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A Review of Growth and Yield Performance of Yam (Dioscorea Alata L.) as Influenced By Fertilization Rates and Planting Materials

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Abstract

Yam (Dioscorea alata L.) is a significant root and tuber crop in tropical and subtropical regions, providing food security and income generation. The growth and yield performance of yam can be influenced by factors such as fertilization rates and planting materials. This review aims to summarize the existing literature on the growth and yield performance of yam, focusing on the impact of fertilization rates and planting materials. Proper nutrient management through fertilization is crucial for optimal growth and maximum yield potential in yam cultivation. Various fertilization rates, including nitrogen, phosphorus, and potassium levels, have been investigated to determine the most effective combination for promoting yam growth and tuber formation. Additionally, the authors reviewed several previously published articles over the years from agricultural science-related journals such as Scopus Index, Web of Science, JSTOR, Elsevier, ProQuest, and Google Scholar. It took four months between March and June 2023. This paper delves into the botany of yam, its origin and geographical distribution, its uses, its planting materials, the advantages of propagating yam, and its watering intervals. The choice of planting materials, including true yam seedlings, tuber pieces, and vine cuttings, can significantly affect yam growth and yield. Understanding the effects of different planting materials is essential for selecting appropriate planting methods and ensuring successful yam production. This review synthesizes the available information, providing insights into best practices for yam cultivation and contributing to sustainable production systems.

Keywords: *Fertilization rates, Yam (Dioscorea Alata L.), growth yield performance, planting materials, sustainable agriculture*

1. INTRODUCTION

The Yam (*Dioscorea alata L.*) is an important root and tuber crop cultivated in many tropical and subtropical regions around the world (Yawson, et al, 2014; Akoroda, 1983). It serves as a staple food for millions of people and also contributes significantly to income generation and food security (Kasan, et al., 2023; Yawson, et al, 2014). However, the growth and yield performance of yam can be influenced by a range of factors, including fertilization rates and planting materials. Understanding the impact of these factors is crucial for improving yam production and ensuring sustainable yields (Aloy, et al, 2017). Fertilization rates play a crucial role in determining the nutrient availability and uptake for yam plants. Proper nutrient management through fertilization is essential for achieving optimal growth and maximizing yield potential. Different fertilization rates, including varying levels of nitrogen, phosphorus (P), and potassium (K), have been investigated to identify the most suitable combination that promotes the growth and yield of yam (Momodu, et al., 2015). The effects of different fertilization rates on yam growth, development, and tuber formation are vital for improving fertilizer application strategies and optimizing resource utilization in yam cultivation. In addition to fertilization rates, the choice of planting materials also influences the growth and yield performance of yam. Planting materials can include true yam seedlings, tuber pieces, and vine cuttings (Asare, et al., 2014). Each planting material has its advantages and disadvantages in terms of ease of propagation, disease resistance, and the ability to produce uniform and high-yielding crops. Exploring the impact of different planting materials on yam growth and yield is essential for selecting the most suitable planting method and ensuring successful yam production (Vigneron, 2012). This review aims to summarize and evaluate the existing literature on the growth and yield performance of yam, specifically focusing on the influence of fertilization rates and planting materials. By synthesizing the available information, this review will provide valuable insights into the best practices for yam cultivation and contribute to the development of sustainable yam production systems.

2. METHODOLOGY

This abstract summarizes the methodology and key findings of a review article on the growth and yield performance of yam (Dioscorea alata L.). The review aimed to summarize existing literature on the impact of fertilization rates and planting materials on yam cultivation. The authors conducted a comprehensive review of previously published articles from agricultural science-related journals, including Scopus Index, Web of Science, JSTOR, Elsevier, ProQuest, and Google Scholar. The review focused on studies investigating the effects of different fertilization rates, including nitrogen, phosphorus, and potassium levels, on yam growth and tuber formation. Additionally, the review examined the influence of various planting materials, such as true yam seedlings, tuber pieces, and vine cuttings, on yam growth and yield. The authors also explored the botany of yam, its origin and geographical distribution, its uses, advantages of propagating yam, and watering intervals. The review aimed to provide insights into best practices for yam cultivation and contribute to sustainable production systems. The review was conducted over a four-month period between March and June 2023.

3. AREAS REVIEW

Botany of Yam

Yam, scientifically known as *Dioscorea*, is a genus of flowering plants that belongs to the family Dioscoreaceae. It is a tuberous crop widely cultivated for its starchy edible tubers, which are consumed as a staple food in many parts of the world, particularly in Africa, Asia, and the Caribbean (Obidiegwu, et al, 2020; Akoroda, 1993).

Botanically, yams are perennial herbaceous vines with long, twining stems. They are dioecious plants, meaning that individual plants are either male or female. The leaves of yam plants are large, heart-shaped, and alternate along the stem. The vines climb and attach themselves to supports using tendrils.

The edible part of yam is the tuber, which is an enlarged underground stem. Yams come in various shapes, sizes, and colors, depending on the species and cultivar. The outer skin can be rough and thick, while the flesh inside can range from white, yellow, or purple. Yams are rich in carbohydrates, dietary fiber, vitamins, and minerals.

Yams are propagated through tubers or by planting vine cuttings. They require a warm, tropical or subtropical climate with well-drained soil. The plants prefer full sun but can tolerate partial shade. Yams have a long growing season, typically taking 6 to 12 months to mature, depending on the variety (Aighewi, et al, 2021; Fofana, et al., 2019).

The Philippines is a popular planting destination for types like Florido, Kabus-ok, Kinabayo, Kinampay, Basco, Zambales, and Leyte. Wumbei, et al, (2022) state that the potential yields of these genotypes range from 10 to 56 metric tons/ha. D. rotundata (white yam), D. alata (water yam), D. cayenensis (yellow yam), D. dumetorum (bitter yam), D. esculenta (Chinese yam), and D. bulbifera (aerial yam) are the most significant edible species among the 600 species of the genus Dioscorea. Of them, D. rotundata is the most favored and farmed variety, making up a significant amount of yam output in West Africa, which produces 93% of all yams worldwide (FAO, 2018).

The regions of Ilocos, Southern Tagalog, Bicol, Central Visayas, and Northern Mindanao account for the majority of production in Southeast Asia, especially in the Philippines. Annual production is estimated to be 15 metric tons, with planting taking place in March and June and harvesting taking place in December and February (Azeteh, et al, 2019). Purple yam (*D. alata) is* one of the varieties that can be a potential source of local food ingredients. It contains carbohydrates, proteins, fats, fiber, vitamins, minerals, and antioxidants, but is not used or processed into flour as an alternative to wheat flour. This plant grows well from the lowlands to an altitude of 800 m above sea level, but it can also grow at an altitude of 2700 m above sea level **(**Goulden, et al, 2012). Yam plants also grow in sloping areas (Cornet, et al.,2014; Diby, et al., 2011).

Origin and Geographic Distribution of Yam

Yams may have been present in Africa, Asia, South America, the Caribbean, and the South Pacific islands for a very long time. Reports suggest that *Dioscorea rotundata* was first domesticated in West Africa in about 5000 BC. The three identified main centers of origin of yam are West Africa, Southeast Asia, and Tropical America. Different species of the genus *Dioscorea* may have different regions of origin. Yam cultivation is widespread in the tropics and spans the entire globe along the so-called ‘yam belt,’ a band of some degrees north and south of the equator, where people grow yams (Mota, A. Z. (2022).

Uses of Yam

Among the different varieties of yam, the purple variety is the most popular in the Philippines because of its many uses. It is usually processed into food products like jam, ice cream, yogurt, "hopia", "piyaya", cakes, pastries, and breads. The big demand for yam is for ice cream production and as powder or puree, which are marketed abroad. Lately, the high anthocyanin content of purple yam has made it very popular as a health food, and it is processed into heart tablets and wine. This gives added value to purple yams, which makes them a potential novel medicine for hypertension and other immune-related diseases like diabetes. Aside from these, yam production is also essential for the survival of many generations of people in the tropics. It continues to be highly important for ensuring sustainable food security and income generation (IS, et al., 2017; Hamza, 2011).

One of the primary uses of yam is as a dietary staple. The starchy tubers are cooked and consumed in various ways, including boiling, frying, roasting, or grinding into flour. Yam provides a significant source of carbohydrates, essential minerals, and vitamins in many traditional diets, contributing to food security and nutrition in these regions (FAO, 2018).

In addition to its use as a food crop, yam has medicinal properties and is utilized in traditional medicine systems. Different parts of the yam plant, such as the tubers, leaves, and rhizomes, are believed to possess therapeutic properties. They are used to treat various ailments, including digestive disorders, inflammation, and respiratory conditions (Oboh, et al., 2015).

Yam is also utilized in industrial applications. The starch extracted from yam tubers is used in the production of food products, such as noodles, cakes, and bread. It is also used as a thickening agent in soups, sauces, and confectionery. Additionally, the fibers obtained from yam stems and leaves are used in the production of textiles and paper (Oladunmoye, et al., 2017).

The versatile nature of yam extends to cultural and ceremonial practices. In many communities, yam plays a central role in festivals and rituals, symbolizing abundance, fertility, and prosperity. Yam festivals are celebrated with great enthusiasm, showcasing the cultural significance and deep-rooted traditions associated with this crop (Olayiwola, et al., 2019).

In conclusion, yam is a crop with diverse uses, ranging from its role as a staple food to its medicinal, industrial, and cultural significance. The utilization of yam extends beyond its nutritional value, making it an essential part of various aspects of life in tropical and subtropical regions. According to FAO (2018), yam is a significant source of carbohydrates and essential nutrients in many traditional diets.

Yam Planting Material

Yam (Dioscorea spp.) is propagated using various planting materials, and the choice of planting material significantly affects yam growth and yield. Different types of planting materials, such as true yam seedlings, tuber pieces, and vine cuttings, have been employed in yam cultivation practices.

True yam seedlings are commonly used as planting material for yam production. These seedlings are obtained from the propagation of yam seeds. They offer several advantages, including genetic purity, disease-free status, and the potential for higher yields. True yam seedlings are particularly beneficial in areas with limited access to disease-free yam tubers (IITA, 2016).

Tuber pieces are another commonly used planting material for yam. Tubers are cut into smaller pieces, each containing a bud or an "eye," which is responsible for sprouting. These tuber pieces are planted directly into the soil. This method of propagation is convenient and cost-effective, as it allows farmers to utilize existing tubers for planting. However, it carries the risk of introducing diseases and pests to the new crop (Egesi, et al., 2014).

Vine cuttings are also employed as planting materials for yam cultivation. Vines are cut from mature yam plants, and these cuttings are planted directly into the soil. This method is advantageous as it allows for the multiplication of planting materials from a single yam plant. However, vine cuttings require careful handling and establishment, as they are more susceptible to damage and desiccation compared to other planting materials (Asiedu, et al., 2012).

Moreover, one of the main obstacles to yam growing in Ghana is the scarcity of planting material, which drives up the price of yams (Mignouna, et al., 2015; Mignouna, et al., 2014). It is estimated that purchasing planting material for yams often accounts for up to 50% of the overall production costs (Asala & Ebukiba, 2016; Aidoo, et al., 2011;). As a result, farmers set aside roughly 30% of the tubers they have harvested for the following planting season, which lowers the overall amount of yam produced for human consumption and revenue creation (Azeteh, et al., 2019; Nweke, et al., 2019). The amount of labor required for weeding, harvesting, staking, and land preparation (mounding) is significantly more than that required for other major tuber crops like cassava. This makes up around 40% of the costs associated with producing yams; the remaining 50% is spent on planting supplies. When the leaves turn yellow, indicating that the tubers are mature, it is possible to harvest 7-9 months after planting (Stark, et al., 2020; Caradonia, et al., 2020). The seed yams are heavy to carry and difficult to keep for an appropriate amount of time (Aighewi, et al., 2015).

In conclusion, the choice of yam planting material plays a crucial role in yam cultivation. True yam seedlings offer advantages such as genetic purity and disease-free status, while tuber pieces and vine cuttings provide cost-effective options for propagation. Understanding the effects of different planting materials is essential for selecting appropriate planting methods and ensuring successful yam production. According to the International Institute of Tropical Agriculture (IITA, 2016), true yam seedlings offer several advantages, including genetic purity and disease-free status.

Yam Setts

Yam setts can be obtained by cutting them into tops, middles, and bottoms, each weighing 200 to 500g. The setts are planted when cut surfaces are dry, usually after a day or two; hence, only the head portion would have a sprout. It is preferred because it establishes itself better and faster. Shoots from the middle and bottom portions take longer to emerge after planting because they are not planted with pre-formed sprouting points. Generally, tubers from the cut setts are milked or harvested after seven (7) to 12 months, depending on the variety and agro-ecology. Setts that sprout earlier have a longer growth period because the crop is harvested when the dry season sets in and plants senesce (Iseki & Matsumoto, 2020).

Farmers claim that setts with suberized surfaces rot less than freshly cut ones when planted during hot weather, as is done in most parts of the yam-growing zone of Nigeria. Farmers in Ikire, Nigeria, dig a trench and bury the setts for suberization before planting. This practice is labor-intensive, but the setts with healed surfaces are as good as whole seed yams in terms of protection from fungal infections (Aighewi, *et al.,* 2015; Coyne, et al., 2018).

Mini-setts Production

Mini-setts are small pieces of tubers, 25–50g in size, that are usually dipped into a fungicide–insecticide mixture. The cut surfaces are then allowed to dry before planting to produce seed yams (planting material). The mini sett technique produces both healthy and high-yielding planting materials while reducing the cost of seed yam production and improving availability of planting material (Oguntade, et al., 2010).

The mini-sett technique was developed by the National Root Crops Research Institute (NRCRI), Nigeria, (Morse, 2018), as a modification of the normal size setts for planting**.** The aim of the technique is to increase the quantity and quality of seed tubers available to farmers. This is based on the principle that any section of the tuber is capable of developing buds and sprouting, if it has a portion of the periderm (Pelemo, 2021). In the mini-sett technique, 'mother seed' yams of 500– 1000g that are not dormant are cut into pieces (mini-setts) weighing 25g (Eyitayo, et al., 2010). The 25g recommendation was meant to be a compromise between the competing requirements of maximizing setts from a single tuber and the need for a reasonable proportion of seed yams in the field (Morse, 2022). Others pointed out that mini-setts larger than 25g would be better (Cornet, et al., 2023; Diouf, et al., 2022). While there is much variation in the response of *D. Rotundata* to the mini-sett technique (Aighewi, et al, 2021), it has been suggested that increasing the size of mini-setts of some varieties would enhance their sprouting potential (Igwilo & Okoli, 1988).

The freshly cut mini-setts are treated in a suspension containing wood ash or fungicide and insecticide, and then spread in light shade to dry for 1–2days (IITA, 2016). Treatment of setts before planting is influenced by challenges of unavailability, and high cost of chemicals. While the use of wood ash as a substitute of fungicides and insecticides has been recommended, its effectiveness has been variable (Otoo, 2013).

Mini-setts can be planted directly in the field on ridges at a depth of 9–12 cm with a plant spacing of 25–30 cm by 100 cm (4 stands per m^2) when the rains are well distributed. Otherwise, they could be pre-sprouted in beds, baskets or boxes using topsoil, saw dust, shredded coir or carbonated rice husk as media. Sprouting and tuber yield of directly planted setts are strongly affected by variety (Igwilo, & Okoli, 1988). The condition of the soil at the time of planting also affects the survival of propagules.

Although the treated mini-setts can be directly planted in the field, it is usually recommended that they are first pre-sprouted in a nursery before transplanting. Pre-sprouting in a medium free of pest and disease can ensure the survival of mini-setts, but it is more labor intensive (Asfaw, 2016). When mini-setts are pre-sprouted, there is better crop establishment because only sprouted mini-setts are transplanted to the field, and this can be timed for a period when the soil is sufficiently wet to support adequate growth. With pre-sprouting, additional time and cost are required to check the mini-setts at intervals and select those that have sprouted for transplanting.

Despite for the advantages of the mini-sett technique which include fewer tubers being used as seed, faster rate of multiplication than with traditional methods, ease of operation as well as potential for production of better-quality seed and mechanization, the level of adoption remains low. Some factors responsible for this are the scarcity and high cost of inputs as well as additional costs for cutting and treating mini setts (Griffin, 2016), and farmer reluctance to buy seeds. The mini-sett technique is meant to produce mini tubers, so its promotion should be on the production of mini tubers planting materials that are few in yam growing areas. In traditional system, farmers sell their exist planting materials after their fields are planted and will buy if there are unplanted area due to the shortage of planting materials.

Vine Cuttings for Seed Yam Production

According to Asiedu, et al. (2012), vine cuttings provide a method for multiplying planting materials and increasing seed yam production. West African yam researchers have been concentrating on employing vine cuttings as a substitute for tubers in the creation of planting material. After eight months, mini-tubers weighing between 50 and 600 g were produced from 20 cm long, rooted vine cuttings with one to three nodes (Pelemo, 2021; Aarakit, 2021). This represents a 1:30 propagation ratio. Vine cuttings from healthy plants should be obtained 30 to 60 days after shoot emergence and before tuber formation begins in order to produce tubers (Oyetunji, et al., 2007). Cuttings are rooted in carbonized rice hulls or high-humidity chambers before being immediately planted in dirt in a garden or transplanted into soil. Vines cuttings were planted in vertical grow bags within the screenhouse of the International Institute of Tropical Agriculture (IITA) in Nigeria, where scientists are producing seed yam. Soil is placed into black polythene bags, which are then tied and fastened to poles or ropes that cross the top of the screenhouse. To enable the planting of vine cuttings, holes are punched through the bags, depending on their size. Watering cans or irrigation pipes are used to provide water to the plants. To make seed yams, "mother seed" yams (500–1000 g) are chopped into mini-setts (25–30 g) and planted.

As the vine cuttings grow, it is important to provide support and trellising structures to ensure proper growth and prevent damage. These structures help the vines climb and reduce the risk of breakage, allowing for optimal development and yield potential (Joie, & Ambos, 2022).

In conclusion, vine cuttings offer a viable method for seed yam production. By carefully selecting healthy vines, providing appropriate planting conditions, and ensuring necessary support, farmers can effectively propagate yam plants and increase their seed yam production.

Advantages of Propagating Yam Vine Cuttings

There are few advantages of propagating yam vine cuttings mentioned below:

1. Increased planting materials: Propagating yam vine cuttings allows farmers to multiply their planting materials rapidly. Each vine cutting has the potential to develop into a new yam plant, resulting in a larger number of plants for cultivation.
2. Genetic preservation: Vine cuttings help preserve the genetic characteristics of the parent plant. By using vine cuttings, farmers can ensure that the desirable traits of the parent plant are passed on to the new yam plants, maintaining genetic purity and consistency.
3. Disease control: Using vine cuttings from healthy and disease-free plants reduces the risk of introducing pathogens into the new crop. By carefully selecting vines with no signs of diseases, farmers can minimize the spread of diseases and protect their yam plants.
4. Cost-effective method: Propagating yam vine cuttings can be a cost-effective method of yam production. It eliminates the need to purchase new planting materials, as farmers can utilize their existing yam plants to generate more vines for cultivation.

Improved propagation methods of yam vine cuttings to raise 827 yam cuttings produced a year using one node per cut from seedling until the yam plant senesced. This innovation maximizes the use of space in seed production. While varietal differences in the rooting of vines have been noted (Almekinders, et al., 2019). observed significant increase in the number of roots after treatment with indole butyric acid (Shahab, et al., 2013) while Afolayan, et al., (2018) that with the use of single node cuttings, multiplication of yams could be several hundred folds in 1 year. Appropriate and cheap methods of large-scale rooting of *D. rotundata* are yet to be established, although vine cuttings root well in an aeroponics system (Pelemo, 2021).

A major advantage of this method of propagation is that the entire tuber is saved for food, thus improving the economic value of the crop. Setts produced will also be free of nematodes and soil-borne pathogens if a sterilized medium or pest-free soil is used for propagation. Also, large quantities of small size minitubers that are appropriate for international exchange of germplasm can be produced using vine cuttings, as well as normal seed size tubers for production of ware yam depending on the time of harvest of vines (Aighewi, *et al.,* 2015).

Watering Intervals

In order to meet the water needs of crops for optimal growth, water requirement refers to the total amount of water delivered to the growing surface (land or media) in addition to the water supplied by rainfall and soil profile (Weil & Brady, 2017). Since stem cuttings can rapidly desiccate, the most important component in plant proliferation through stem cuttings is water stress. Watering should continue until roots that can absorb water have grown and maintaining a high level of humidity during the root growth process requires covering the cuttings or maintaining them under a misting system (McElrone, et al, 2013; Rajkumar, et al., 2017). Partial leaf clipping can help limit evaporation from soft wood cuttings. However, since various parameters may be controlled in tunnel or greenhouse settings, it is advised that cuttings be rooted in partial shade (Hassan, et al., 2017). When water is lacking plants will use long term storage of starch to build energy through respiration. If water is not replenished, the conversion of starch into energy exceeds the production of starch and therefore makes the plant weak, the leaves wilt indicating that plants need water. However, plants also display the same characteristics when our watered. Water logging occurs when the rooting media is too wet making it difficult to absorbed gases (Liu, et al., 2020).

Roots need air just as much as they need water. However, it is necessary to get plant dry slightly between watering since shallow or frequent watering creates lazy roots that stays at the upper surface not the media or soil.

Watering deeply, then allowing the plants to dry slightly between watering intervals will force the roots to grow deeper into the soil to find moisture. The plants become better established in the growing container/beds. Plant type, sun exposure, media conditions and weather will all determine has often the plants need to be water (Poorter, et al., 2012).

It is recommended to keep foliage dry to prevent diseases but plants need more water when they are actively growing. Watering in bedding plants or nursery beds should be done regularly especially after planting to help fill the voids in between the root ball and growing media allowing the plant to root and grow faster. Watering intervals should be gradually increased after planting (Xu, et al., 2010). The criteria for scheduling irrigation or watering or watering schedules includes: soil moisture depletion approach, plant basis or plant indices, climatological approach, critical growth approach and plant water status itself (Weil & Brady, 2017).

The soil moisture depletion approach is done by determining the amount of moisture available in the root zone. When 50% of the available moisture in the root zone is depleted, irrigation should be started. Since plants are the uses of water, their appearance such as dropping, curling of leaves are indication for watering but do not give qualitative estimate of their water needs.

4. CONCLUSION AND RECOMMENDATIONS

Reviewing the research on yam development and yield performance, with an emphasis on the effects of planting materials and fertilizer rates, is the goal of this review. When growing yams, proper nutrition management through fertilization is essential for achieving the best possible growth and yield potential. The best fertilization rate combination for accelerating yam development and tuber formation has been studied, taking into account variations in nitrogen, phosphorus, and potassium levels. In order to contribute to sustainable production systems and offer insights into optimal methods for yam growing, this review synthesizes the material that is currently accessible. It was suggested that future researchers, educators, and farmers follow the yam pattern and performance in their own regions. This would allow people to concentrate on ways to enhance the input of planting materials and fertilizer. In addition, future academics can undertake further in-depth study to build on this title and accomplish more.

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