum	11259.941	7305.089	15498.387	10548.102	44611.519	40.396

Concluding Remark

The value of the effectiveness of the application of DNA testing on oil palm seedlings is still not maximized, it is still expected that in the future this DNA test will include detection of genetic disorders and purity of hybrid tenera seed. Considering that the loss of seeds due to genetic disorders reaches 15% and the cost of breeding each stage is not cheap, it is hoped that in the future DNA tests for purity and genetic abnormalities are carried out on preheated seeds or before nurseries stage. The analysis of the purity of the seed is very necessary for quality control of crosses and early selection in the nursery in the oil palm breeding program. Oil palm breeding must be free from hereditary impurities both during crossing activities, the process of seed germination, and seeding to planting in the field. If the results of the analysis of seed purity are used for the purpose of selecting commercial parent trees, should be selected on the basis of individual seedlings. However, if the results of the analysis of hereditary purity are used for seed testing or as genetic material in the field, it is better to select seeds based on population selection. By eliminating non-Tenera contamination, comprehensive DNA-testing like Sh Testing can improve sustainability by increasing yields on existing planted lands.

Conclusion

SHELL genetic testing (Sh-Testing) would have a major positive economic impact while improving oil palm sustainability by optimizing the utilization of existing planted area. The additional cost of DNA tetsing is not something that is accepted by the industry easily. The reaosn is that the economic impact will be seen after the productive years of plantation.

In oil palm nurseries, purity is an essential factor in determining superior seeds. Guaranteed seed purity must be confirmed by DNA testing. Considering the cost of DNA testing is not cheap and easy to do, so it is necessary to consider the application of DNA testing at the most appropriate stage. Based on this study, it was found that DNA testing at the stage of ready-to-plant seeds was the most effective and efficient purity test. The difference in the effectiveness of the implementation of DNA testing in model 1 and model 4 is only IDR 434 per seed, but considering the need for oil palm seeds nationally, it can save quite a large budget. The rate of of oil palm seeds due to genetics and fungal diseases of 15% is also an important factor in the seedling to be taken into account in obtaining superior seeds.

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Data Availability: All the data is available in the article.

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