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RESEARCH ARTICLE

Effect of harvesting time on groundnut yield and yield components in Northern Mozambique

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ABSTRACT

Groundnut (*Arachis hypogaea* L.) is one of the most important legume crop in Mozambique which is grown for food as well as cash. It's an indeterminate growth habit and below the ground nature of fruiting makes it difficult to determine the time of optimal maturity of pods. This results in reduced crop yields if either harvested too early or too late. The objectives of the study were therefore to evaluate the effect of harvesting time for optimum yield of groundnut pods for three Spanish varieties and to estimate yield losses as a result of harvesting time at two locations, namely; Nampula Research Station (PAN) and Mapupulo Agricultural Research Center (CIAM) in Nampula and Cabo Delgado provinces respectively. The experiment was laid out in a randomized complete block design in a split-plot arrangement with four replicates. The varieties (*ICGV-SM-99568*, *ICGV-SM-01514* and *JL-24*) were the main factor and three harvesting times (10 days before physiological maturity, at physiological maturity and 10 days after physiological maturity) were the sub-plots. Highest pod yields of 1276.9 and 1503.6 kg/ha were recorded at CIAM and PAN as a result of harvesting at physiological maturity compared to harvesting 10 days before (904.6 and 950 kg/ha) and 10 days after (826.8 and 1047.4 kg/ha) physiological maturity. Furthermore, yield losses ranged from (16-25 %) and (30-40 %) as a result of harvesting groundnut 10 days before and 10 days after physiological maturity respectively. It is therefore advisable that farmers' harvest their groundnut crop at physiological maturity in order to obtain maximum pod yields of the groundnut.

Keywords: Groundnut, harvesting time, optimum pod yield, yield loss, Spanish varieties

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INTRODUCTION

The storage Groundnut is one of the most important food legumes in the world and is the third largest oilseed crop after soybean and cotton seed globally. Additionally, it is an important source of vegetable protein and oil in sub-Saharan Africa (Kaba et al., 2014). In Mozambique groundnut is the third most important crop after cassava and maize (Muitia, 2013). Groundnut is an essential crop in northern Mozambique where it is grown both as a cash and food crop. The crop is grown throughout the country, mainly by resource-poor small-scale farmers under rain-fed conditions. However, groundnut yields realized by these small-scale farmers are reasonably low (400-600 kg/ha) and of poor quality (Muitia, 2005). The low yields have been attributed to several constraints. Some of the major groundnut production constraints include; lack of improved cultivars, poor cultural practices, insect pests, diseases, weeds and drought and the non-timely execution of agronomic practices (Muitia, 2013; Jeffrey, 2011).

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The timely execution of cultural and agronomic practices of groundnut farmers is very important as it contributes to kernel yield and quality. In general, some activities are not executed on time, resulting in reduced crop yield. Among these activities is harvesting of the crop. It has been observed that groundnut is always harvested several weeks before or after physiological maturity in both Nampula and Cabo Delgado provinces, as farmers are always engaged in both farm and off-farm activities. Furthermore, there is little information on the effect of early and delay of harvesting on the pod and kernel yield of groundnut in Northern Mozambique. It was in the light of this that three Spanish groundnut varieties were subjected to different harvesting times, starting from 10 days before the actual physiological maturity, to assess the pod and grain yield at each harvesting time and grain quality with time.

MATERIALS AND METHODS

Description of the Study Area

Due to The study was conducted during the 2015/2016 growing season in two locations, namely; Nampula Research Station (PAN) and Mapupulo Agricultural Research Center (CIAM), located in Nampula and Cabo Delgado Provinces, respectively. Nampula Research Station (PAN) is located about 7 km east of the Nampula city in Northern Mozambique (15° 09' S, 39° 30' E) and is elevated at 432 m above sea level. The soil type is sandy loam and the vegetation is predominantly grassland. The average rainfall is slightly over 1000 mm which starts around November/December up to April/May, with its peak in January. The maximum temperature in the region is about 39 °C and the minimum temperature is 19 °C (Muitia, 2013).

The Mapupulo Agricultural Research Center (CIAM) is located about 18 km south of Montepuez town about 200 km west of Pemba the capital of the province, which lies at (13° 12' S, 38° 53' E) and is elevated at 476.7 m above sea level. The soils are clay loam and deep brown loam. It receives annual precipitation of 1200 mm on average from November/December to April/May, and the average temperature is between 20 and 25 °C (Muitia, 2013).

Experimental design and treatments

The experiments were laid out in a split plot arrangement of treatments in a randomized complete block design with four replications. The main plot was made up of three groundnut varieties that take 90 days to mature while sub-plots were three harvesting times. The test varieties were Spanish groundnut varieties, namely: *ICGV-SM-99568*, *JL-24* and *ICGV-SM-01514*. The harvesting times were (i) 10 days before physiological maturity indicated as H1; (ii) at physiological maturity indicated as H2 and (iii) 10 days after physiological maturity indicated as H3. The net plots were 6 rows by 6 m long with one seed per planting station, which were spaced at 50 cm between rows and 10 cm within rows.

Harvesting was carried out at each stage by either digging, using a hand-held hoe, when the soil was dry and by uprooting the plant by hand when the soil was wet. Harvesting was carried out every 10 days with the first harvest at 10 days before the actual physiological maturity.

Data collection

Data collected included; number of pods per plant, pod yield (kg/ha), kernel yield (kg/ha), 100-seed weight (g) and shelling percentages (%).

Pod yield: Ten plants harvested from the middle of the rows from each net plot were used to estimate pod yield per hectare using the expression:

$$\text{Pod yield per ha} = \frac{\text{Pod weight (Kg)}}{\text{Area harvested } (m^2)} \times 10000$$

Kernel yield: To estimate kernel yield per hectare it involved drying pods harvested from each net plot, after which the pods were shelled and the following expression was used:

$$\text{Kernel yield per ha} = \frac{\text{Kernel weight (Kg)}}{\text{Area harvested } (m^2)} \times 10000$$

Shelling percentage %: To estimate the groundnut shelling percentage for the varieties the following expression was used:

$$\text{Groundnut shelling \%} = \frac{\text{Kernel weight (kg)}}{\text{Pod weight (kg)}} \times 100$$

Data analysis

The data on yield and yield components were subjected to analysis of variance (ANOVA) to establish treatment and the interaction effect on the parameters measured. Statistical analyses were performed using the statistical software GenStat Discovery edition 4 (Muitia, 2013). Groundnut varieties and harvesting times were treated as fixed effects and replication was treated as a random effect. Main effects and all interactions were considered significant at 0.05 and 0.01 probability level of the F-test. Means were separated using Fisher's protected LSD test at P = 0.05.

RESULTS

Number of pods per plant

Results of number of pods per plant at different harvesting times are presented in Table 1. Significant differences in the total number of pods per plant were observed in both study locations ($P \leq 0.01$). The highest number of pods per plant was recorded when harvesting was done at physiological maturity (H2) and the lowest when harvesting was executed 10 days before physiological maturity (H1). The variety *ICGV-SM-01514* produced the highest number of pods per plant (39 and 30) while *JL-24* produced the lowest number of pods per plant (18 and 21) at CIAM and PAN respectively. Additionally, harvesting at H3 lead to a reduced number of pods per plant, however, these were to some extent higher than when harvesting was executed at H1.

Pod and kernel yield

Pod yields among the groundnut varieties were directly related to the kernel yields. Significant differences were observed in the total pod yields as a result of harvesting time ($P \leq 0.05$) and ($P \leq 0.001$) at CIAM and PAN respectively (Table 2). The highest pod yields among the groundnut varieties were recorded at PAN (1166.94 kg/ha) compared to that at CIAM

(1002.8 kg/ha). In general, harvesting the groundnut varieties at physiological maturity produced the highest pod yields than the subsequent dates.

Table 1. Effect of harvesting time on number of pods among groundnut varieties.

	Mapupulo Agricultural Research Center			Nampula Research Station		
	Harvesting time			Harvesting time		
Variety	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**
ICGV-SM-99568	20^{d}	32^{ab}	27^{cd}	23^{bc}	25^{b}	24^{bc}
ICGV-SM-01514	20^{d}	39^{a}	28^{bc}	21^{c}	30^{a}	20^{c}
JL-24	18^{d}	31^{bc}	24^{c}	21^{c}	28^{ab}	24^{c}
CV (%)	17.9	9.9	11.9	41.2	29.8	37.5
Mean ± SE		**26.0 ± 1.68**			**23.4 ± 1.40**	

Means followed by the same letter in the same column are not significantly different at (P ≤ 0.01).

The highest pod yields were obtained from *ICGV-SM-01514* (1412.5 kg/ha) and *JL-24* (1596.2 kg/ha) and the lowest pod yields were obtained from *JL-24* (693.1 kg/ha) and *ICGV-SM 01514* (835.4 kg/ha) at CIAM and PAN respectively. Kernel yields significantly differed among the groundnut varieties as a result of harvesting time (Fig 1). The highest kernel yields were recorded at physiological maturity for all the groundnut varieties.

In addition, kernel yields tended to decline with harvesting 10 days before and 10 days after physiological maturity. However, the kernel yields of harvesting at physiological maturity and harvesting 10 days after physiological maturity were higher than that for harvesting at 10 days before physiological maturity.

The kernel yields ranged from 525 kg/ha for *JL-24* and 668.7 kg/ha for *ICGV-SM-01514* for harvesting 10 days before physiological maturity to 1165.3 kg/ha for *ICGV-SM-01514* and 1429.6 kg/ha for *JL-24* for harvesting at physiological maturity at CIAM and PAN respectively.

100-seed weight

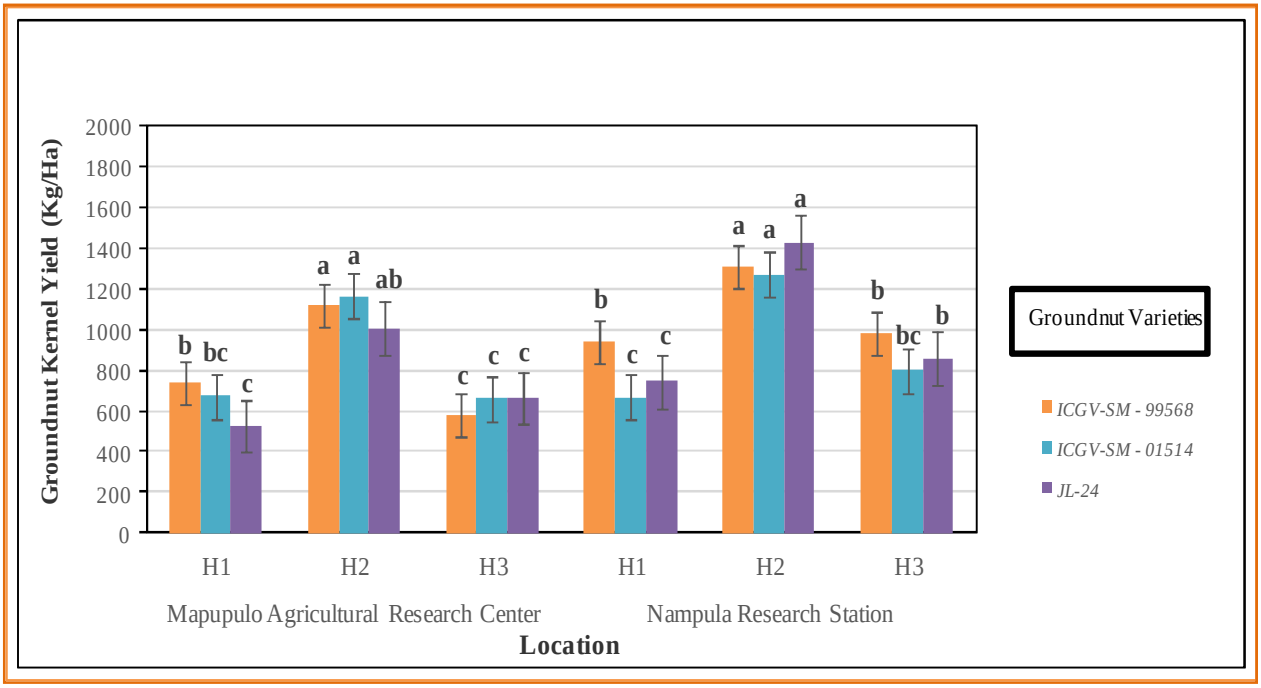
100-seed weight of the three groundnut varieties differed significantly as a result of the effect of harvesting time (Table 3). Maximum 100-seed weight (54.9g and 56.9g) was obtained from the variety *ICGV-SM-99568* at CIAM and PAN respectively when harvesting was executed at physiological maturity. In addition, the weight of *JL-24* was significantly higher than that of *ICGV-SM-01514* which recorded the lowest kernel weight regardless of harvesting time. The bigger nuts of *ICGV-SM-99568* could be responsible for its higher kernel weight than the *ICGV-SM-01514* variety which had the smallest kernel weight. It has also been established that harvesting 10 days before physiological maturity recorded the lowest 100-kernel weight than the succeeding harvesting times. The 100-kernel weight ranged from 22.4g for *ICGV-SM-01514* for harvesting 10 days before physiological maturity to 56.9g for *ICGV-SM-99568* for harvesting at physiological maturity.

Table 2. Effect of harvesting time on groundnut pod yield (kg/ha).

	Mapupulo Agricultural Research Center			Nampula Research Station		
	Harvesting time			Harvesting time		
Variety	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**
ICGV-SM-99568	1043^{b}	1250^{a}	786.1^{d}	1102.1^{b}	1479.9^{a}	50.6^{b}
ICGV-SM-01514	977.8^{c}	1412.5^{a}	873.6^{cd}	835.4^{cd}	1434.7^{a}	66.7^{c}
JL-24	693.1^{d}	1168.1^{b}	820.8^{cd}	912.5^{c}	1596.2^{a}	.025^{b}
Level of sig.	*	*	NS	**	**	NS
CV (%)	23.6	15.2	16.6	29.1	17.9	28.1
Mean ± SE	**1002.8 ± 3.21**			**1166.9 ± 5.62**		

Means followed by * are significant at 5% level, ** are significant at 1% level, NS are Not Significant.

Fig 1. Effect of harvesting time on groundnut kernel yield



Mean values followed by a common letter do not differ significantly according to Fisher's protected LSD test at P = 0.05.

Visual observations (qualitative) on kernel quality showed that harvesting time had an influence on the kernel quality. The highest quality among the three varieties was obtained at H2 whilst H1 was characterized with poorly formed immature kernels which were shrinkled and small while as for H3 the kernels were characterized by damaged kernels as a result of insect activity and some of which had started sprouting.

Table 3. Effect of harvesting time on groundnut 100-seed weight (g)

	Mapupulo Agricultural Research Center			Nampula Research Station		
	Harvesting time			Harvesting time		
Variety	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**
ICGV-SM-99568	42.1^{c}	54.9^{a}	49.9^{b}	44.1^{c}	56.9^{a}	51.9^{b}
ICGV-SM-01514	22.4^{e}	27.4^{d}	26.2^{de}	24.4^{e}	29.4^{d}	28.2^{de}
JL-24	36.7^{bc}	46.9^{ab}	45.1^{ab}	38.2^{c}	48.9^{ab}	47.1^{ab}
CV (%)	4.1	4.3	2.2	4	4.1	2.1
Mean ± SE	**49.1 ± 1.03**			**41.1 ± 1.05**		

Means followed by the same letter in the same column are not significantly different at (P ≤ 0.05)

Shelling percentage

Significant differences were observed in groundnut shelling percentages as a result of the influence of harvesting time (Table 4). Maximum shelling percentages of the three groundnut varieties were observed when the crop was harvested at physiological maturity. The variety *ICGV-SM-99568* and *JL-24* recorded the highest shelling percentages PAN and CIAM respectively. Harvesting at 10 days before physiological maturity recorded the lowest shelling percentage compared to the subsequent dates, this indicated a low amount of kernel production at the first harvest time.

Table 4: Effect of harvesting time on groundnut shelling percentage (%)

	Mapupulo Agricultural Research Center			Nampula Research Station		
	Harvesting time			Harvesting time		
Variety	**H1**	**H2**	**H3**	**H1**	**H2**	**H3**
ICGV-SM-99568	72.2^{d}	89.3^{a}	73.4^{d}	84.5^{ab}	88.40^{a}	85.2^{ab}
ICGV-SM-01514	70.1^{d}	83.1^{b}	76.01^{cd}	72.6^{c}	88.08^{a}	80.5^{bc}
JL-24	76.2^{c}	86.6^{a}	78.8^{c}	81.1^{bc}	89.39^{a}	82.4^{b}
CV (%)	9.7	4.6	3.5	12.6	2.5	7
Mean ± SE	**78.4 ± 2.57**			**83.6 ± 4.09**		

Means followed by a different letter in a column significantly different at P ≤ 0.001.

DISCUSSION

Appropriate harvest timing is critical for optimizing both yield and quality of groundnuts. It has been determined through this study that harvesting time had significant effects on the yield and yield components of groundnut varieties.

Harvesting at physiological maturity recorded the highest groundnut pod and kernel yields compared to early and delayed harvest. Furthermore, the groundnut quantitative traits (pod and kernel yields, number of pods per plant and 100-kernel weights) significantly decreased with harvesting at 10 days before and 10 days after physiological maturity. This confirmed the results found by (Marsalis et al., 2009) who reported that significant reductions in groundnut yields can occur if harvesting is either executed too early or delayed too long. Additionally, the results of the study are consistent with the findings of (RELC, 2000) who reported that the timely execution of cultural and agronomic practices, especially harvesting time by groundnut farmers is very important as it contributes to kernel yield and quality.

Harvesting groundnut 10 days before physiological maturity resulted in a reduced number of pods per plant which in-turn resulted into low pod and kernel yields among the varieties. Yield losses of up to (22.5 %, 20.4 % and 16 %) and (23.3 %, 16.6 % and 18.5 %) for *ICGV-SM-99568*, *ICGV-SM-01514* and *JL-24* respectively, were incurred at CIAM and PAN respectively as a result of harvesting the crop 10 days before physiological maturity. This was attributed to the level of immaturity of pods and some which were empty and shrinkled kernels. This is concurrent with the study findings of Wright and Porter (1991) who indicated that harvesting groundnut too early can reduce yield by 15 %. Furthermore, Kombiok (2012) indicated that harvesting groundnuts too early resulted in immature nuts, low yields, and off flavors. Additionally, it has been reported by Singh and Oswalt (1995) that premature harvesting of groundnut pods lowered the yield, oil content and seeds quality of groundnuts due to immature pods and seeds.

Field observations from the planting of the groundnut crop to harvesting confirmed the suspicion that significant yield losses occur when harvesting is delayed after physiological maturity. The consequence of this action led to the destruction of the crop by pests especially termites. The results also showed that harvesting at physiological maturity gave the lowest quantities of groundnut pods damaged by termites, then the subsequent harvesting time for all the varieties. Studies by Singh and Oswalt (1995) found that insect damage to pods tended to increase with delay in harvesting due to an increase in insect population with time agreeing with this study. Delayed harvesting also resulted in sprouting of nuts under the soil due to lack of dormancy of the varieties which resulted into reduced pod and kernel yields. This is concurrent with the study findings of Asibuo et al. (2008) who reported that pre-harvest sprouting in groundnut kernels is undesirable since it leads to substantial loss of kernels, both in quantity and quality. Another factor that may have led to lower yields as a result of harvesting 10 days after physiological maturity was adverse effects of dry weather which made uprooting by hand difficult as the soil was too dry and hard. This resulted into harvesting by digging using hand hoes which led to most nuts being left in the soil as a result of weakened pegs due to over maturity and others were physically damaged. This is consistent with the findings of Singh and Oswalt (1995) who indicated that delay in harvesting after physiological maturity resulted in many pods left in the soil due to weakening of pegs.

Yield losses of up to (31.7 %, 35.2 % and 33.1 %) and (36.6 %, 30.7 % and 32.6 %) for *ICGV-SM-99568*, *ICGV-SM-01514* and *JL-24* respectively, were incurred at CIAM and PAN respectively as a result harvesting the crop 10 days after physiological maturity. This phenomenon confirmed the findings of Young et al. (1982) who reported that delayed harvesting resulted in groundnut pod losses of up to 40 %, depending on the variety and growing conditions. The current study has also shown that there were variations among varietal kernel yields between the two study locations. Mapupulo Agricultural Research Center recorded lowest kernel yields from the variety *ICGV-SM-99568* (576.4 kg/ha), *ICGV-SM-01514* (662.5 kg/ha) and *JL-24* (664.4 kg/ha) and Nampula Research Station recorded lowest kernel yields from the variety *ICGV-SM-01514* (800.0 kg/ha), *JL-24* (858.3 kg/ha) and *ICGV-SM-99568* (983.3 kg/ha). These differences could be attributed to environmental factors such as; rainfall, temperature and relative humidity, soil conditions and severity of late leaf spots between the two study locations. These findings are in accordance with a similar study conducted in Northern Nigeria by Kamara et al. (2011) who

reported that different agricultural ecologies have different effects on the yield of groundnuts.

In both locations, *ICGV-SM-99568* had significantly higher 100-kernel weight (heavier seeds) than *ICGV-SM-01514* but was not significantly different with *JL-24* at each harvesting time. Moreover, the kernel weight of *JL-24* was significantly higher than that of *ICGV-SM-01514*, which recorded the lowest kernel weight regardless of harvesting time. The bigger nuts of *ICGV-SM-99568* could be responsible for its higher 100-kernel weight than *ICGV-SM-01514* which had the smallest kernel size. Mean 100-kernel weight is an expression of the amount of dry matter allocated to the kernel development by treatments which is attributed to plant or varietal factors (Kamara et al., 2011). The large kernel nature of *ICGV-SM-99568* and *JL-24* could be the reason farmers prefer to cultivate those varieties in Mapupulo and Nampula.

The shelling percentage (%) of the groundnut varieties varied significantly between the two study locations due to the variation in harvesting time. However, shelling percentages were higher when the crop was harvested at physiological maturity. Furthermore, the shelling percentages were affected by harvesting 10 days before and 10 days after physiological maturity; this reduced the total kernel yields for those harvesting times. This confirmed the findings of Hartmond et al. (1996) who found out that kernel yield was directly related to shelling percentage, so that the higher the shelling percentage the higher the kernel yield of that variety.

CONCLUSION

The results of this study have indicated that harvesting at physiological maturity gave the highest groundnut pod and kernel yield than harvesting 10 days before and 10 days after physiological maturity. Indicating that harvesting at physiological maturity minimizes pod and kernel yield losses in groundnut. Moreover, the study findings have revealed that premature harvesting of groundnut pods lowered the yield and kernel quality by 16-25 % and delayed harvesting resulted in yield losses ranging from 30-40 %. It is, therefore, recommended that, for farmers to obtain maximum pod yields with high quality kernels, make sure to harvest their crop at physiological maturity by keeping the date of planting which can assist in decision making on when to execute harvesting.

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