BIO Web of Conferences **246**, 00028 (2026) https://doi.org/10.1051/bioconf/202624600028
1st SRI-ICAS 2026

A comparison of the growth and yield of upland rice accessions under two different conditions: oil palm polyculture and natural conditions

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Abstract. Optimizing land under mature oil palm plantations offers an opportunity to support food production through the cultivation of upland rice. However, information regarding the adaptability of local upland rice varieties in oil palm-based polyculture systems remains restricted. This study aims to evaluate the growth and yield of selected upland rice genotypes from South Sumatra. Therefore, rice was planted under mature oil palm crops (polyculture) and compared with natural conditions (open fields). This study was conducted from November 2025 to April 2026 using two upland rice varieties (IPB 9G and Pandan Wangi) and four local genotypes (Dayang Rindu, Besar, Halus, and Seluang). The rice were planted in two cropping systems: under 18-year-old oil palm trees (polyculture), and in natural open fields (open space) without treatment replicates, thus not using a experimental design. Twenty sample plants were selected from each variety and genotype population. Growth and yield components of all rice varieties were analyzed using a t-test for each cropping system. The results of the study showed that light intensity under oil palm shade ranged from 14,000–16,000 lux, with temperatures of 30.26–31.56°C and relative humidity of 57.43–57.74%. All upland rice accessions and varieties exhibited reduced plant height and a prolonged flowering period under polyculture conditions. Upland rice accessions from South Sumatra, namely Seluang, Halus, and Besar, have the potential to be developed as intercrops in oil palm plantations.

1 Introduction

Indonesia is one of the countries with high rice consumption, and as such, it remains committed and is working hard to achieve sustainable rice self-sufficiency in order to strengthen national food security [1]. Amid the ongoing conversion of fertile agricultural land into non-agricultural areas, the optimization of suboptimal land has become a crucial strategy. One significant potential that can be fully utilized is land within oil palm plantations. Oil palm plantations in Indonesia are unique because they encompass two distinct land types: dryland and wetland, each requiring different management strategies [2]. The utilization of dryland among oil palm stands, particularly during the non-productive phase, presents a significant opportunity for food crop integration without disrupting the main crop.

Various accessions of upland rice (gogo rice) are considered to have potential for cultivation under the canopy of oil palm trees in oil palm plantations through an oil palm-rice polyculture system [3]. The main constraint in this polyculture system is the limited sunlight intensity caused by the shading of oil palm fronds. These shaded conditions directly affect the physiological processes and photosynthetic efficiency of rice plants. Nevertheless, the prospects for success remain wide open. Based on research by [4], there is a significant and positive correlation between grain weight per clump under shaded conditions and the number of productive tillers, total grain count, number of filled grains, and 1000-grain weight. This indicates that by selecting the appropriate morphological and agronomic characteristics, the productivity of upland rice in shaded fields can still be optimized.

South Sumatra Province is rich in the genetic diversity of local upland rice varieties that have long been cultivated and adapted to local environmental stress conditions. Farmers in this region generally plant various upland rice accessions during the rainy season, with local accessions such as Dayang Rindu and Seluang being the primary choices due to their perceived good resilience [5]. Both of these accessions possess superior genetic potential; however, their growth response and yield potential under oil palm shade (polyculture system) compared to unshaded conditions (natural conditions) still require more in-depth scientific study. Therefore, this study aims to compare the growth and yield of these upland rice accessions under two different conditions: an oil palm polyculture system and natural conditions. Through this study, it is hoped that the best upland rice accessions those most tolerant and adaptable can be identified for development in oil palm plantation areas, to support the program for expanding new planting areas and achieve national food self-sufficiency.

2 Materials and methods

This study was conducted at the Oil Palm Research Station, Faculty of Agriculture, Sriwijaya University, from November 2025 to February 2026. The research site is located at the geographical coordinates 3°13'11" S 104°38'22" E, Ogan Ilir Regency, South Sumatra. The

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oil palm trees used as shade in this study were 20 years old.

The materials used were upland rice seeds from 6 accessions/varieties, consisting of 1 control variety (IPB 9G) and 5 local accessions (Dayang Rindu, Besar, Halus, Pandan Wangi, and Seluang), as well as 20-year-old oil palm trees. The equipment used in the study included a 4x4 tractor (80 HP) for soil preparation, a measuring tape, Tools for measuring microclimates, an analytical balance, label boards, stakes, and writing materials.

This study employed a non-experimental design; all accessions and varieties were planted under polyculture/shade conditions (under oil palm frond shade) and non-polyculture/open space/ natural conditions (without shade).

Soil preparation in the inter-row areas of oil palm trees was carried out using a 4x4 tractor (80 HP). Once the soil was loosened, six planting plots were established, each measuring 3 x 3 meters. The same land preparation and plot establishment procedures were also applied to non-polyculture land (natural conditions/open land) as a control. Each plot was planted with a single variety/accession of upland rice using a planting spacing of 20 x 20 cm. The planting process involves placing 3 rice seeds into each planting hole. The total rice plant population obtained were 169 crops per plot. For physiological and agronomic observations, 20 sample crops were randomly selected (random sampling) from each plot.

The observed data on growth components and yields of upland rice include: Germination Rate (%): Calculated based on the number of effectively germinated planting holes per plot at 14 days after planting (DAP). Crop Height (cm), measured on sample crops upon entering the flowering stage. Number of Tillers (stems/clump), calculated on sample crops during the flowering phase. Flowering Time (days), recorded when crops in the plot begin to produce flowers. Number of Panicles (panicles/hill), calculated from sample crop clumps prior to harvest. Panicle Weight (g/hill), weighed using an analytical balance after the panicles were harvested. Dry Grain Weight (g/hill), weighed at harvest after the grains had undergone the drying process.

All observational data obtained from the two environmental conditions (oil palm polyculture and non-polyculture) were tabulated to identify any significant differences in the growth and yield of each accession due to differences in light intensity; the data were then analyzed using a 5% t-test.

3 Result and discussion

The differences in environmental conditions between open land (natural conditions/open space) and oil palm polyculture systems were the main factors influencing the growth dynamics and yields of the six upland rice accessions tested during the period from November 2025 to February 2026 (Figur 1). Intercropping upland rice (*Oryza sativa* L.) among oil palm plantation trees is one solution to address the scarcity of agricultural land. Upland rice cultivation under mature oil palm stands (20 years old) exposes the crops to complex abiotic stresses, particularly a drastic reduction in sunlight intensity [6].

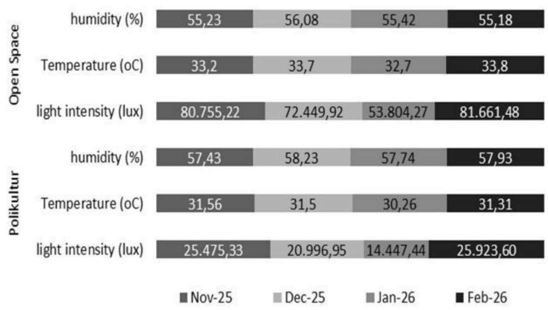
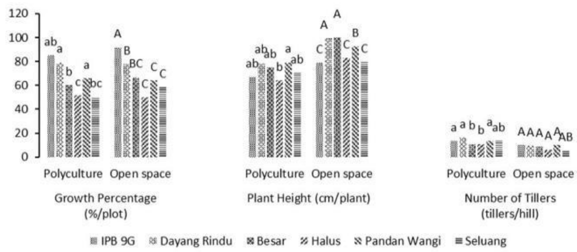


Fig. 1. Microclimate fluctuations in humidity, temperature, and solar radiation intensity between open spaces and polycultures

Open spaces are characterized by very high light intensity (ranging from 53,804.27 lux to 81,661.48 lux), warmer air temperatures (32.7°C – 33.8°C), and relatively lower relative humidity (55.18%–56.08%). The presence of the oil palm canopy creates a significant shading effect on the polyculture system. This results in a drastic reduction in light intensity to just 14,447.44 lux to 25,923.60 lux. The environment beneath this canopy is also cooler, with temperatures ranging from 30.26°C to 31.56°C and higher humidity (57.43%–58.23%).

Based on the data obtained, there were stark contrasts in morphological and agronomic responses among the six upland rice accessions grown under oil palm polyculture conditions compared to natural conditions (open space). In the early stages of crop growth, the percentage of crops that emerged per plot at 14 days after planting (DAP) revealed a unique interaction pattern between genotype and microenvironment. The research results (Figure 3.2 and Table 3.1) show that the Seluang accession experienced a 13.75% increase in germination rate in the polyculture environment compared to open fields, followed by the Besar accession (+9.51%) and the control variety IPB 9G (+7.31%).



Note: small letters indicate a comparison of accession of paddy in polyculture, capital letters indicate a comparison of accession of paddy in open space, and the same letter indicates no significant difference (T-test, α = 0.05)

Fig. 2. Percentage of growth, crop height, and number of tillers in several upland rice accessions under a polyculture system of oil palm and open space

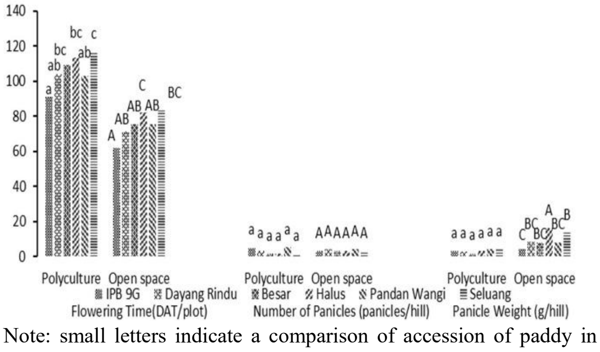
This increase in germination rate and early growth under polyculture conditions indicates that the Seluang, Besar, and IPB 9G accessions possess seed viability tolerant to the microclimatic conditions beneath the oil palm canopy. A 20-year-old oil palm canopy effectively reduces evaporation occurring at the soil surface, thereby creating higher average air humidity and more stable soil temperatures compared to open land exposed to direct solar radiation [7].

These humid microconditions promote a more consistent and optimal germination process [8]. In contrast, the accessions Halus (-3.52%), Pandan Wangi (-3.32%), and Dayang Rindu (-1.74%) exhibited reduced germination rates under shade. This indicates the sensitivity of seed structure to lower soil temperatures under the oil palm canopy, which slows down metabolism in breaking down endosperm food reserves [9]. The most striking morphological phenomenon in this study was a general reduction in crop height across all accessions tested under polyculture conditions. The reduction in crop height ranged from -11.73% to -25.28%, with the most severe stunting occurring in the Besar accession (-25.28%) and the Halus accession (-22.31%), while the Seluang accession showed the least reduction (-11.73%).

Table 1. Comparative Analysis of Growth Rate Changes in Several Upland Rice Accessions Between Open Fields and Polyculture Systems

Accession	Comparative Analysis of Rice Growth in Open Space and Polyculture (%)			
	Growth Percentage (%/plot)	Plant Height (cm/plant)	Flowering TIme (DAT/plot)	Number of Tillers (tillers/hill)
IPB 9G	7,31	-14,91	47,96	36,30
Dayang Rindu	-1,74	-21,09	45,80	72,56
Besar	9,51	-25,28	45,36	20,89
Halus	-3,52	-22,31	38,41	71,09
Pandan wangi	-3,32	-14,64	36,12	37,50
Seluang	13,75	-11,73	40,11	135,45

The environmental conditions of oil palm polyculture radically slowed the transition from the vegetative to the generative phase in all upland rice accessions (Figure 3.3).



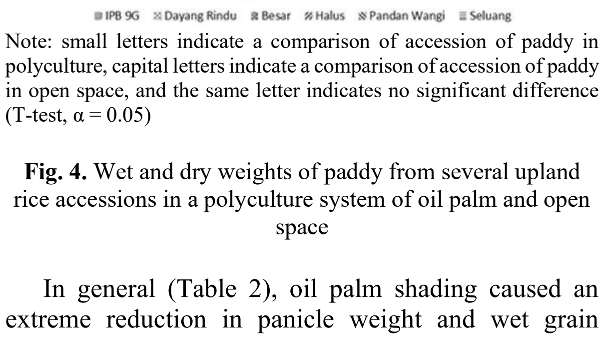
Note: small letters indicate a comparison of accession of paddy in polyculture, capital letters indicate a comparison of accession of paddy in open space, and the same letter indicates no significant difference (T-test, α = 0.05).

Fig. 3. Flowering Time, Number of Panicles, and Panicle Weight in Several Upland Rice Accessions in a Polyculture System of Oil Palm and Open Fields

The delay in flowering in polyculture was very significant, ranging from 36.12% to 47.96% later than in open fields. The IPB 9G variety recorded the longest delay (+47.96%), followed by Dayang Rindu (+45.80%), while Pandan Wangi was relatively the most adaptive in terms of flowering time stability, although it was still delayed (+36.12%). Flowering initiation in upland rice is controlled by photoperiodic pathways and phytochrome signaling that is sensitive to the ratio of red (R) and far-red (FR) light [10].

The data on the number of tillers (Table 3.1) reveal a highly intriguing paradoxical phenomenon. While crop height growth was stunted and flowering was delayed, all accessions actually produced significantly more tillers under polyculture conditions, with increases ranging from 20.89% to 135.45%. The most spectacular surge in tiller production was exhibited by the local accession Seluang (+135.45%), followed by Dayang Rindu (+72.56%) and Halus (+71.09%). The agronomic mechanism behind this anomaly is closely related to the extended duration of the crop's vegetative phase due to the delayed flowering time discussed earlier. Because the crops remain in the vegetative phase longer, the time window for lateral buds on the lower stem nodes to become active and develop into new tillers remains open for a much longer period [11].

In addition, stunting or growth inhibition of the main apical meristem reduces the intensity of apical dominance, which is regulated by the hormone auxin [12].



Note: small letters indicate a comparison of accession of paddy in polyculture, capital letters indicate a comparison of accession of paddy in open space, and the same letter indicates no significant difference (T-test, α = 0.05)

Fig. 4. Wet and dry weights of paddy from several upland rice accessions in a polyculture system of oil palm and open space

In general (Table 2), oil palm shading caused an extreme reduction in panicle weight and wet grain weight in nearly all local accessions, with the greatest reductions in panicle weight observed in the Halus (79.97%) and Besar (77.24%) accessions. This failure in yield formation is a direct result of the sink-source limitation phenomenon, in which low photosynthesis rates during the pollination (anthesis) and grain-filling phases cause a severely limited supply of sucrose to the panicles, thereby triggering a high percentage of empty grains [4].

Table 2. Comparative Analysis of Percentage Changes in Yield Components of Several Upland Rice Accessions Between Open Fields and Polyculture Systems

Accession	Comparative Analysis of Rice Yield in Open Space and Polyculture (%)		
	Panicle Weight (g/hill)	Fresh Grain Weight (g/hill)	Dried Grain Weight (g/hill)
IPB 9G	30,02	38,15	3,21
Dayang Rindu	66,51	66,71	60,82
Besar	77,24	79,06	76,33
Halus	79,97	82,91	83,64
Pandan wangi	48,50	44,23	41,90
Seluang	69,14	70,24	75,78

The IPB 9G variety demonstrated its superiority as a control variety with the lowest yield depreciation rate, at just 3.21%. IPB 9G is capable of halting inefficient metabolism and directing all limited assimilates directly to grain-filling components [1].

Among the local accessions, Pandan Wangi (41.90%) and Dayang Rindu (60.82%) demonstrated significantly more promising agroforestry performance compared to their local counterparts. These two local varieties are believed to have chlorophyll b content that is more adaptive under shade, which serves to broaden the absorption spectrum of the dominant blue-green light waves that pass through the gaps in the oil palm canopy [2]. Conversely, the Halus (83.64%), Besar (76.33%), and Seluang (75.78%) accessions were categorized as highly shade-sensitive. The case of the Seluang accession serves as a clear example where the plant's metabolic energy is completely drained (energy drain) solely to produce an abundance of vegetative tillers (+135.45%), yet fails to allocate assimilates to reproductive organs, resulting in light panicles and empty grains [13][14].

4 Conclusion

A comparison of the growth and yield of various upland rice accessions in oil palm polyculture systems and under natural conditions shows that all rice accessions and varieties exhibited reduced crop height and delayed flowering in the polyculture environment. Nevertheless, various accessions from South Sumatra and the test varieties exhibited nearly identical growth and yield responses in non-polyculture (open space) conditions. Among all these genotypes, the accessions from South Sumatra including Seluang, Halus, and Besar were assessed as having the greatest potential for development as intercrops in oil palm plantations.

Acknowledgment

The publication of this article was funded by the Indonesian Endowment Fund for Education (LPDP) on behalf of the Indonesian Ministry of Higher Education, Science and Technology and managed under the EQUITY Program (Contract Numbers 0011/UN9/SK.BUK.HT/2025 and 0042/UN9.R/SK.SU/2026).

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