THE POD PERFORMANCE AND POD YIELD OF PEANUT (*ARACHIS HYPOGAEA* L.) GENOTYPES GROWN UNDER WET CONDITION AND THEIR MICROBIAL QUALITY UNDER DIFFERENT CURING TIMES

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Abstract. In Indonesia, about 64% of peanut crops are grown in dry land both in early and mid of the wet season with high rainfall intensity. Therefore, the entire growing periods, harvesting, drying, and curing the pods are conducted under wet condition. This results in lower pod yields because of an excessive vine growth, foliar and pod diseases, peg deterioration, and non-uniform pods maturity. Also, the wet and humid conditions are favourable for *Aspergillus flavus* and *A. parasiticus* infection that subsequently may produce aflatoxin. This study aimed to evaluate the yield performance and pod maturity level at harvest, as well as to find out the effect of pod drying delay on *A. flavus* infection and aflatoxin contamination. Twelve peanut promising lines, three improved varieties, and one local variety were used as planting materials, and the trial was arranged in a randomized block design with three replicates. The crops were harvested at 89 days after sowing (DAS), then the pods were stripped and underwent drying treatments *i.e.*, directly dried after harvesting (without curing) and delayed drying or curing for 36 hours. Observations included the yield and yield components, physical quality of seeds, pod maturity level, infection of *A. flavus* and aflatoxin content. The results indicated that wet condition during the entire growing season resulted in diverse maturity levels of the pods. Most genotypes including local variety had not reached full maturity yet as the harvested pods were dominated by intermediate and premature pods. However, GH 2, GH 11, and GH 12 had higher percentage of full maturity than the local variety. GH 5 and GH 12 showed higher pod yields and only one genotype had lower pod yield than the local variety. The superior and inferior pod yields of these genotypes were positively correlated with the number of harvested plants. Almost all genotypes were highly resistant to *A. flavus* infection, except two genotypes that were moderately resistant with 15-30% of seed infection. The 36-hour delay of pod drying (curing) definitely increased the number of seed infected by *A. flavus* and aflatoxin contamination in all peanut genotypes. However, the aflatoxin B_1 content was far below the permitted level (15 μg/kg), thus it is safe for human consumption.
Keywords: *aflatoxin, Aspergillus flavus, high rainfall, pod drying, pod maturity*

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Introduction

Peanuts or groundnuts (*Arachis hypogaea* L.) play a crucial role in human health through their function as an essential source of oil, folate, antioxidants, protein, and essential fatty acids (Sebei et al., 2013). Globally, peanut is the largest oil seed crop after soybean, rapeseed, and cotton. Based on the protein and oil contents, peanut grain is utilised for various foods and industrial purposes (Singh et al., 2021). About two third of the world peanut production is crushed for oil and the remaining one third is used for food consumption (Variath and Janila, 2017). The oil extracted from peanut grain can be used for cooking, soap making, as a cosmetic component, and as an ingredient of other industrial products. It is well known that peanuts are an important source of protein and fat in the diets of people in arid and semi-arid tropical and sub-tropical regions (Dhamsaniya et al., 2012; Mekki, 2015) where approximately 95% of the world peanut production is coming from developing countries (FAO, 2002).

In Indonesia, the popularity of peanut as food is shown by the fact that around 89% of available grain is directly consumed in numerous types of foods and snacks (Sholihah, 2016). The average of annual production and consumption were 509,699 tons and 657,578 tons, respectively during the period of 2015 to 2019 (Sholihah, 2016; BPS, 2019). Since the amount of consumption was higher than the production, The Government of Indonesia has to import about 266 thousand tons of peanut grains in order to meet the national demand (Pusdatin, 2020). In spite of importing grains, The Government is also making a lot of efforts to increase the domestic production both through increasing the productivity and extending the planting/harvesting areas. One of the strategies to increase productivity is planting improved varieties as this is the easiest agricultural input that can be adopted and practiced by farmers. In spite of high productivity, improved varieties are also resistant to biotic and or tolerant to abiotic constraints (Balitkabi, 2016).

In Indonesia, peanuts had been grown for more than 300 years (Hammons et al., 2016). Initially, peanuts were grown in dry lands, and then people brought them into wet land and grew the plant in the dry season following the cropping pattern of rice-rice-peanut. About 64% of peanuts is grown in dry land and the rest 36% is grown in wet land (Rahmianna et al., 2015). In dry land, peanut is planted both in early and mid of the wet season, and therefore the entire growing periods are under wet condition. The harvesting and curing (reducing the moisture content) of pods, therefore, are also conducted under such condition. Whilst the main planting time in wet land (irrigated and rainfed lands) is normally in early or mid of the dry season, suggesting that harvesting and threshing are undertaken under dry condition and therefore the curing process occurs quickly. In both agro-ecosystems, peanuts are generally grown under rainfed condition and rainfall is the mere source of water. Planting peanut in the wet season with high intensity of rainfall results in the following consequences:

First, the pod yield in the wet season is lower compared to the production in the dry season. High precipitation results in an excessive vine growth, the incidence of foliar and pod diseases, peg deterioration, and non-uniform pod maturity (Nigam et al., 2004). Wet season with high precipitation reduces solar radiation received by the plant canopy, thus reducing photosynthetic rate (Nautiyal et al., 2012), and hence sunshine or solar radiation has significant correlation with pod yield (Canavar and Kaynak, 2010). Moreover, wet condition is also favourable for infection of *Cercospora arachidicola* and *Cercosporidium personatum i.e.* the causal fungi for early and late leaf spot diseases, respectively. The severe infection of these fungi results in leaf discolouration and then

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defoliation (Damicone, 2017). Low photosynthetic rate together with high incidence of leaf spot disease are the common reasons for huge reduction of pod yield.

Secondly, the seed may have higher *Aspergillus flavus* infection and aflatoxin (AF) contamination. When peanut is grown during the wet season, farmers quite often delay picking and drying the harvested pods due to limited farm labour force. The same situation is also experienced by farmers in Mozambique (Zuza et al., 2017). As a result, drying process lasts very slowly and the pods stay under high moisture condition for a longer period. These wet and humid conditions, furthermore would stimulate fungal infection, particularly *A. flavus* and *A. parasiticus* that subsequently may produce AF (Verheecke et al., 2015). It is important to note that seed moisture content should be rapidly reduced to 8-9% to be safely stored with minimum infection of such fungi.

Wu (2015) highlighted the huge cost caused by AF contamination both through the market and human-related losses. About 5% of corn and peanut production in Indonesia, Philippines and Thailand was disposed during the sorting process due to fungal contamination. Therefore, the annual cost related to contamination of AF and other fungi in these three countries is estimated as high as US$ 367 million. These annual costs include product spoilage, human health effects, and losses in the livestock sector (Agricultural Trade, 2022). AFs have been proven hazardous to human health (Wu and Khlangwiset, 2010; Kumar et al., 2017) by causing liver cancer, cirrhosis, imuno suppression, as well as growth impairment especially for children under 36-month old (Narayan et al., 2014; Chen et al., 2018; Fitri et al., 2019; Alamu et al., 2020). The fungi produce toxin only when the substrates (peanut seeds) and surrounding environmental conditions are critical *i.e.* moisture contents of the seed range from 15–30% (Crop Link, 2000), temperature of the environments range from 25-30^{o}C (Kerstin and Charity, 2011), and low plant immune system (Mannaa and Kim, 2017). The fungal infection and AF production may occur either in the field when the pods are still attached to the plants (pre-harvest AF contamination), or after harvesting, particularly during drying, storage and marketing (post-harvest AF contamination) (Kumar et al., 2017). Recent studies have linked AF contamination in foods with environmental conditions, poor processing, and lack of proper storage facilities in developing countries (Farombi, 2006). Contamination is reported to be the most frequent and most serious case occurring during storage and processing as well as in the marketing chains (N'dede et al., 2012). This study therefore aimed 1) to evaluate the yield performance as well as the pod maturity level of peanut genotypes at harvest grown in the wet season, and 2) to find out the effect of the delay of pod drying on *A. flavus* infection and AF contamination.

Materials and Methods

The experiment was conducted during the wet season at Lamatti Riaja Village, Bulupoddo Sub-District, Sinjai Regency of South Sulawesi Province, Indonesia (120°11'16.1" E and 5°06'28.3" S) (*Figure 1*). About 16 peanut genotypes, which consisted of 12 promising lines, three checked varieties, and one local variety, were used in the treatments. In the trial a randomized complete block design was applied with three replicates. The genotypes tested and their main characters were listed in *Table 1*. Each genotype was planted in a 2.4 m × 5 m (12 m^2) plot size, and the plants grew under rainfed condition during the entire growing season without any additional irrigation.

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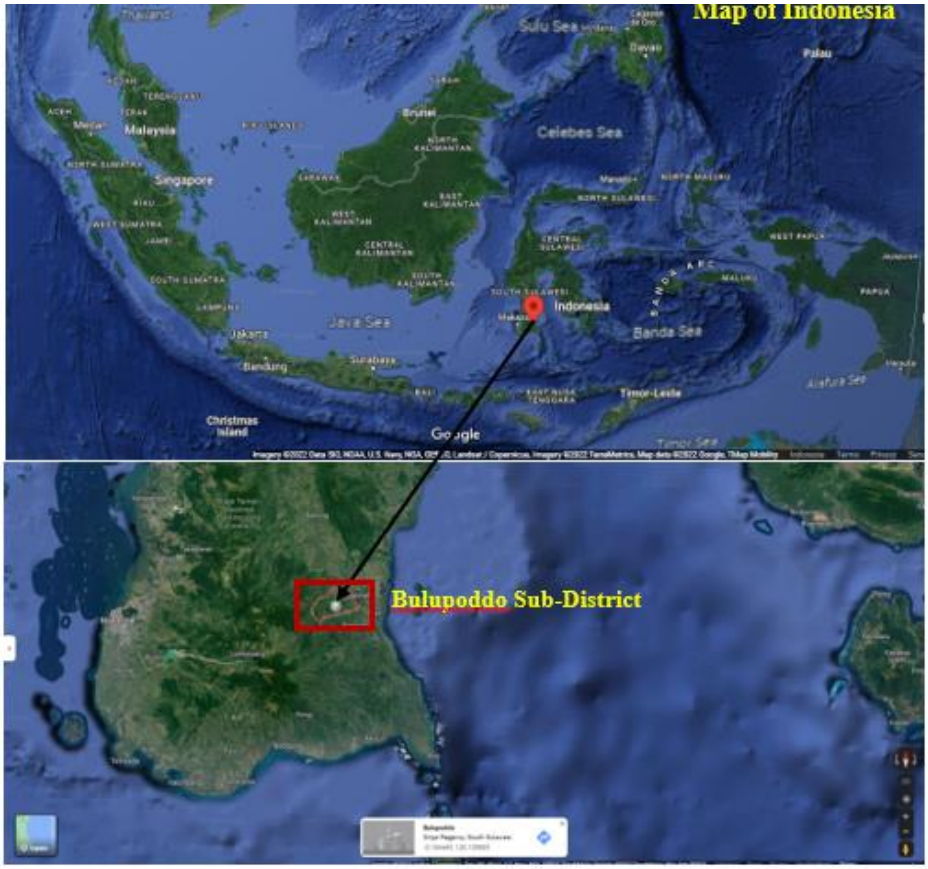

Figure 1. *Map of study site of Lamatti Riaja Village, Bulupoddo Sub-District, Sinjai Regency, South Sulawesi Province, Indonesia (Scale 1:200,000)*

Table 1. *List of peanut genotypes used in this study*

Code	Genotypes	Main characters
GH 1	GH 502/G-00-B-677-49-43	Early maturity*), resistant to bacterial wilt
GH 2	GH 502/G-00-B-679-46-47	Early maturity*), resistant to bacterial wilt
GH 3	PC 87123/86680-83-13-75-55	Early maturity*), resistant to main LS & R
GH 4	IP 991230.03	Early maturity*), resistant to main LS & R
GH 5	IP 9913-03-9-78-8	Early maturity*)
GH 6	JP/87055-00-733-174-117-1	Early maturity*)
GH 7	JP/87055-00-879-91-26	Early maturity*)
GH 8	145/G-00-879-91-26	Early maturity*)
GH 9	Jerapah variety	Early maturity*), susceptible to LS & R
GH 10	Kancil variety	Early maturity*), resistant to bacterial wilt and *A. flavus*, tolerant to high soil pH
GH 11	Litbang Garuda 5 variety	Early maturity*), resistant to bacterial wilt and *A. flavus*, low aflatoxin contamination
GH 12	Mj/G-00b-884-95-41	Early maturity*), resistant to bacterial wilt
GH 13	C/G-008-644-20-175-20	Early maturity*), resistant to bacterial wilt
GH 14	JP/8705500B-807-145-36	Early maturity*), resistant to bacterial wilt
GH 15	MH 91278-99C-180-13-74	Early maturity*), moderately resistant to LS & R
GH 16	Local variety	

Note: LS & R: Leaf spot and rust: the main foliar diseases. *) early maturity: pods mature within 85-90 DAS (Coulibaly et al., 2017)

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The trial was initiated by ploughing the soil until the friable soil condition was obtained and the soil was free from weeds. The plots were separated by furrows with around 25 cm depth and 25 cm width to drain the rain water out. Before sowing, the seeds were treated with fungicide (10 g Captan kg/seeds) to avoid fungal infection both on seeds and seedlings. The seeds were planted following plant spacing of 40 cm × 15 cm, and one seed was sown in every hole. About 250 kg/ha of composite NPK fertilizer (which consisted of 15% of N, P, and K, respectively) was applied in the furrow adjacent to seed rows just after planting. Pesticides were applied to control pest attack and disease infestation. Manual weeding was conducted at 21 and 35 days after sowing (DAS). Dolomite as a source of calcium with a dose of 500 kg/ha was applied in the furrow along the plant rows at flowering (35 DAS).

Harvesting was undertaken at 89 DAS as most of the leaves have already changed from green to yellow and defoliated because of severe leaf spot disease infection. Pod stripping (separation the pods from the vines) were completed within 24 hours after harvesting. The next process was pod curing, which was normally done to reduce the moisture content of the fresh pods prior to drying and prevent prolonged exposure to wet or rainy condition in the field. There were two treatments of curing: 1) Direct drying (no curing treatment). The pods were directly dried after stripping by spreading the pods onto the tarpaulin mat and sun-dried starting from 8 am up to 3 pm during 6 consecutive days, and 2) Delayed drying (curing): The fresh pods were placed in a plastic net bag for 36 hours at room temperature prior to sun-drying for 6 consecutive days starting from 8 am up to 3 pm. Drying was done by thoroughly spreading the pods onto the tarpaulin mat that was laid on the ground. The process was stopped when the pods were becoming very light and produced clear sound when they were shaken. This drying trial was arranged using a factorial randomized block design with three replicates. Peanut genotype was used as the first factor and drying treatment as the second factor.

At harvesting time, five plants were randomly selected from each treatment for observing the plant height, number of primary branches, number of pegs, number and weight of dry immature and mature pods, dry seed weight, as well as shelling percentage and pod maturity level. The criteria of peg, immature and mature pod were as follow: Peg refers to all hanging pegs (all pegs that had not penetrated the soil surface yet), and peg that had penetrated the soil surface with less than 1 cm length. The mature pod is characterized by fully formed pod with at least shriveled seeds inside the pod (Mathur et al., 2007), orange to brown/black inner shells color (Carter et al., 2017), hard and tough when the pod is manually pressed (Bindlish et al., 2017), as well as pods become reticulated, seeds are separated from the shell of the pod, and the inside of the shell has dark color (Nigam et al., 2004). The immature pod is characterized by the “raisin” or shriveled pod, pop, or empty pod (Pattee et al., 1980), yellow shell color (Carter et al., 2017), and soft when the pod is manually pressed (Bindlish et al., 2017). The dried pod was manually sorted and grouped into immature or mature pod based on the above categories. Conversion of peg to immature pod, immature pod to mature pod, and peg to mature pod were calculated based on the formula mentioned by Puangbut et al. (2013).

$$\text{Peg to pod: } \frac{(\text{mature pod number}+\text{immature pod number})}{\text{peg number}+\text{immature pod number}+\text{mature pod number}} \times 100\% \quad \text{(Eq.1)}$$

$$\text{Immature pod to mature pod: } \frac{(\text{mature pod number})}{\text{mature pod number}+\text{immature pod number}} \times 100\% \quad \text{(Eq.2)}$$

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$$\text{Peg to mature pod: } \frac{(\text{mature pod number})}{\text{peg number+immature pod number+mature pod number}} \times 100\% \quad \text{(Eq.3)}$$

Pod maturity level was observed by opening the dry mature pod, and we grouped the maturity by accessing the blotching area of the inner pericarp. There were four classes of maturity *i.e*., class 1, 2, 3 and 4 with 76-100%, 51-75%, 26-50%, and ≤ 25% of blotching area of the inner pericarp, respectively characterized by the presence of dark brown-black color, also the number of pods in every class was noted. The pod production and number of plant population at harvest per acreage were calculated based on dry pod yield and number of harvested plants per 12 m^2 plot size. Seed moisture content at harvest was observed by gravimetric method. The weight of sound mature kernel (SMK), shriveled kernel (SHV), and damaged kernel (DMG) were obtained from 250 g of seeds that were randomly obtained from shelling 500 g of dry pod. Sound mature kernel is intact and healthy kernel, shriveled kernel is kernel with wrinkle testae and shrinked seeds. Damaged kernel is a kernel with at least one of these conditions: rotten, split cotyledons, physically broken cotyledons, pest bitten, torn up testae, stained testa, germinated seed (National Standardization Agency, 1995). The *A. flavus* infection on the kernel was observed soon after the curing treatment completed. For each treatment, 100 kernels were plated onto AFPA (*Aspergillus flavus* and *parasiticus* agar) media in 10 petri dishes (as replications) or 10 kernels per petri dish. The infected kernels by *A. flavus* were indicated by orange color of the media under the kernels after 3 days of incubation. The number of kernels with yellow fungal colony was recorded (Pitt and Hocking, 1997). AF contamination of kernels was detected by Enzyme-linked immunosorbent assay (ELISA) method and identified as aflatoxin B1 (Lee and Kennedy, 2002a,b). The severity of leaf spot and rust diseases were observed at 85 DAS based on the method developed by Subrahmanyam et al. (1995) using 1-9 scale where 1 = no disease and 9 = plants severely affected. All data were statistically analyzed using MStat-C program 1.4 version developed by Crop and Soil Sciences Department, Michigan State University. The parameters that showed to be significantly different ($p<0.05$ and $p<0.01$) were then subjected to a Duncan Multiple Range Test (DMRT) to find out the differences between treatments.

Results and Discussion

Climatological condition of site

The research area of Lamatti Riaja Village, Bulupoddo Sub-District, Sinjai Regency is dominated by soil-forming materials derived from lava, breccia, tuff, and conglomerate materials. Based on the National Classification System which is equivalent to the Soil Taxonomic Classification System, these materials form soils classified as Mediterranean Haplic (Typic Hapludalfs) and Eutric Cambisol (Typic Eutrudepts) (Soil Survey Staff, 2014; Subardja et al., 2016). The characteristics of these soils are good drainage, fine texture, slightly acidic, medium cation exchange capacity (CEC), and high base saturation (BS) (BBSDLP, 2016). Based on these characteristics, it is biophysically very supportive for peanut growth, which needs good drainage, fine to medium texture, slightly acidic to neutral pH (5.5-7.0), moderate to high soil fertility, moderate to high CEC and BS (Ritung et al., 2011).

Climatic elements that directly affect plant growth are rainfall, air temperature, humidity, solar radiation, and wind speed. Rainfall is used as one of the criteria to

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determine the climatic conditions of an area in relation to the suitability and requirements of plant growth. As a guideline for determining the adequacy of water requirements for most cultivated plants, the rainfall limit of 100 mm and 200 mm per month are applied. Rainfall of <100 mm per month is referred to as the Dry Month, while rainfall of >200 mm per month is referred to as the Wet Month (Oldeman and Frere, 1982). Rainfall at experimental site was between 300-500 mm, which is in the category of high. The average annual rainfall in the last 10 years was between 2,300-3,400 mm in Sinjai Regency with monthly rainfall of >200 mm occurred for 7-9 months and monthly rainfall <100 mm occurred for 2-4 months. Based on the Oldeman Agroclimate zone, Sinjai Regency is dominated by Zone B2 (BMKG, 2022). During this study, high amount of rainfall was noted. The monthly precipitation during the growing season starting from March through April, May to June was 264, 276, 285, and 441 mm, respectively. It is therefore, the crops grew under wet months as the amount of rainfall was higher than 200 mm per month. These wet months were consistent within the recent years since 2010 (*Figure 2*).

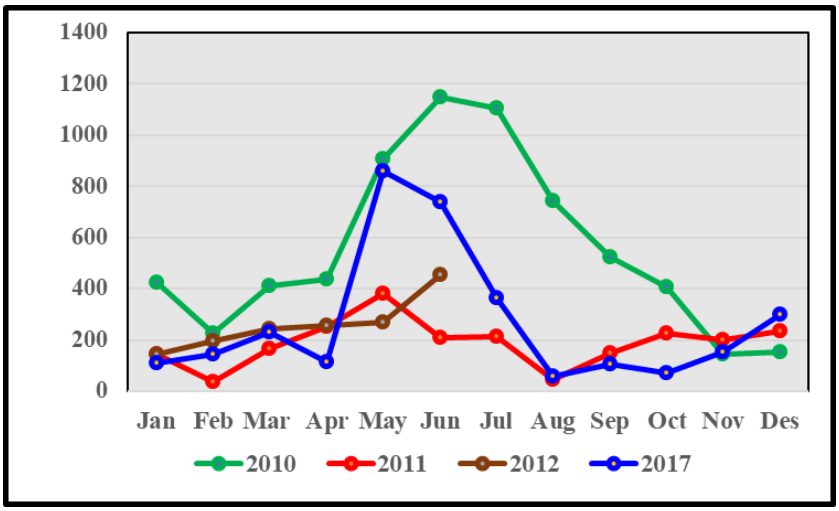

Figure 2. *The profile of monthly rainfall at three years and during the growing season (March-June 2012) in the experimental site*

BMKG has released information on the results of the Normal Change in Rainfall analysis to identify changes in long-term rainfall patterns in Indonesia. This information contains the normal change in rainfall for 30 years, using monthly average rainfall data from the period 1980 to 2010. A suitable location as a representative of the rainfall pattern in the research area is the Bubung Luwuk and Kasiguncu Poso Meteorological Stations (*Figure 3*). These locations as well as the experimental site are both in the east coast of Sulawesi Island (BMKG, 2022a). The pattern of changes in rainfall for 3 decades at the Stations is almost the same or similar to the pattern for 3 years at Sinjai Station (*Figure 2*). The rainfall pattern tends to be high between February to July/August, with the highest rainfall between April and June, which is more than 200 mm. Meanwhile, the rainfall pattern tends to be low between August and September, which is less than 150 mm. In general, during the rainy season, the pattern of rainfall in the 1981-1990 decade tended to be higher than the 2001-2010 decade (BMKG, 2022a,b).

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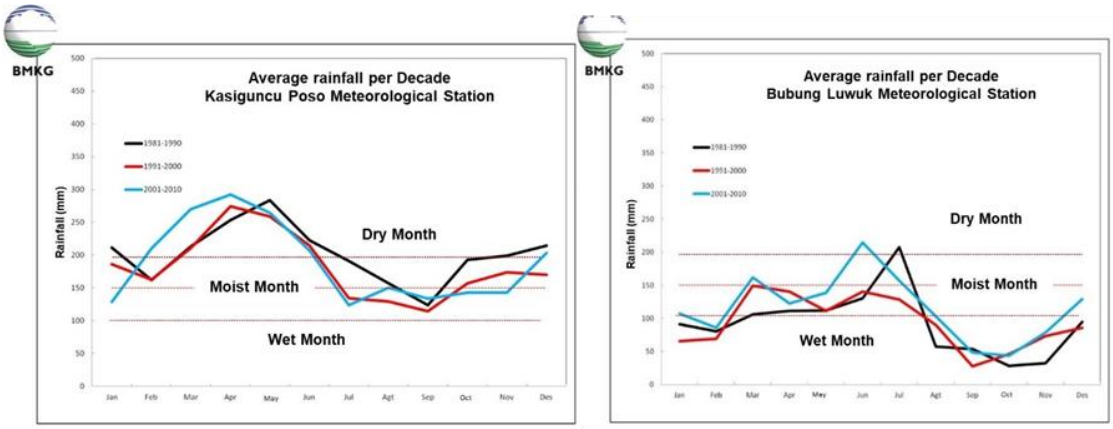

Figure 3. *Changes in rainfall patterns at the Kasiguncu Poso and Bubung Luwuk Meteorological Stations*

The average of minimum and maximum air temperatures for Sinjai Regency was 24°C and 31°C, with the minimum and maximum relative humidity of 65 and 95%. This temperature range is suitable for peanut as Luo (2011) summarized that the optimum temperature for vegetative development up to fruit set ranged from 29-33°C, and for generative growth such as pod yield, seed yield, pod harvest index, and seed size was around 23-24°C. A previous study (Vara Prasad et al., 2003) reported that the temperature limit (where seed yield=0) for peanut was 44.6 and 34.6°C for daytime maximum and nighttime minimum temperatures. The pod yield and yield components reduced when the daytime maximum/nighttime minimum temperatures increased above 32 or decreased below 22°C, respectively. Another study (Singh et al., 2012) revealed that peanut plant would accelerate flowering and maturity as well as give higher pod yield and yield components as the air temperature increased whenever the crops grew under air temperature lower than 28°C. Once the mean temperature of the site was higher than 28°C, the peanut yield decreased due to reduction of number of pods and seed size. Recent study conducted by Gulluoglu et al. (2018) reported that air temperature higher than 35°C during generative period have reduced fruit set and consequently reduced the number of pods and seed yield. The temperature pattern in the study area during the growing season between March and April, and May to June, was normal, namely between 23°C and 31°C (Weather Spark, 2022; BMKG, 2022c) (*Figure 4*). These conditions are suitable for supporting peanut growth phases, especially generative growth in pod formation and seed size (Luo, 2011).

Analysis of variance

The mean square of genotype pointed out that number of branches per plant, kernel moisture content at harvest, number and weight of dry mature pods per 5 plants, dry seed yield per 5 plants, shelling percentage, and % dry weight of SHV was significantly different ($p \leq 0.05$) among genotypes (*Table 2*). In addition, the mean squares of dry pod yield and plant population at harvest/ha, % number of mature pods and pegs per 5 plants, pod size, % dry weight of SMK were highly significant at $p \leq 0.01$. Plant height, % number of immature pods, and % dry weight of DMG was similar among genotypes. The differences at $p \leq 0.05$ and $p \leq 0.01$ indicated that each genotype responded differently to the environmental conditions during growing. This phenomenon indicated the variability of the tested genotypes.

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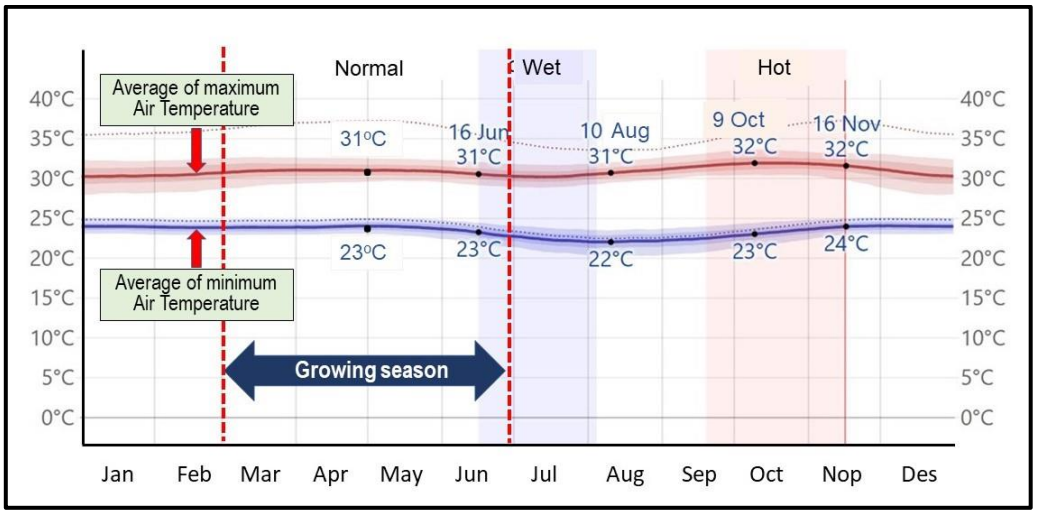

Figure 4. *Average temperature for all the year in Sinjai Regency, Indonesia*

Table 2. *Mean squares of vegetative growth, yield and yield components*

Variables	Mean square	Variables	Mean square
Plant height (cm)	53.995ns	% no of pegs/5 plants	184.704**
No of branches/plant	0.540*	Pod size (g/100 pods)	412.429**
Dry pod yield (t/ha)	0.228**	Kernel moisture content (%)	58.260*
Plant population at harvest/ha	8945961296**	Shelling percentage (%)	17.200*
Dry pod yield (g/5 plants)	168.624*	Dry weight of SMK (%)	144.713**
Dry seed yield (g/5 plants)	95.445*	Dry weight of SHR (%)	54.299*
No of mature pods/5 plants	238.083*	Dry weight of DMG (%)	30.105ns
% no of mature pods/5 plants	218.296**	*A. flavus* infection	0.237**
% no of immature pods/5 plants	33.494ns	Aflatoxin content	0.084ns-

Note: ***, ****: significant at probability of 0.05, 0.01; ns: non-significant; SMK: sound mature kernel, SHR: shriveled kernel, DMG: damage kernel

Vegetative growth

All genotypes showed similar plant heights during vegetative growth. Ten genotypes grew taller than 50 cm height and according to Wahyu and Budiman (2013), these genotypes were categorized as tall. All tested genotypes therefore grew tall except GH 2 and GH 7, which had plant heights below 50 cm. Further, Wahyu and Budiman (2013) noted that peanut plants grew taller especially in the wet season. The growers, however, prefer short plant rather than tall figure because the tall plant was susceptible to lodge (Nurhalimah et al., 2021). The present experiment supported by Yadav et al. (2013) who reported that under well distributed rainfall during the rainy season cropping, peanut plants grew taller *i.e.* 69.7 cm in average. On the other hand, under drier condition during the dry season cropping in arid and wet season cropping in semiarid areas, peanut grew shorter *i.e.* 28-35.3 cm in average (Rahmianna and Yusnawan, 2016; Rahmianna et al., 2020). Peanut even grew much shorter (16.6-23.6 cm height) when planted in semi-arid region of West Timor Regency, East Nusa Tenggara (ENT) Province, Indonesia during the dry season with additional irrigation (Berek et al., 2017). It is necessary to be informed that ENT Province is identic with dry lands with dry climate as the total annual rainfall

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<2,000 mm during 3-5 months only, with more than seven dry months (with <100 mm of monthly rainfall) annually (Manu, 2013; Nursyamsi et al., 2014). It can be summarized that plant height is a growth variable that significantly was affected by growing environment conditions. It is important to consider the study reported by Olayinka et al. (2016) that plant height together with number of leaves, 50% flowering date, seed yield, and harvest index had positive trend with seed size, where seed in this context is related to multiplication material.

The current study conducted under very wet condition during the entire growing season resulted in 4.1 branches per plant in average. Out of 16 genotypes, two genotypes (GH 2, GH 3) produced the highest number of branches (4.9 branches) and four genotypes (GH 7, GH 13-15) had the lowest number of branches (*Table 3*). The current study obtained lower number of branches compared to that reported by Hampannavar et al. (2018) i.e. 5.5 branches per plant for peanut genotypes grown during the rainy season. Formerly, a study conducted by Yadav et al. (2013) reported that under well distributed rainfall during the rainy season cropping, peanut produced 6.3 branches in average. These similar amounts of branches were also produced by peanuts when grew in semi-arid areas under wet condition during the first month and dry condition in the following 2 months (Rahmianna et al., 2020). It is necessary to note that a number of factors influenced the number of branches, such as air temperature, soil fertility (Kabir et al., 2013; Rahmianna et al., 2015; Pratiwi and Nugrahaeni, 2018), and plant spacing (Kriswantoro et al., 2020).

Table 3. *Plant height, number of branches, score of leaf spot and rust on peanut genotypes*

GH	Genotype	Plant height (cm)	No of branches/plant	Score of leaf spot*)	Score of rust*)
GH 1	GH 502/G-00-B-677-49-43	52.3	3.9 abc	8.0 HS	6.3 S
GH 2	GH 502/G-00-B-679-46-47	45.0	4.9 a	8.0 HS	6.0 S
GH 3	PC 87123/86680-83-13-75-55	57.9	4.9 a	7.0 S	5.6 MR
GH 4	IP 991230.03	56.1	4.0 abc	7.6 S	6.0 S
GH 5	IP 9913-03-9-78-8	51.3	4.3 abc	7.0 S	6.0 S
GH 6	JP/87055-00-733-174-117-1	61.7	4.4 ab	7.3 S	5.3 MR
GH 7	JP/87055-00-879-91-26	46.7	3.8 bc	7.6 S	5.6 MR
GH 8	145/G-00-879-91-26	55.7	4.1 abc	7.6 S	5.6 MR
GH 9	Jerapah variety	52.8	4.3 abc	7.6 S	6.3 S
GH 10	Kancil variety	55.1	4.3 abc	7.6 S	5.6 MR
GH 11	Litbang Garuda 5 variety	53.7	4.2 abc	7.6 S	6.0 S
GH 12	Mj/G-00b-884-95-41	55.2	4.0 abc	8.0 HS	6.0 S
GH 13	C/G-008-644-20-175-20	54.9	3.6 bc	8.3 HS	6.0 S
GH 14	JP/8705500B-807-145-36	58.9	3.5 bc	8.0 HS	5.6 MR
GH 15	MH 91278-99C-180-13-74	57.5	3.4 c	7.6 S	5.6 MR
GH 16	Local variety	56.1	4.0 abc	7.3 S	5.3 MR
	Mean	54.4	4.1	7.6	5.8

Note: Numbers followed by the same letter in each column were not significantly different based on Duncan test at α=0.05. *) 1 = highly resistant (HR), 2 – 3 = resistant (R), 4 – 5 = moderately resistant (MR), 6 – 7 = susceptible (S), and 8 – 9 = highly susceptible (HS) (Subrahmanyam et al., 1995)

Wet condition during the entire growing season gave a consequence that 11 and five genotypes were susceptible and highly susceptible to leaf spot disease. Meanwhile, eight genotypes were moderately resistant and another eight genotypes were susceptible to rust disease caused by *Puccinia arachidis* infection (*Table 3*). The present study showed a

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similar response as the study conducted by Rahmianna and Yusnawan (2016) which recorded the leaf spot scores ranging from susceptible to highly susceptible and rust scores ranging from susceptible to moderately resistant on 25 peanut genotypes grown during the wet season in dry land of Banjarnegara, Central Java Province of Indonesia. These two studies revealed that leaf spot incidence was more prominent than the rust.

Being very wet as a result of high precipitation of more than 1000 mm during the growing season have presented the spots all over the plants, defoliation of lower and middle leaves in susceptible genotypes. In highly susceptible genotypes, moreover, these susceptible symptoms were followed by defoliation of less than 50% of total leaves (Subrahmanyam et al., 1995). Most farmers in developing countries believe that high rainfall is a major cause of leaf spot and leaf defoliation. Defoliation together with brown spots are the main determinants for maturity of peanut and signs for harvesting time (Moses et al., 2018).

Generative growth

GH 5 and GH 11 produced the highest number of mature pods per plant, weight of mature pods and seed weight per plant. Meanwhile, the lowest values of these three parameters were noted in GH 4, GH 8, GH 12-15 (*Table 4*). The generative growth of all genotypes was similar to the local variety except for the number of mature pods per plant of GH 4 and GH 8. This reflects that all genotypes strongly adapted to the site conditions. It is well known that seed yield of certain genotypes is highly affected by environmental conditions of growing including different micro climates as well as cultivation practices (Yol et al., 2018).

Table 4. *Number of mature pods, weight of dry pods, weight of seeds, and shelling percentage*

GH	Genotype	Number of mature pods/ 5 plants	Weight of mature pods (g/5 plants)	Weight of seeds (g/5 plants)	Shelling percentage (%)
GH 1	GH 502/G-00-B-677-49-43	28.3 $^{c-e}$	29.7 ^{abc}	22.0 ^{bcd}	73.9 $^{a-c}$
GH 2	GH 502/G-00-B-679-46-47	43.0 $^{a-c}$	34.1 ^{abc}	24.6 ^{abcd}	73.0 ^{bc}
GH 3	PC 87123/86680-83-13-75-55	33.0 $^{b-e}$	28.9 ^{abc}	20.3 ^{cd}	70.8 ^{c}
GH 4	IP 991230,03	22.7 ^{e}	21.9 ^{c}	16.3 ^{d}	74.7 $^{a-c}$
GH 5	IP 9913-03-9-78-8	50.3 ^{a}	45.4 ^{a}	34.8 ^{a}	76.4 ^{ab}
GH 6	JP/87055-00-733-174-117-1	38.3 $^{a-e}$	32.5 ^{abc}	23.9 ^{abcd}	73.1 ^{bc}
GH 7	JP/87055-00-879-91-26	40.3 $^{a-d}$	33.3 ^{abc}	25.2 ^{abcd}	75.3 $^{a-c}$
GH 8	145/G-00-879-91-26	23.7 ^{de}	25.2 ^{bc}	18.4 ^{cd}	73.0 ^{bc}
GH 9	Jerapah variety	48.7 ^{ab}	37.7 ^{abc}	29.3 ^{abc}	77.0 ^{ab}
GH 10	Kancil variety	44.3 $^{a-c}$	40.1 ^{ab}	29.2 ^{abc}	73.1 ^{bc}
GH 11	Litbang Garuda 5 variety	51.0 ^{a}	44.9 ^{a}	33.7 ^{ab}	74.9 $^{a-c}$
GH 12	Mj/G-00b-884-95-41	27.7 $^{c-e}$	25.4 ^{bc}	19.9 ^{cd}	78.5 ^{a}
GH 13	C/G-008-644-20-175-20	31.0 $^{c-ef}$	25.3 ^{bc}	19.6 ^{cd}	77.3 ^{ab}
GH 14	JP/8705500B-807-145-36	28.7 $^{c-e}$	22.9 ^{c}	18.0 ^{cd}	78.8 ^{a}
GH 15	MH 91278-99C-180-13-74	30.3 $^{c-e}$	24.2 ^{bc}	18.3 ^{cd}	75.2 $^{a-c}$
GH 16	Local variety	45.0 $^{a-c}$	33.0 ^{abc}	23.7 ^{abcd}	71.2 ^{c}
	Mean	36.7	31.5	23.6	74.8

Note: Numbers followed by the same letter in each column were not significantly different based on Duncan test at α=0.05

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GH 12 and GH 14 showed the highest shelling percentage, which represents the ratio of seeds weight to pods weight, while GH 5 and GH 11 had slightly lower values (*Table 4*). The mean shelling percentage was 74.8%, suggesting that the seed weight was at least 70% of the pod weight. This value was similar to the value obtained from another study conducted during the rainy season by Salingkat and Noviyanty (2019). However, lower values were obtained by Yadav et al. (2013) and Okello et al. (2016) that was 69.7% and 60.7%, respectively for peanuts grown under well distributed rainfall during the rainy season. On the other hand, Parwada et al. (2020) reported higher shelling percentage, ranging from 68% to 87%. Variation of shelling percentage obtained in this study were probably attributed to the genotypic differences as previously reported by Parwada et al. (2020).

Pod development

Higher percentage of mature pods were noted in all genotypes relative to immature pods and pegs (*Figure 5*). GH 9 and GH 16 had the highest number of mature pods, suggesting that the developing process from peg to mature pod with SMK was considerably efficient and early started. On the other hand, GH 1, GH 4, GH 8 and GH 14 had low percentages of mature pods as those peg percentages were reasonably high. In other words, the pod developing and seed filling process of these four genotypes were late and slow. The number of pods and pegs varied among genotypes tested, and this may be attributed to inherent variation as all genotypes were grown in similar environmental conditions (Kaba et al., 2014).

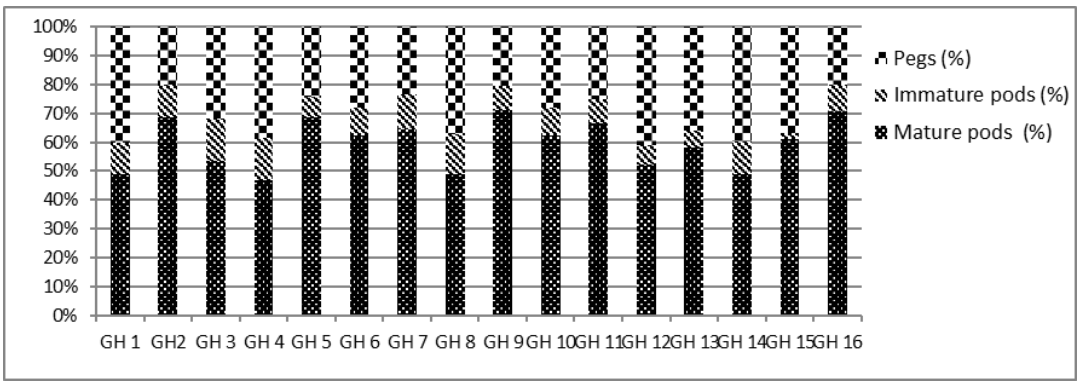

Figure 5. *The distribution of mature, immature and peg of peanut genotypes*

In general, as many as 69.3% of total pegs developed to immature pods and about 85.6% of the immature pods were subsequently developed to mature pods. Therefore, only 59.6% of total pegs were successfully developed to mature pods (*Table 5*). A study conducted by Arioglu et al. (2018) concluded that only 15-20% of flowers were successfully develop to mature pods.

The current study showed that about 70% of pegs derived from GH 10 and GH 16 developed to mature pods. Meanwhile, GH 1, GH 3, GH 4, GH 8 and GH 12-14 owned the least percentages. Five genotypes, namely GH 2, GH 5, GH 6, GH 7, and GH 15 together with the check varieties of Jerapah (GH 9), Kancil (GH 10), and Litbang Garuda 5 (GH 11) had the same success as the local variety in developing peg to mature pod. In other words, five promising lines (GH 2, GH 5-7, and GH 15), and three released varieties

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(Jerapah, Kancil, and Litbang Garuda 5) were in the same level as the local variety, which has been well adapted to wet growing season.

Table 5. *Conversion of peg to immature pod and immature pod to mature pod of 16 genotypes under wet condition*

GH	Genotype	Peg to immature pod (%)	Immature pod to mature pod (%)	Peg to mature pod (%)
GH 1	GH 502/G-00-B-677-49-43	59.9 ^{e}	80.6 $^{b-d}$	48.8 ^{de}
GH 2	GH 502/G-00-B-679-46-47	80.1 ^{a}	86.1 $^{a-d}$	68.7 ^{ab}
GH 3	PC 87123/86680-83-13-75-55	68.0 $^{b-e}$	77.3 ^{cd}	53.5 $^{c-e}$
GH 4	IP 991230.03	61.4 ^{de}	76.3 ^{d}	46.9 ^{e}
GH 5	IP 9913-03-9-78-8	75.8 ^{ab}	90.5 ^{ab}	68.6 ^{ab}
GH 6	JP/87055-00-733-174-117-1	72.1 $^{a-d}$	87.2 $^{a-d}$	62.4 $^{a-c}$
GH 7	JP/87055-00-879-91-26	76.7 ^{ab}	84.0 $^{b-d}$	64.5 $^{a-c}$
GH 8	145/G-00-879-91-26	62.8 ^{de}	77.6 ^{cd}	48.9 ^{de}
GH 9	Jerapah variety	79.6 ^{ab}	89.2 ^{abc}	70.9 ^{a}
GH 10	Kancil variety	72.1 $^{a-d}$	86.7 $^{a-d}$	62.5 $^{a-c}$
GH 11	Litbang Garuda 5 variety	74.7 $^{a-c}$	88.9 ^{abc}	66.4 ^{ab}
GH 12	Mj/G-00b-884-95-41	59.1 ^{e}	88.4 $^{a-d}$	52.3 $^{c-e}$
GH 13	C/G-008-644-20-175-20	63.8 $^{c-e}$	90.7 ^{ab}	57.9 $^{b-e}$
GH 14	JP/8705500B-807-145-36	60.1 ^{e}	81.6 $^{b-d}$	49.1 ^{de}
GH 15	MH 91278-99C-180-13-74	63.1 $^{c-e}$	96.9 ^{a}	60.9 $^{a-d}$
GH 16	Local variety	79.9 ^{ab}	88.2 $^{a-d}$	70.5 ^{a}
	Mean	69.3	85.6	59.6

Note: Numbers followed by the same letter in each column were not significantly different based on Duncan test at α=0.05

Mathur et al. (2007) reported a negative correlation of rainfall with number of flowers for peanut grown in the wet season with high amount of rainfall. In the rainy season, the weather parameters such as minimum temperature, high rainfall, relative humidity, as well as maximum temperature take a role in a higher number of flowers produced relative to those produced in the post rainy season. Further, the number of mature pods positively correlated with the number of flowers either for peanut grown in the rainy or post rainy season. It is well known that the number of flowers will dictate the number of mature pods. Both Kancil and Jerapah varieties used in the present study had a lower number of mature pods (45 and 46, respectively) compared to that described in their variety descriptions, *c.a.* 75-100 mature pods per 5 plants (Balitkabi, 2016) as listed in *Table 5*.

Distribution of pod maturity

Due to indeterminate growth habit, peanuts have various stages of pod maturity at harvesting time. The development of pod maturity will be characterized by changing of inner pericarp colour from white as immature pod to yellow, orange, and light brown at the beginning of maturity, and then turns to dark brown when it reaches the full or optimum maturity. The blotching area of dark brown increases from 80% to >90% as pod maturity moves from full maturity to over maturity (Liew et al., 2021). Generally, harvesting is conducted when at least 75% of set-up pods have reached physiological

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maturity as shown by darkening colour of the inner pericarp (Ranga Rao et al., 2010) or 70-80% of pods having brown/black inner pericarp (Carter et al., 2017).

In the current study, despite GH 11 (Litbang Garuda 5 variety) had the highest full mature pods (class 1) *c.a.* 36.8%, the pod maturity of most genotypes belonged to class 2 with intermediate maturity, especially for GH 2, GH 7, and GH 10 (*Table 6*). Among all genotypes tested, GH 2, GH 11, and GH 12 succeeded with high percentages of class 1 and class 2 and low percentages of class 3 and 4 maturity levels, reflecting that these genotypes developed more intermediate to full mature pods. On the other hand, GH 3, GH 4 and GH 8 had the lowest number of physiological mature pods as most pods were still in the stage of prematurity with class 3 and 4 (*Table 6*). High percentages of immature pods due to high rainfalls during the growing season and the occurrence of severe leaf spot disease were also reported by Liew et al. (2021).

Table 6. *The distribution of pod maturity levels of 16 genotypes*

GH	Genotype	Class 1 (%)	Class 2 (%)	Class 3 (%)	Class 4 (%)
GH 1	GH 502/G-00-B-677-49-43	6.5 ^{ef}	27.9 $^{a-c}$	28.6 ^{a}	36.9 $^{a-c}$
GH 2	GH 502/G-00-B-679-46-47	20.7 $^{b-e}$	41.6 ^{ab}	21.1 ^{a}	16.6 ^{d}
GH 3	PC 87123/86680-83-13-75-55	6.5 ^{ef}	15.2 ^{c}	35.9 ^{a}	42.4 ^{a}
GH 4	IP 991230,03	6.3 ^{ef}	23.0 ^{bc}	34.7 ^{a}	36.1 $^{a-d}$
GH 5	IP 9913-03-9-78-8	11.1 $^{c-f}$	36.6 $^{a-c}$	31.4 ^{a}	20.9 $^{b-d}$
GH 6	JP/87055-00-733-174-117-1	16.9 $^{b-f}$	27.8 $^{a-c}$	26.9 ^{a}	28.4 $^{a-d}$
GH 7	JP/87055-00-879-91-26	6.9 ^{ef}	45.1 ^{ab}	25.5 ^{a}	22.4 $^{b-d}$
GH 8	145/G-00-879-91-26	9.5 $^{d-f}$	37.4 $^{a-c}$	23.4 ^{a}	39.7 ^{ab}
GH 9	Jerapah variety	12.9 $^{c-f}$	31.3 $^{a-c}$	31.6 ^{a}	24.2 $^{a-d}$
GH 10	Kancil variety	2.2 ^{f}	50.0 ^{a}	26.1 ^{a}	21.7 $^{b-d}$
GH 11	Litbang Garuda 5 variety	36.8 ^{a}	22.6 ^{bc}	16.3 ^{a}	24.3 $^{a-d}$
GH 12	Mj/G-00b-884-95-41	28.0 ^{ab}	33.2 $^{a-c}$	21.3 ^{a}	17.4 ^{cd}
GH 13	C/G-008-644-20-175-20	24.7 $^{a-c}$	24.7 ^{bc}	24.1 ^{a}	26.5 $^{a-d}$
GH 14	JP/8705500B-807-145-36	23.1 $^{a-d}$	28.4 $^{a-c}$	28.2 ^{a}	20.4 $^{b-d}$
GH 15	MH 91278-99C-180-13-74	11.4 $^{c-f}$	34.4 $^{a-c}$	26.4 ^{a}	27.9 $^{a-d}$
GH 16	Local variety	9.9 $^{c-f}$	36.9 $^{a-c}$	16.4 ^{a}	36.8 $^{a-c}$
	Mean	14.6	31.6	26.1	27.7

Note: Numbers followed by the same letter in each column were not significantly different based on Duncan test at α=0.05. Class 1: 76-100%, Class 2: 51-75%, Class 3: 26-50%, Class 4: $\leq$ 25% of inner shell area had turned to brown/black. Based on (Liew et al., 2021): class 1 belongs to full maturity, class 2 belongs to intermediate maturity, and class 4 belongs to prematurity

Physical quality of kernels

The highest and lowest moisture content of the kernel (inside the fresh pod) in the current experiment was 61.3% and 41.2% that was obtained in GH 4 and GH 1, respectively (*Table 7*). These values were higher than those reported by Dimanche et al. (2001), and Ranga Rao et al. (2010) that were about 30-40%, and 41.1% (Liew et al., 2021). Our results, however, were in agreement with the peanut moisture contents normally noted during harvesting that ranged from 35-60% (Nigam et al., 2004; Ahmad and Mirani, 2012; Azmoodeh et al., 2014; Cavichioli et al., 2014; Rahmianna et al., 2015). It was also stated that moisture content of the kernel at harvest in the wet season was higher compared to that harvested in the dry season as it was considerably influenced by

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the soil wetness or soil moisture around the pods (Rahmianna et al., 2012). High moisture content at harvest in the current study was not a problem as pulling up the pods was done manually. However, harvesting or digging the plant using a machine should be applied to dry pods with a kernel moisture content below 20% (Santos et al., 2021).

Table 7. *The distribution of physical quality of peanut kernel derived from 16 genotypes*

GH	Genotype	Sound mature (%)	Shriveled (%)	Damage (%)	Kernel moisture content at harvest (%)
GH 1	GH 502/G-00-B-677-49-43	87.8 ^{ab}	7.4 $^{b-d}$	4.8 ^{bc}	41.2 ^{c}
GH 2	GH 502/G-00-B-679-46-47	77.8 $^{a-d}$	11.2 $^{a-d}$	11.0 ^{abc}	48.8 ^{bc}
GH 3	PC 87123/86680-83-13-75-55	71.7 ^{cd}	14.1 $^{a-d}$	14.2 ^{a}	58.1 ^{ab}
GH 4	IP 991230,03	87.6 ^{ab}	8.2 $^{b-d}$	4.2 ^{c}	61.3 ^{a}
GH 5	IP 9913-03-9-78-8	84.9 $^{a-c}$	7.6 $^{b-d}$	7.5 ^{abc}	51.2 ^{b}
GH 6	JP/87055-00-733-174-117-1	75.1 $^{b-d}$	16.5 ^{ab}	8.4 ^{abc}	52.7 ^{ab}
GH 7	JP/87055-00-879-91-26	82.1 $^{a-d}$	11.8 $^{a-d}$	6.1 ^{bc}	50.4 ^{bc}
GH 8	145/G-00-879-91-26	82.5 $^{a-d}$	10.2 $^{b-d}$	7.3 ^{abc}	52.8 ^{ab}
GH 9	Jerapah variety	72.1 ^{cd}	15.4 $^{a-c}$	12.5 ^{ab}	50.2 ^{bc}
GH 10	Kancil variety	69.5 ^{d}	20.0 ^{a}	10.5 ^{abc}	49.3 ^{bc}
GH 11	Litbang Garuda 5 variety	89.2 ^{a}	6.2 ^{cd}	4.6 ^{bc}	49.2 ^{bc}
GH 12	Mj/G-00b-884-95-41	83.8 $^{a-c}$	8.5 $^{b-d}$	7.7 ^{abc}	49.9 ^{bc}
GH 13	C/G-008-644-20-175-20	91.1 ^{a}	4.9 ^{d}	4.0 ^{c}	52.9 ^{ab}
GH 14	JP/8705500B-807-145-36	85.7 ^{ab}	9.1 $^{b-d}$	5.2 ^{bc}	49.5 ^{bc}
GH 15	MH 91278-99C-180-13-74	89.9 ^{a}	5.8 ^{d}	4.3 ^{c}	48.5 ^{bc}
GH 16	Local variety	78.9 $^{a-d}$	13.0 $^{a-d}$	8.1 ^{abc}	53.7 ^{ab}
	Mean	81.8	10.6	7.4	51.2

Note: Numbers followed by the same letter in each column were not significantly different based on Duncan test at α=0.05

The SMK were predominantly observed in GH 11, GH 13, and 15. Conversely, GH 3, GH 9, and GH 10 had the lowest SMK as most of the kernels were shriveled for GH 10, damaged for GH 3, and both shriveled and damaged for GH 9 (*Table 7*). In general, physical characteristics of the kernel derived from all genotypes were similar to the local variety. Despite the shriveled kernel is caused by inadequate contents of gibberellic acid (GA), abscisic acid (ABA) and zeatin (ZT) during pod development stage (Hou et al., 2018), and groundnut rosette disease (Appiah et al., 2016), it is also an inherited trait that is controlled by a single recessive allele at one locus (Jakkula et al., 1997). This suggests that genetic factor may contribute to variation in the number of shriveled kernels.

Pod yields

GH 12 showed the highest productivity, *c.a.* 1.678 t/ha of dry pods, while Jerapah variety had the lowest value with 0.576 t/ha dry pods (*Table 8*). The yield of GH 12 was 191.3%, 66.5%, and 55.4% higher than Jerapah, Kancil, and Litbang Garuda 5 varieties, respectively. The local variety gave the same productivity as most of the genotypes; however, the yield was significantly lower than GH 5 and GH 12. Conversely, the productivity of local variety was greater than Jerapah, an old improved variety. Low productivity of Jerapah variety was due to its small number of plant population at harvest as a consequence of severe attack of soil-borne fungal disease. In line with pod yield, GH

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12 showed the highest number of harvested plants (plant population at harvesting time), *c.a.* 283,680 plants/ha, and was conversely to that of Jerapah with 80,208 plants/ha only (*Table 8*). As a legume crop, peanut is a non-tillering plant and therefore pod yield positively correlates with the number of plants per unit area or plant population at harvest (Morla et al., 2018; Oakes et al., 2020).

Table 8. *Number of harvested plants, pod yields*

GH	Genotype	Pod yields*) (t/ha)	Number of harvested plants/ha
GH 1	GH 502/G-00-B-677-49-43	1.573 abc	201,041 d
GH 2	GH 502/G-00-B-679-46-47	1.162 cde	215,972 cd
GH 3	PC 87123/86680-83-13-75-55	1.256 bcde	217,013 cd
GH 4	IP 991230,03	1.427 abcde	280,208 ab
GH 5	IP 9913-03-9-78-8	1.639 ab	224,305 cd
GH 6	JP/87055-00-733-174-117-1	1.160 cde	230,902 bcd
GH 7	JP/87055-00-879-91-26	1.427 abcde	227,777 cd
GH 8	145/G-00-879-91-26	1.443 abcd	192,708 d
GH 9	Jerapah variety	0.576 f	80,208 f
GH 10	Kancil variety	1.008 e	140,972 e
GH 11	Litbang Garuda 5 variety	1.080 de	119,791 ef
GH 12	Mj/G-00b-884-95-41	1.678 a	283,680 a
GH 13	C/G-008-644-20-175-20	1.445 abcd	255,555 abc
GH 14	JP/8705500B-807-145-36	1.403 abcde	244,097 abcd
GH 15	MH 91278-99C-180-13-74	1.378 abcde	211,458 cd
GH 16	Local variety	1.166 cde	207,291 cd
	Mean	1.031	208,312

Note: *) at 14% of moisture content. Numbers followed by the same letter in each column were not significantly different based on Duncan test at α=0.05

The highest pod yield of GH 12 was not influenced by the number and weight of dry mature pods as well as dry seed weight but more likely as a result of the highest plant population at harvest. As shown in *Table 4*, the number of mature pods per plant, weight of mature pods and dry seeds per plant of GH 12 were lower compared to those of GH 5 and GH 11. These two genotypes significantly had the highest number and weight of mature pods per plant as well as dry seeds weight per plant, however GH 11 showed low productivity as the plant population at harvest was considerably low (*Table 8*).

The average pod yield obtained in the current study was 1.301 t/ha with a population of 208,312 plants/ha at harvest (*Table 8*). A study conducted at Kyoga Plains, Uganda by Okello et al. (2016) recorded a lower pod yield of 1.24 t/ha when peanuts were grown during the rainy season under rainfed condition with a population of 333 thousands plants/ha and no application of fertilizer and fungicide. A lower pod yield of 1.216 t/ha was also obtained from planting peanut in the wet season at the Sudan savannah areas with low total annual rainfall, *c.a.* 721.4 mm. Under such condition, the application of 100 mg gibberellic acid/L could increase the pod yield becoming 2.064 t/ha as a result of greater kernel weight (Yakubu et al., 2013). Meanwhile, growing peanuts under rainfed condition in the rainy season with NPK fertilizer and calcium sulphate application, gave higher pod yield *c.a.* 3.020 to 4.635 t/ha with the population of 297,000 plants/ha (Parwada et al., 2020).

A much higher pod yield (2.361 t/ha) was obtained when peanuts were grown at Baybay, Leyte, The Philippines in the wet season with 718.3 mm rainfall, 25.5 and 29.7^{o}C

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of mean minimum and maximum temperatures, and 86.6% of mean relative humidity during the growing season. However, this value was yet lower compared to that produced in the dry season, *c.a.* 2.862 t/ha (Cagasan and Coral, 2021) due to optimal moisture condition with minimum and maximum temperatures of 25.4 and 32.4^{o}C and relative humidity of 81.7%. Higher yield obtained in the dry season planting was mainly caused by superior seed size and seed yield (Cagasan and Coral, 2021). According to Puangbut et al. (2013), wet condition during the entire growing season resulted in inferior reproductive growth, such as lower numbers of flower, peg, pod, and 100-seed weight, and in particular the number of mature pods per plant which predominantly would contribute to the final pod yield. Yadav et al. (2013) reported that peanuts grown under well distributed rainfall during the rainy season cropping, along with NPK fertilization, pesticide application and weeding practiced at appropriate phase of the crop growth gave an average of 2.023 t/ha pod yield that ranged from 1.501-2.603 t/ha.

Infection of Aspergillus flavus and aflatoxin contamination

The moisture content of peanut kernels inside the harvested pods ranged from 41.2-61.3% for all genotypes (*Table 7*). This amount was beyond the optimal moisture content for *A. flavus* infection and AF production, which is in the range of 15-30% (Crop Link, 2000). In addition to moisture content, a relative humidity of around 85% with surrounding air temperature of 27^{o}C is also a favorable condition for *A. flavus* to produce AF (Wu and Khlangwiset, 2010; Aini, 2012).

There was a significant interaction effect of curing time and genotype on the infection rate of *A. flavus* (*Table 9*). On average, delayed drying (curing) for 36 hours increased the infection rate of *A. flavus* from 2.4% (without curing) to 6.7% (*Table 9*). High kernel moisture content and environment relative humidity during the wet season as well as warm condition as a result of pod respiration that yet occurs after harvesting, are favourable for *A. flavus* infection and growth. A shorter curing time (24 hours) was reported to have no difference in *A. flavus* infection compared to 0-hour curing treatment (Sumartini et al., 2006), suggesting that delaying drying for more than 24 hours is risky for *A. flavus* infection. This statement was supported by Rahmianna et al. (2020) that 36 hours curing time increased *A. flavus* infection from 1.9% to 2.4%. Osman and Ali (2005) reported that the inverted drying method (pods were placed upwards, well exposed to sunlight and air currents) rapidly reduced the kernel moisture content to around 10% compared to the traditional drying method (plants stacked over each other with pods are not fully exposed to sunlight) with kernel moisture content above 15% after 4 days of drying. Slow curing process in the traditional drying method resulted in higher *A. flavus* infection rate of 50% compared to the inverted drying method with 20% of such infection rate.

Table 9 also reflects that there was a genetic resistance of genotypes tested to *A. flavus* infection. Ten genotypes showed an increase in *A. flavus* infection when cured for 36 hours, while a slight decrease was noted for three genotypes. Interestingly, three genotypes, namely GH 9, GH 10, and GH 13 showed a consistent low rate of *A. flavus* infection for both curing times (0 and 36 hours). Despite all genotypes had infection rate below 15%, GH 4 and GH 6 had the highest infection rate, therefore both genotypes were categorized as moderately resistant to *A. flavus* infection as referred to SiuLin et al. (1996). Meanwhile, GH 1-3, GH 5, and GH 7-16 genotypes belonged to highly resistant according to SiuLin et al. (1996). This variation among genotypes may relate to differences in pod and kernel coat resistance against *A. flavus* infection associated with

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the presence of phenolic compounds that have capacity to inhibit the growth of *A. flavus* (Commey et al., 2021).

Table 9. *Aspergillus flavus infection and aflatoxin contamination on seeds of 16 peanut genotypes*

No.	Genotype	Seed infection of *A. flavus* (%)*		Aflatoxin B_1 content (µg/kg)	
		Direct drying	Delayed drying**)	Direct drying	Delayed drying**)
GH 1	GH 502/G-00-B-677-49-43	3.0 ijk	6.6 f (HR)	1.12	1.25
GH 2	GH 502/G-00-B-679-46-47	2.6 jkl	5.6 g (HR)	0.87	1.10
GH 3	PC 87123/86680-83-13-75-55	2.6 jkl	11.0 d (HR)	1.17	1.27
GH 4	IP 991230,03	1.6 mno	15.6 b (MR)	0.77	1.43
GH 5	IP 9913-03-9-78-8	4.0 h	11.3 d (HR)	0.85	0.93
GH 6	JP/87055-00-733-174-117-1	3.3 hij	19.3 a (MR)	0.89	1.02
GH 7	JP/87055-00-879-91-26	3.6 hij	14.0 c (HR)	0.77	1.29
GH 8	145/G-00-879-91-26	5.3 g	8.3 e (HR)	0.77	0.97
GH 9	Jerapah variety	1.0 o	1.0 o (HR)	1.22	1.35
GH 10	Kancil variety	1.3 no	1.0 o (HR)	0.97	0.90
GH 11	Litbang Garuda 5 variety	2.6 jkl	1.0 o (HR)	1.14	1.26
GH 12	Mj/G-00b-884-95-41	3.0 ijk	1.0 o (HR)	1.13	1.17
GH 13	C/G-008-644-20-175-20	1.0 o	1.0 o (HR)	1.05	1.54
GH 14	JP/8705500B-807-145-36	1.0 o	2.0 lmn (HR)	1.00	1.20
GH 15	MH 91278-99C-180-13-74	2.3 klm	1.0 o (HR)	0.90	1.30
GH 16	Local variety	1.0 o	7.3 f (HR)	1.00	1.09
	Mean	2.4	6.7	0.97	1.20

Note: Numbers followed by the same letter in the same parameter were not significantly different based on Duncan test at α=0.05. *) Highly resistant (HR): <15% seed infection; moderately resistant (MR): 15-30% seed infection, moderately susceptible (MS): 30-50% seed infection; highly susceptible (HS): >50% seed infection (SiuLin et al., 1996). **) Delayed drying: Pod drying was delayed for 36 hours by keeping the fresh pods in the plastic net bag before the pods were sun dried during 6 consecutive days starting from 8 am up to 3 pm

There was no interaction effect of curing time and genotype on aflatoxin B_1 (AFB_1) content. The AFB_1 contents of all genotypes were fairly low for both direct and delayed drying treatments (*Table 9*). A slight increase of AFB_1 content was actually observed for 36-hour curing treatment following the increase in *A. flavus* infection; however, the amounts of all genotypes were yet relatively low. Waliyar et al. (2015) summarized a number of studies and highlighted that direct stripping of the pods at the same day with harvest and subsequent drying (without any delay) are essential to obtain peanut pod or kernel with low AF contamination. The current study shows that even though curing or delayed drying of the fresh pods occurs up to 36 hours due to wet or rainy season condition, it is yet relatively safe for marketing, processing, and consumption as the AFB_1 amounts were less than the permitted level established by the Indonesian National Standardization Agency (2009) for peanut kernels and products that was 15 and 20 µg/kg for AFB_1 and total AF, respectively. Most of peanut manufacturers give a limit of 24 to 48 hours after harvesting in making decision to accept or reject the supplied fresh pods to their factories. This study suggests that 16 tested genotypes can be cured up to 36 hours prior to drying as the AFB_1 contents were yet below the safe level. Samples of peanut kernels owed by farmers in the study area which were grown and harvested at the same

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time with this study as well as samples collected from nearby local market contained AFB_1 around 20-59 μg/kg that were much higher than this study findings. Using the same local variety and cultivated using farmer practices, the pod yield obtained was also considerably lower, *c.a.* 0.56 t/ha compared to our results (*Table 8*). It is likely that application of high yielding improved varieties, proper cultivation and postharvest handling is essential in control *A. flavus* infection and aflatoxin contamination in this area.

Correlation between variables

Pod yield per acreage positively correlated with % weight of SMK, plant population at harvest, and pod size. Conversely, pod yield had a negative correlation with % weights of SHV and DMG kernels and kernel moisture content at harvest (*Table 10*). The predominant effect of plant population on pod production ($r = 0.73^{**}$) was also previously investigated by Rahmianna et al. (2020). Shukla and Rai (2014) reported that pod yield per acreage positively correlated with seed yield, pod yield per plant, seed size, and shelling percentage for peanut grown during rainy season. Kumar et al. (2019) pointed out that pod yield positively correlated with days to maturity, seed size, SPAD Chlorophyll Meter Reading at 45 DAS, and negatively correlated with days to flower initiation and rust disease. Seed size was likely the most important trait in dictating the final pod yield during the rainy season cropping.

Pod yield per plant highly correlated with seed yield, number of mature pods, and number of branches. Meanwhile, pod yield per plant had negative correlation with leaf spot and rust diseases scores and % number of pegs. Seed yield per plant highly correlated with number of mature pods in a positive trend. Seed yields also positively correlated with number of mature pod, % number of mature pod, and number of branches. Conversely, seed yield negatively correlated with score of leaf spot, score of rust, and % number of pegs (*Table 10*). Meanwhile, Hampannavar et al. (2018) reported that pod yield per plant positively correlated with seed yield per plant, mature pod per plant, SMK, and haulm yield per plant.

The present study summarized that pod yield and seed yield per plant negatively correlated with both leaf spot and rust. Instead of having negative influence to yield and yield components, leaf spot positively correlated with rust under wet season planting. In addition, leaf spot positively correlated with per cent number of pegs, while rust disease positively correlated with per cent number of immature pods. Both foliar diseases negatively correlated with % number of mature pods. A study conducted by Phakamas et al. (2008) on peanut grown in the rainy season with heavy rainfall pointed out that the infection of *Phaeoisariopsis personata*, which causes the late leaf spot at early growing season, resulted in defoliation, reduced leaf weight and leaf area index that ultimately would reduce the pod yield.

Shelling percentage positively correlated with % weight of SMK, % number of class-1 physiologically mature pods. On the contrary, shelling percentage negatively correlated with % weight of SHR and DMG, number of branches and % number of mature pods class-4. SMK had positive correlation with % number of class-1 physiologically mature pods and pod size. SMK had negative correlation with % of shriveled and damage seeds, and number of branches. Damaged seeds correlated with leaf spot score in a negative way. In wet season, plant height positively correlated with % number of pegs and % number of least mature pods (class-4 physiological maturity).

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Table 10. *Coefficients of correlation between parameters observed*

	PY	SMK	SHR	DMG	PP	TT	NB	DP	K	SP	MP	K-1	K-2	K-3	K-4	PS	LS	RS	M	IM	PG
PY	--																				
SMK	0.41**	--																			
SHR	-0.32*	-0.89**	--																		
DMG	-0.39**	-0.79**	0.43**	--																	
PP	0.73**	0.26	-0.20	-0.26	--																
TT	0.05	0.05	0.05	-0.20	0.10	--															
NB	-0.18	-0.36*	0.22	0.41**	-0.17	0.05	--														
DP	-0.19	-0.19	0.09	0.25	-0.40**	-0.19	0.41**	--													
MC	-0.285*	-0.13	0.16	0.03	0.14	0.23	0.09	-0.24													
K	-0.18	-0.13	0.03	0.21	-0.40**	-0.19	0.37**	0.99**	--												
SP	0.09	0.47**	-0.47**	-0.30*	0.06	0.02	-0.29*	-0.06	0.06	--											
MP	-0.33*	-0.26	0.16	0.29*	-0.44**	-0.21	0.38**	0.94**	0.93**	-0.07	--										
K-1	0.01	0.30*	-0.28*	-0.22	0.05	-0.04	-0.04	0.14	0.17	0.31*	0.15	--									
K-2	0.04	-0.04	0.02	0.05	-0.09	-0.22	-0.04	0.41**	0.42**	0.13	0.40**	-0.27	--								
K-3	-0.12	-0.17	0.11	0.19	-0.01	-0.03	0.05	-0.26	-0.26	-0.14	-0.30*	-0.19	-0.52**	--							
K-4	0.07	-0.09	0.14	-0.02	0.06	0.30*	0.04	-0.35*	-0.39**	-0.47**	-0.31*	-0.48**	-0.37**	-0.15	--						
PS	0.29*	0.28*	-0.24	-0.24	0.06	0.23	-0.12	-0.18	-0.18	-006	-0.37*	-0.12	-0.28	0.14	0.29*	--					
LS	0.001	0.34*	-0.23	-0.38**	0.02	-0.03	-0.21	-0.31*	-0.29*	0.16	-0.33*	0.17	0.04	-0.10	-0.12	-0.01	--				
RS	-0.03	0.07	-0.002	-0.14	-0.07	0.08	0.01	-0.38**	-0.36*	0.11	-0.39**	-0.14	-0.25	0.23	0.19	-0.09	0.46**	--			
M	-0.46**	-0.28	0.18	0.37*	-0.42**	-0.24	0.20	0.65**	0.64**	-0.09	0.77**	0.12	0.33*	-0.14	-0.34*	-0.47**	-0.29*	-0.37**	--		
IM	0.06	-0.12	0.08	0.13	0.08	-0.02	0.11	-0.24	-0.25	-0.15	-0.26	-0.37**	0.01	-0.06	0.40**	0.08	0.04	0.36*	-0.49**	--	
PG	0.49**	0.36*	-0.22	-0.41**	0.42**	0.32*	-0.24	-0.58**	-0.56**	0.18	-0.72**	0.06	-0.36*	0.18	0.17	0.50**	0.30*	0.24	-0.87**	-0.46**	--

Note: ***, ****: significant at probability of 0.05, 0.01; PY: pod yield/ha; SMK: % sound mature kernel; SHR: % shriveled; DMG: % damaged; PP: plant population at harvest/ha; TT: plant height; NB: number of branches; DP: dry pod yield/plant, MC: kernel moisture content; K: kernel yield/plant; SP: shelling percentage; MP: number of mature pods; K-1: % number of mature kernel class 1; K-2: % number of mature kernel class 2; K-3: % number of mature kernel class 3; K-4: % number of mature kernel class 4; PS: weight 100 pods; LS: leaf spot score; RS: rust score; M: % number of mature pods; IM: % number of immature pods; PG: % number of pegs

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Conclusion

Planting promising lines and improved varieties of peanut in wet season with high amount of rainfall during the growing period resulted in similar vegetative (*i.e.*, plant height and number of branches) and generative growth (*i.e.*, number of mature pods, weight of mature pods, weight of seeds, physical quality, and moisture content) as those of local variety. Meanwhile, local variety obtained superior distribution of mature pods, development of pegs to mature pods compared to those of promising lines and improved varieties. However, local variety was inferior in terms of pod yield per acreage, shelling percentage, and pod maturity despite that local varieties had been well adapted to agro-ecological characteristics of the growing site.

Wet condition during the entire growing season resulted in diverse maturity levels of mature pods. Most genotypes including local variety had not reached the full maturity level yet, as among pods intermediate and prematurity classes dominated. However, there was only three tested genotypes (GH2, GH 11, and GH 12) that had higher percentage of full maturity than that of local variety. GH 5 and GH 12 obtained higher pod yield compared to that of local variety, and only one genotype had lower pod yield than that of local variety. The superior and inferior pod yields of these genotypes positively correlated with the number of harvested plants.

The 36-hours delay of pods drying (curing) definitely increased the number of *A. flavus* infected kernels that was noted for 16 peanut genotypes. Almost all genotypes were highly resistant to *A. flavus* infection except two genotypes that were moderately resistant with 15-30% of kernel infection. Delaying pod drying for 36 hours after harvesting and stripping, promoted the *A. flavus* infection and aflatoxin production in most genotypes. However, the level of aflatoxin B_1 was still far below the permitted level for human consumption.

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