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Revista Facultad Nacional de Agronomía

UNIVERSIDAD NACIONAL DE COLOMBIA

The growth and yield of cocoyam (*Colocasia esculenta* (L.) Schott) as affected by storage methods

Crecimiento y rendimiento del cocoyam (*Colocasia esculenta* (L.) Schott) afectados por los métodos de almacenamiento

https://doi.org/10.15446/rfnam.v78n1.111202

Tajudeen Bamidele Akinrinola[1]* and Hassan Tijani-Eniola[1]

ABSTRACT

Keywords:
Corm storage
Emergence
Growth
Taro
Weight loss
Yield

Cocoyam (taro) (*Colocasia esculenta*) is an important tropical crop that requires minimal inputs compared to yam. However, increasing its production to meet the growing population's food demand is hindered by the susceptibility of planting materials to rotting in the field before the next season. While reports on storage conditions for cocoyam cormels are available, information on the storage of corms (propagules) remains limited. Hence, this study assessed simple storage methods and the field performances of corms stored under these methods at the Ayepe research field of the University of Ibadan, Ibadan, Nigeria in 2019. Corms stored under shade, in pits, and on raised platforms were evaluated in a completely randomized design with three replicates. On the field, freshly harvested corms (S1), corms stored under shade (S2), corms stored in pits (S3) and corms stored on raised platforms (S4) were evaluated in a randomized complete block design with three replicates. The results indicated that weight loss and storage efficacy differed significantly ($P<0.05$) among the storage conditions. Weight loss ranged from 8.95 (S2) to 29.87% (S4), while storage efficacy ranged from 71.20 (S4) to 91.20% (S2). Corm emergence was significantly higher in S2 compared to S4 at 2 and 4 weeks after planting but was similar to the other treatments. Propagule storage conditions had no significant influence on cocoyam growth and yield. However, cormel yields for S1, S2, S3 and S4 were 7,483, 6,625, 6,729 and 6,208 kg h^{-1}, respectively. Corms stored under shade or in pits were, therefore, recommended.

RESUMEN

Palabras clave:
Almacenamiento de cormos
Emergencia
Crecimiento
Taro
Pérdida de peso
Rendimiento

El cocoyam (taro) (*Colocasia esculenta*) es un importante cultivo tropical que requiere unos insumos mínimos en comparación con el ñame. Sin embargo, el aumento de su producción para satisfacer la creciente demanda de alimentos de la población se ve dificultado por la susceptibilidad de los materiales de siembra a pudrirse en el campo antes de la siguiente temporada. Aunque existen informes sobre las condiciones de almacenamiento de los cormos de cochayama, la información sobre el almacenamiento de los cormos (propágulos) sigue siendo limitada. Por lo tanto, este estudio evaluó métodos de almacenamiento simples y el rendimiento de campo de los bulbos almacenados con estos métodos en el campo de investigación Ayepe de la Universidad de Ibadan, Ibadan, Nigeria en 2019. En el campo, se evaluaron cormos recién cosechados (S1), cormos almacenados bajo sombra (S2), cormos almacenados en fosas (S3) y cormos almacenados en plataformas elevadas (S4) en un diseño de bloques completos al azar con tres repeticiones. Los resultados indicaron que la pérdida de peso y la eficacia del almacenamiento difirieron significativamente ($P<0,05$) entre las condiciones de almacenamiento. La pérdida de peso osciló entre 8,95 (S2) y 29,87% (S4), mientras que la eficacia de almacenamiento varió entre 71,20 (S4) y 91,20% (S2). La emergencia de cormos fue significativamente mayor en S2 en comparación con S4 a las 2 y 4 semanas después de la siembra, pero fue significativamente mayor en S2 en comparación con S4, similar a los otros tratamientos. Las condiciones de almacenamiento de los propágulos no tuvieron influencia significativa sobre el crecimiento y rendimiento del cocoyam. Sin embargo, los rendimientos de cormel para S1, S2, S3 y S4 fueron 7.483, 6.625, 6.729 y 6.208 kg h^{-1}, respectivamente. Por lo tanto, se recomendó almacenar los bulbos bajo sombra o en fosas.

[1]Department of Crop and Horticultural Sciences, Faculty of Agriculture, University of Ibadan, Ibadan. Nigeria. tb.akinrinola@gmail.com, tijanieniola@yahoo.com

* Corresponding author

Received: July 14, 2024; Accepted: November 25, 2024

Rev. Fac. Nac. Agron. Medellín 78(1): 11047-11056. 2025

ISSN 0304-2847 / e-ISSN 2248-7026

Cocoyam [*Colocasia esculenta* (L.) Schott] is a common crop cultivated in the tropics and subtropics, and consumed as a vegetable and tuber crop. The swollen underground stem of cocoyam is called the corm, while the smaller offshoots from the corm are called cormels (Castro et al. 2005). The cormel has relatively high starch content, minerals, vitamin C, niacin thiamine, and riboflavin, better than cereals (Mitharwa et al. 2022). Although yams have greater cultural significance, cocoyam has more agronomic advantages and limited input requirements. Therefore, the crop is relatively cheaper, and the production is limited to small-scale farmers. Nigeria is the world's largest cocoyam producer, with an estimated 3.20 and 3.21 million metric tons annually from 0.81 and 0.82 million hectares of land in 2020 and 2021, respectively (FAO 2022). Despite the increase in production and land area, the yield of cocoyam in Nigeria decreased from 39,771 kg h^{-1} in 2020 to 39,408 kg h^{-1} in 2021. The reduction in yield per unit area can be attributed to storage challenges faced by small-scale and resource-limiting farmers, who are Nigeria's primary contributors to cocoyam cultivation (Mukaila et al. 2022). One of the major constraints of cocoyam production has always been the availability of vegetative propagule for the expansion of the crop (Owusu-Darko et al. 2014).

Cocoyam is propagated vegetatively through corms that can be sourced locally from previous harvests. After harvest, the corms are left on the field and quite a large amount get rotten before the next season, leading to a shortage of propagation materials (Opara 2003). Consequently, some cormels are used as planting material for field establishment or expanding crop cultivation for more income. Using cormels as a propagule for field establishment in cocoyam reduces the sufficiency of food supply and farmers' income (Mukaila et al. 2022). Another attempt to obtain adequate vegetative materials for planting is through micropropagation or tissue culture but this method is expensive for small-scale farmers with limited resources for cultivation (Quain et al. 2018). These resource-limited farmers require an affordable means by which the corms for propagule can be stored after harvest. According to Opara (2003), aside from the traditional method of heaping corms under shade for storage, suspending corms tied into bundles with the attached basal petiole is common in the South Pacific and this is not a common practice in Nigeria. Also, using special structures for corms storage in cocoyam cultivation has not been a common practice, but rather for cormel storage. Information on the loss or damage of cocoyam propagules in storage is limited. Most reports on *Colocasia esculenta* storability have been for the cormels (Eze et al. 2015; Mugumo 2021).

The effect of storage conditions on tannia (*Xanthosoma sagittifolium*) and taro cormels (*Colocasia esculenta*) has been reported (Mugumo 2021). However, the method that was reported as most appropriate could be inappropriate for taro under varying conditions, due to their differences in moisture content and variation in skin toughness against storage pests and diseases may cause differences in the rate of rotting in storage (Sajeev et al. 2004; Oyefeso et al. 2021). According to Opara (2003), tannia has a lower respiration rate than taro cormels when the temperature in storage increases. Consequently, taro rotten faster in storage than tannia when not properly monitored. Similarly, the performances of corms stored under different conditions could differ in establishment and growth rate due to variations in the condition of corms at planting. Hence, there is a need to assess different inexpensive and efficient storage methods for taro vegetative propagule to improve crop production by resource-limited farmers. This study aimed to determine the easily accessible on-farm methods of storing taro corms for propagule and evaluate these propagules for variation in field performance.

MATERIALS AND METHODS

Site Description

The study involved storage and field experiments conducted in 2019 at the Ayepe research station of the Department of Agronomy, University of Ibadan, at Isokan Local Government Area, Osun State, Nigeria. The coordinates of the location were Latitude 7.288029°N and Longitude 4.284788°E. The vegetative descriptions at the location were reported by UN-Habitat (2014), while the prevailing relative humidity, temperature, and rainfall were obtained from NASA POWER project (Table 1).

Table 1. The weather conditions at the experimental site in 2019.

	Temperature at 2 meters (°C)	Relative Humidity at 2 meters (%)	Precipitation Corrected (mm/day)
January	23.13	70.81	0.00
February	26.00	84.62	0.00
March	26.07	85.88	5.27
April	25.82	87.69	0.00
May	25.47	90.94	5.27
June	24.75	91.38	5.27
July	24.48	89.94	5.27
August	24.37	89.81	5.27
September	24.51	90.62	5.27
October	25.26	90.06	5.27
November	25.34	84.62	0.00
December	22.55	63.25	0.00
Annual average	24.80	84.94	5.27

NASA POWER project (2024).

Treatments and Experimental Design

The treatments for the storage conditions involved corms stored under shade, corms stored in pits, and corms stored on raised platforms evaluated for three months (January to April) in a completely randomized design with three replicates. The treatments for the field experiments (from April to December) were the establishment of the corms collected from freshly harvested corms (S1) and the various storage conditions (corms stored under shade (S2), corms stored in pits (S3) and corms stored on raised platforms (S4) carried out in a randomized complete block design with three replications.

Storage Experiment

Cocoyam corms of 150 to 200 g that were healthy, and without wounds or any physical primary injuries were separated and bulked for the different storage methods study. The S1 corms were collected from the research field of the Department at Ayepe, while the S2 corms were stored under the shade of cassia trees. A pit of 1 m in length, 1 m breath, and 0.5 m deep was constructed and corms were placed at the bottom of the pit, then covered with palm frond for the S3 storage condition. Raised platforms for the S4 were erected from bamboo sticks, one meter high above ground level. The corms were covered with palm fronds in all the storage conditions, except for the freshly harvested corms. The freshly harvested corms were the undisturbed corms collected from under cocoa and kola nut trees as practiced by farmers and planted directly at the time of field establishment.

Field Establishment and Management

The vegetation was manually cleared, and the refuse was removed from the plot marked out for the study. Each plot size was 5 m x 5 m per plot and 1 m between plots. Heaps were manually constructed at 1 m x 1 m apart. From the stored corms, good corms (150 to 200 g each) were selected as planting materials from each of the storage methods on 26/4/2019. Planting was done by planting one corm per heap. One plant per heap was maintained to reduce overcrowding by regularly rouging out every other offshoot from the main stalk. Weeding operations were manually carried out on the field at 4, 8, and 12 weeks after planting. Subsequently, weeding of the plot was carried out, when necessary.

Data Collections

Data were collected on corm weight loss in storage after three months of storage by measuring the corm weight before and after storage for each storage condition and expressing the result in percentages (Equation 1). The storage efficiency was calculated by determining the percentages of the good corms after storage (Equation 2). The storage loss and storage efficiency were determined after three months (January - April 2019) in storage.

$$\text{Weight loss}\,(\%) = \frac{\text{Weight of corm at storage} - \text{Weight of corm after storage}}{\text{Weight of corm at storage}} \text{ x } 100 \quad (1)$$

$$\text{Storage Efficacy}\,(\%) = \frac{\text{Number of corms at storage} - \text{Number of corms after storage}}{\text{Weight of corms at storage}} \text{ x } 100 \quad (2)$$

The rate of corm emergence was determined at 2, 4, 6 and 8 weeks after planting (WAP). Cocoyam height (the tallest petiole of the leaves that stand erect from the underground corm) was measured using a ruler. The stem diameter (the base of the leaves petiole from the underground corm) was determined using a Vernier caliper starting from the 12th WAP and continued at monthly intervals for seven months. Harvesting of the corms and cormels were done 9 months after planting as practiced by farmers in the locality. At harvest, corm and cormel length (using a ruler) and diameter (using a Vernier caliper) were measured. The weight of corms ha^{-1}, the number of cormels ha^{-1} and cormel ha^{-1} were determined using the Camry dial scale model SP-20.

Data Analysis

The observed data were subjected to descriptive statistics and analysis of variance and the significantly different means were separated using Least Significant Difference (LSD) at $P<0.05$.

RESULTS AND DISCUSSION

Corms weight loss and the efficiency of different storage conditions

Weight loss in taro corm was significantly ($P<0.05$) affected by the storage conditions (Table 2). The corm stored under S2 had the least weight loss, while the corm stored in S4 had the highest weight loss. Weight loss during storage in cocoyam (aroids) like every other root and tuber crop has always been attributed to moisture loss, physical damage, and deterioration resulting from physiological activities and rodent attacks (Ubalua et al. 2016; More et al. 2019). This loss in weight conforms with Eze and Nwani (2014) report that tannia lose more weight in storage than taro, due to the higher moisture content in tannia than taro. A similar result was reported by USAID and CIP (2015), which stated that storage in the pit was more appropriate for sweet potatoes than the other traditional methods due to minimal deterioration through moisture loss, sprouting, and pathological losses.

Table 2. Influence of storage on corms weight loss and the efficiency of the storage conditions.

Storage methods	Weight loss (%)	Storage efficacy (%)
Freshly harvested propagule (S1)	-	-
Propagule stored under shade (S2)	8.95	91.20
Propagule stored in pits (S3)	15.43	81.60
Propagule stored on raised platforms (S4)	29.87	71.20
LSD	4.26	5.51

The storage efficiency varied significantly ($P<0.05$) for storage methods and had a similar trend with the weight loss observed (Table 2). Storing cocoyam corms under S2 gave the highest storage efficiency and retained the number of corms stored by 10.52 and 29.92% more than S3 and S4, respectively. Also, the least efficient method for storing corm is S4. The finding conforms with Behailu et al. (2023) report that using a raised platform for storing cocoyam corm resulted in propagule with the lowest quality of the storage methods evaluated. The inefficiency of the storage method is attributed to a higher rate of evaporation and transpiration that leads to increased rotting and loss of stored materials (Eze and Ameh 2011). According to Baidoo et al. (2014) and Diaguna et al. (2023) rotting of taro in storage starts after two weeks of storage. The time spent by the corms under the different conditions was long enough to facilitate an enormous level of rotting of the corms. For the corms to have stayed three months under the various storage conditions, the pathogens responsible for rotting would have ample time to cause more damage than necessary (Eze and Ameh 2011). The loss of 17.5 (corm) and 40.6% (cormel) under prolonged storage have also been reported by Diaguna et al. (2023). The observed results indicated that the use of S4 in storing propagules was most inefficient compared to the other methods, while the efficiency of S2 was the highest.

Emergence of cocoyam as influenced by corm storage methods

The emergence of the corms obtained from different storage conditions is shown in Figure 1. The corms obtained from S2 had significantly (P<0.05) higher emergence than the S4 at 2 WAP but were similar to the other treatments. While the corms from the other storage condition had less than 50% emergence at 2 WAP, the S2 treatment had over 70%. At 4 WAP, the corm emergence for S1, S2, and S3 were significantly higher than the S4 treatments. The delay in the emergence in S4 may result in the poor performance of crop raise from this storage method. A similar result was reported by Behailu et al. (2023) that storing corms on raised platforms reduced sprouting in cocoyam corms. The result is in support of Finch-Savage and Bassel (2016) report. According to their report the delay in emergence results in poor growth. They were able to report the relationship between weight loss and crop emergence. The poor emergence is attributed to higher weight loss that could have resulted from evapotranspiration and respiration. This may explain the delay in S4 emergence compared to S2. Early emergence in crops ensures that the stands that were established earlier develop roots that enable them to absorb nutrients and become independent of the food reserve in the propagule (Reed 2022). According to Lawles et al (2012) delayed emergence results in staggard plants on the field which may encourage early weed interference on the field and result in crop failure. The emergence at 6 WAP indicated no significant (P<0.05) variation among the different storage conditions. At 8 WAP, all the treatments achieved 100% emergency. This indicated that the variation in the early stand population was for a short time. At 6 and 8 WAP, the difference in stand count became similar, even though S1 and S3 took the lead.

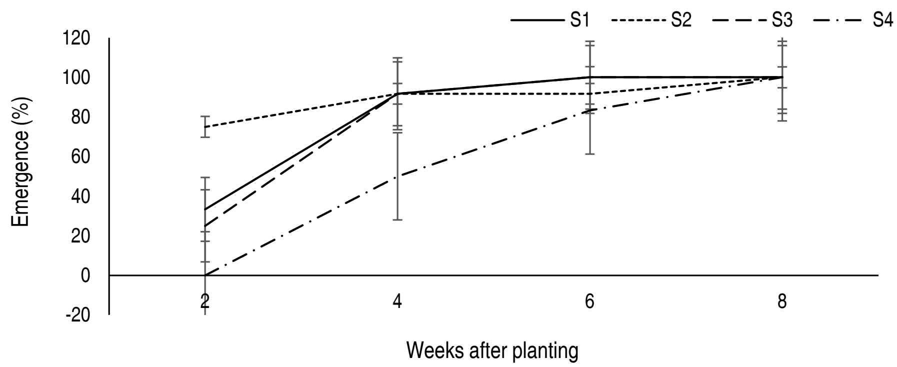

Figure 1. Influence of corm storage methods on the emergence of cocoyam. S1 = Freshly harvested propagule, S2 = propagule stored under shade, S3 = propagule stored in pits, S4 = propagule stored on raised platforms.

Influence of corm storage methods on cocoyam height

The height of cocoyam as influenced by the method of corm storage over 7 months after planting (MAP) is presented in Figure 2. Despite the significant (P<0.05) delay in S4 emergence compared to S2 at 2 WAP and the slow rate to achieve 100% emergence, the plants from S4 were able to close in on S1 and the other treatments concerning height. The height of cocoyam increased progressively for 6 MAP but did not differ significantly among treatments throughout observation periods. However, while S3 and S4 treatments continued to increase in height at 7 MAP, the S1 and S2 heights declined. The increased height for S3 and S4 implied that the plants were still actively growing, while the plants from the other treatments were senescing. The decline in plant height after the maturation of the crop indicates' that the plant is undergoing senescence, except when the decline was as a result of environmental stress (Miryeganeh 2021). The lack of significant difference (*P*<0.05) in height throughout the growth period monitored implies the absence of appreciable variation in the plant's ability to acquire more available resources for development. Similarly, the continuous increase in the S3 and S4 heights suggests that the plants from these two treatments were actively growing, while others were approaching senescence. This could help the plants acquire more resources to increase yield. According to Finch-Savage and Bassel (2016), early attainment in complete emergence will likely increase growth and result in improved yield.

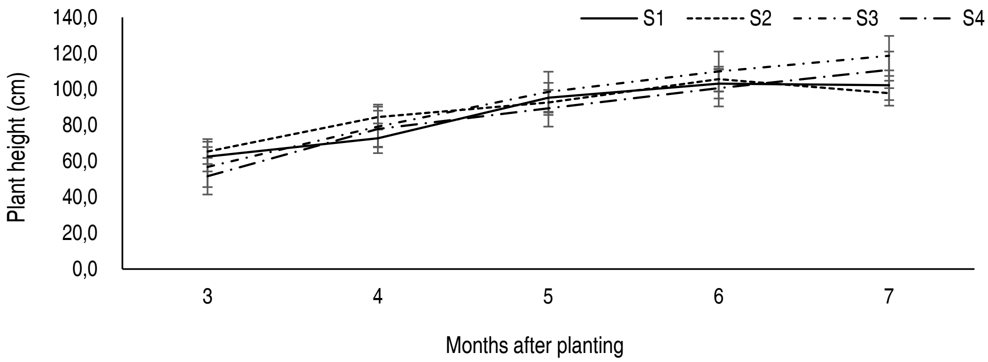

Figure 2. Cocoyam height as affected by corm storage methods. S1 = Freshly harvested propagule, S2 = propagule stored under shade, S3 = propagule stored in pits, S4 = propagule stored on raised platforms.

Cocoyam stem diameter as influenced by corm storage methods

The stem diameter of propagules planted from the different storage conditions did not differ significantly (*P*<0.05) throughout the observation period (Figure 3). Despite the differentials in the time for the plants to emerge, they did not show significant differences (*P*<0.05) in stem diameter during their growth periods. However, S3 consistently had the highest values after the observation made at 3 months after establishment. The plants from S1 had the lowest stem diameter values at 4 and 6 MAP, while S4 had the lowest value at 3 and 5 MAP. The decline in stem diameters for S1 and S2 was at 5 MAP, while the decline was at 6 MAP for plants established from S3 and S4. The fact that S3 and S4 attained the peak stem diameter by a month after S1 and S2 could indicate that the plants could further acquire more nutrients for development and improve crop yield (Miryeganeh 2021). As a consequence, variations in the onset of senescence may lead to differences in harvest times.

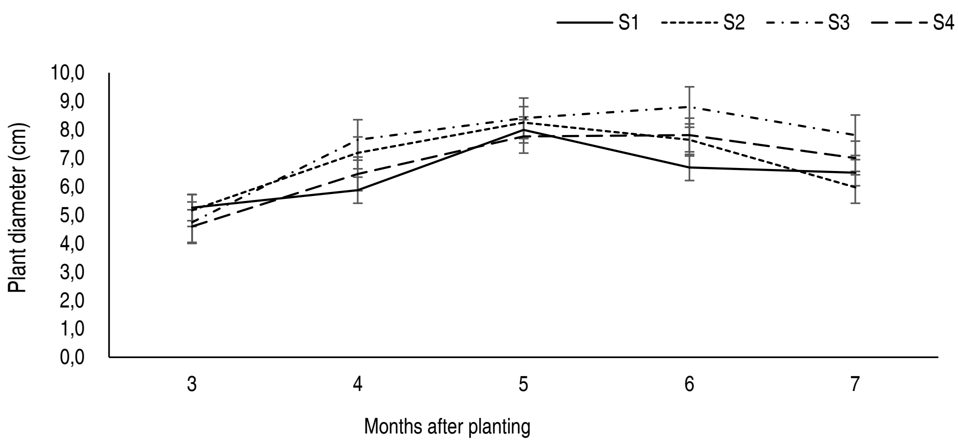

Figure 3. Cocoyam stem diameter as influenced by corm storage methods. S1 = Freshly harvested propagule, S2 = propagule stored under shade, S3 = propagule stored in pits, S4 = propagule stored on raised platforms.

Cocoyam corm yields as affected by propagule storage methods

The corms harvested from the propagule stored under the different conditions did not differ significantly (Figure 4). However, the yield of corms established from the S3 gave the highest value compared to the yields obtained from the other storage conditions. Nonetheless, the corm yield from S3 plant S3 were 15.22, 18.23 and 19.70% higher than the yields from S1, S2 and S4, respectively.

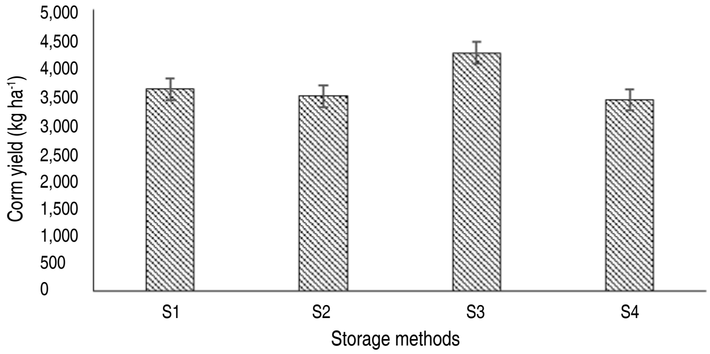

Figure 4. Corm yield as affected by corm storage methods. S1 = Freshly harvested propagule, S2 = propagule stored under shade, S3 = propagule stored in pits, S4 = propagule stored on raised platforms.

Cocoyam cormel yield as influenced by propagule storage methods

The influence of propagule storage conditions on the cormel yield of taro is presented in Figure 5. The highest and lowest cormel yields were observed in the S1 and S4, respectively. However, no significant variation ($P<0.05$) was observed among the different storage methods. The absence of substantial variation in the yields of cormels under the different storage methods could be attributed to the growth responses observed. Despite the differences in the emergence rate, the propagules from the various methods of storage performed similarly throughout the growth period. Indicating no substantial variation, the ability of the plants to outperform the plant from the other storage conditions. The result was reaffirmed by the non-significant difference ($P<0.05$) observed in the cormel yield. Nevertheless, the yield from plants propagated through S1 was higher by 858, 754 and 1,275 kg ha^{-1} compared to the observed yield from plants propagated through S2, S3 and S4, respectively. Similarly, a report by Deshi et al. (2021) showed the yield of potatoes stored under different conditions differed from the observed yield after harvest. However, before the freshly harvested corm was collected for subsequent cropping, the sun would have scotched a larger percentage of the corm, thus limiting the available propagule for field establishment.

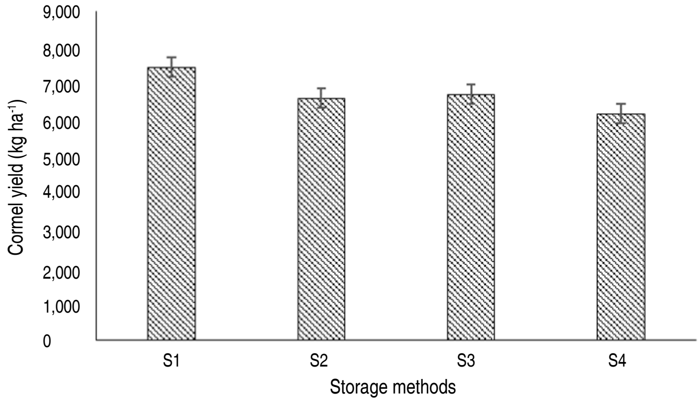

Figure 5. Cocoyam cormel yields as influenced by corm storage methods. S1 = Freshly harvested propagule, S2 = propagule stored under shade, S3 = propagule stored in pits, S4 = propagule stored on raised platforms.

Yield components of cocoyam as affected by the methods of propagule storage

The average length and diameter of corms and cormels produced using propagules from the different storage conditions did not differ significantly (Table 3). However, the propagule from S3 had the highest length and diameter of corms and cormels, while S2 had the lowest values. However, the lack of significant difference in the length and diameter of corms and cormels was not expected due to the absence of appreciable variation in the growth parameters monitored. This response was also reaffirmed by the number of cormels ha^{-1}, with no significant variation among treatments. Nonetheless, S1 differed from S2, S3, and S4 by 3.26, 10.94 and 23.23%, respectively. Although the result was not completely in support of Deshi et al. (2021), inappropriate storage conditions for seed tubers in potatoes could lead to a significant (P<0.05) reduction in crop growth. However, the magnitude of the difference indicated that the variation in growth could be a consequence of improved crop growth under better storage conditions.

Table 3. Yield components of cocoyam as affected by the methods of corm storage.

Storage conditions	Average length corm^{-1}	Average diameter corm^{-1}	Average length corm^{-1}	Average diameter corm^{-1}	Number of cormels ha^{-1}
S1	9.50	7.69	13.00	4.54	82,512.89
S2	8.58	7.65	12.25	4.45	82,485.97
S3	10.33	8.16	13.92	4.64	73,489.83
S4	8.92	7.46	13.42	4.45	63,348.63
LSD	ns	ns	ns	ns	ns

S1 = Freshly harvested propagule, S2 = propagule stored under shade, S3 = propagule stored in pits, S4 = propagule stored on raised platforms.

Correlation coefficient among the observed parameters

The Pearson correlation coefficient indicated a significant (P<0.05) positive relationship between weight loss and storage efficiency (Table 4). However, a significant (P<0.05) negative correlation coefficient was observed between weight loss in storage and corm emergence at 2 and 4 WAP. Although the weight loss also had a negative correlation coefficient with corm weight and number of cormels ha^{-1}, the relationship was not significant (P<0.05). The correlation coefficient indicated a significant (P<0.05) negative relationship between corm emergence at 2 WAP and the weight of cormel produced at harvest. The variation could be due to the lower rate of moisture loss in the taro compared to tannia in storage. Storage efficiency improved with a reduction in the moisture content of the stored produce (Sugri et al. 2017).

Table 4. Pearson's correlation coefficient of the parameters.

	WL	SE	E2	E4	E6	CW	NC
SE	0.55*	-	-	-	-	-	-
E2	-0.53*	0.16	-	-	-	-	-
E4	-0.67*	-0.14	0.59*	-	-	-	-
E6	-0.37	-0.21	0.20	0.72**	-	-	-
CW	-0.01	0.05	-0.28	-0.14	-0.23	-	-
NC	-0.45	-0.17	-0.03	0.35	0.31	0.41	-
WM	0.40	-0.03	-0.69*	-0.36	-0.25	0.37	0.31

*, ** = Correlation is significant at the 0.05 and 0.01 levels of probability, respectively (2-tailed); WL = weight loss; SE = Storage efficiency; E2 = emergence at 2 weeks after planting; E4 = emergence at 4 weeks after planting; E6 = emergence at 6 weeks after planting; CW = weight of corms ha^{-1}; number of corms ha^{-1}; WM = weight of cormels ha^{-1}.

CONCLUSION

The results from the storage conditions study indicated that weight loss and storage efficacy differed among the storage conditions. Weight loss was minimal when storing corms under shade, amounting to 8.95% only. Conversely, storage efficacy was optimal by storing corms on raised platforms (91.20%). Corm emergence was remarkably higher in corms stored under shade and lowest when corms were stored on raised platforms. Propagule storage conditions had no appreciable influence on *Colocasia esculenta* growth and yield. Cormel yields for freshly harvested corms, corms stored under shade, corms stored in pits and on raised platforms were 7,483, 6,625, 6,729 and 6,208 kg ha^{-1}, respectively. In conclusion, storage under shade or in pits proved more suitable for preserving cocoyam corms as propagule in Ayepe and its surrounding environment.

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Revista Facultad Nacional de Agronomía Medellín
vol. 78, no. 1, p. 11047 - 11056, 2025
Facultad de Ciencias Agrarias - Universidad Nacional de Colombia,
ISSN: 0304-2847
ISSN-E: 2248-7026

DOI: https://doi.org/10.15446/rfnam.v78n1.111202