ENHANCEMENT OF SEED GERMINATION IN THE AFRICAN EGGPLANT *(Solanum aethiopicum)*

BY

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DECLARATION

Declaration by the Candidate:

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DEDICATION

To my lovely wife Diana and my children, Daniel and Dorcas for your everlasting patience with me during this study and the moral support and encouragement you gave me. May God bless you throughout your lives.

ABSTRACT

African eggplant *(Solanum aethiopicum)* is an important indigenous vegetable in Tanzania with seed dormancy problem. The overall objective of the study was to improve germination of African eggplant seeds. Two different seeds sources were from Agricultural Seed Agency (ASA) field. A lab experiment was carried out in KEFRI-Muguga. Treatments were completely randomized (CRD) in a growth chamber. Each source consisted of two varieties of this crop, DB3 and Tengeru white. Source one seeds were extracted from fruits harvested at different physiological maturity stages, when were red, yellow red and yellow green. Source two seeds were harvested after every two weeks (14 days) at full red stage between 30 and 72 days after anthesis(DAA). Source one seeds were subjected to the following Cardinal temperatures from 15^{o}C, 20^{o}C, 25^{o}C, 30^{o}C and 35^{o}C to determine the optimum, minimum and maximum temperatures for germination of the crop which were found to be 25^{o}C, 15^{o}C and 30^{o}C respectively for Tengeru white while DB3 germinated only at 30^{o}C and 25^{o}C.The data for source one seeds were subjected to ANOVA using GENSTAT package version 12.2. Seeds germination percentages were highly significant at P = 0.001 under all temperature regimes. Source one seeds were also subjected to alternating temperatures 30/25^{o}Cand 30/20^{o}C in 24 h continuous light. Results indicated that, Tengeru white attained higher germination (87%) while DB3 attained 21% under 30/25^{o} in continuous light. When DB3 subjected to GA_3 (0.01%, 0.02% and 0.03%) and KNO_3 (0.1%, 0.2% and 0.3%) at 30/25^{o}C for 24 h continuous darkness, the effect of these chemicals were highly significant at P = 0.001 on influencing germination whereby higher germination (35.38%) was recorded with GA_3 0.03%. When GA_3 concentrations was raised to 0.05%, 0.08%, 0.1% and 0.2% at 30/25^{o}C (24 h continuous light), germination increased significantly at P = 0.001to 68.45% at 0.1%. Source two seeds which were harvested at different physiological maturity stages, 30, 44, 58 and 72 days after anthesis were subjected to GA_3 = 0.1%, 0.2% and 0.3% in alternating 30/25^{o}C in both continuous darkness and continuous light for 24 h. The data generated were subjected to ANOVA using GENSTAT package version 12.2. Results indicated that, at 72 DAA, Tengeru white seeds attained 80.33% while DB3 seeds attained 38.04% without chemical treatment. When treated with chemical,Tengeru white recorded higher germination at 0.2% GA_3, though this was not statistically different from control (33%). This suggests that, when harvested at its physiological maturity(72 DAA),Tengeru white can germinate well without chemical treatment. DB3 on the other hand, required GA_3(0.1%) to attain higher germination percentage (68.45%) when harvested at 72 DAA. Seeds harvested between 30 DAA and 44 DAA recorded lower germination percentages. It is therefore recommended that, for seed production, both varieties should be harvested 72 DAA and germinated under alternating temperature 30/25^{o}C in continuous light. Further research however needs to be done on breeding to reduce DB3 seeds dormancy and raise germination percentage for DB3 from 68.455 to 100%.

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ABBREVIATIONS

ASA	Agricultural Seed Agency
ABA	Abscisic Acid
AOSA	Association of Official Seed Analysts
AVRDC-RCA	Asian Vegetable Research and Development Centre Regional Centre for Africa
CRD	Completely Randomized Design
DAA	Days AfterAnthesis
DAP	Days After Pollination
FAO	Food and Agriculture Organisation of the United Nations
GA_3	Gibberellic Acid
h	hours
ISTA	International Seed Testing Association
KEFRI	Kenya Forestry Research Institute

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

1.1.1 Global eggplant production

African eggplant is one of the most commonly consumed fruit vegetable in tropical Africa. It is estimated that, an annual fruits production of 8000 t is produced in Senegal, 60,000 t in Cote d'Ivoire and 4500 t in Burkina Faso. However, there is no reliable statistics for Sub Saharan Africa including Tanzania(Lester and Seck, 2004). It is especially important in South-eastern Nigeria, Cameroon and Uganda and it is the most popular vegetable in Kampala market.According to research conducted by Weinberger and Msuya, (2004) in four districts, around 15 ha in Tanzania appears to be under production of indigenous vegetable seeds, out of this, the total area under production of certified seed for African eggplant by three companies is 3.4 ha and area under quality declared seed (QDS) is 1.6 ha.

1.1.2 Botany of the eggplant

Shrub to perennial or annual herb, up to 200 cm tall, often much branched, root system extending both vertically and laterally, branches and leaves with or without prickles and stellate hairs. The genus *Solanum* comprises over 1000 species and is almost cosmopolitan with at least 100 indigenous African species. *Solanum aethiopicum* belongs to subgenus *leptostemonum* section *Oliganthes*, which comprises about 45 species (Lester and Seck, 2004). The popular varieties of *S. aethiopicum*grown in Tanzania includes, Tengeru white and DB3. Seck, (1986) reported that, the flowers of

S. aethiopicum, like those of other solanum species are bisexual, either solitary in inflorescences with short cymes or trusses.

Solitary flowers and cymes are mostly found in the Kumba group, whereas trusses are most common in the Gilo and Aculeatum subspecies, and linked to fruits number and size. The short stamens bearing yellow pore dehiscence anthers at anthesis stage form a cone surrounding the style bearing a stigma placed beneath, beyond or at the same level as the pores. The last type referred to as peristyled flowers, has been observed to favor self pollination. Style heteromorphism observed in *S. melongena* seems to be linked to the sterility of short styled flowers, whereas the Kumba group only bears peristyled flowers.

In the Kumba group, solitary flowers and cymes have been observed to be fertile which my be linked to flowers morphology. In *Solanum aethiopicum*and *Solanummacrocarpon*, plants generally start flowering about 70 days after sowing or 35 to 40 days after transplanting. Stigma receptivity has been observed to start on the day before anthesis whereas pollen viability occurs on the day of anthesis or one day latter and can remain so for up to two days later.

Male sterility, which is rather scarce in *Solanum melongena*, has been reported to be caused by low temperatures or by treatment with growth regulators (Choudhury and George, 1962).

Source: Author (2013)

Plate 1: A photo of African eggplant

1.1.3 Origin and distribution

African eggplant was domesticated from wild *Solanum anguivi*in tropical Africa. It is grown throughout tropical Africa and South America. In the humid zone of West Africa, it is mainly grown for its immature fruits while in the Savanna areas frequently for both its leaves and immature fruits. Although *Solanum* species are grown in all agricultural areas, the greatest concentrations of the species are in the tropical and warm temperate regions. The centers of diversity are found in South America, Australia and Africa while relatively less diverse species are found in Europe and Asia (Edmond and Chweya, 1997).

The crop performs better inwarm, non humid conditions found throughout the savanna belt of West and East Africa. The optimal temperature for the crop is 23-35^{0}C during the day and 18-25^0 C during the night. It can grow on a wide range of well drained soils and optimum pH of the soil is between 5.5 and 6.8.

1.1.4 Economic Importance of African eggplant

African eggplant also known asgarden eggs, ‘mock tomato’, ‘ngogwe’ or ‘nyanyachungu’ and other solanum species such as *S. macrocarpon*, *S. anguivi* which are grown in Tanzania are used as vegetable stew and sometimes eaten raw. The leaves and shoots are also used for cooking. Fruits of bitter cultivars are used as medicine in many African countries. They are used as sedative to treat high blood pressure, leaf juice as a sedative to treat uterine complaints and to treat tetanus after abortion (Lester and Seck, 2004).

Cultivation of African eggplant is expanding in Tanzania because of its economic and nutritional value. It has protein 4.8 g, Ca 523 mg, Fe 6 mg, vitamin C 67 mg and carbohydrate 6.4 mg per 100 g.

Apart from nutrition, farmers earned on average US$1200/ha/season and small-scale growers account for about 80% of the total production. Thus, this indigenous vegetable crop has brought increased income to a number of people involved in the production and marketing (Chadha and Mndiga, 2008). There is increase in acceptance and utilization of indigenous African vegetables in the east and southern Africa (Jansen van Rensburg *et al*.,2004). These indigenous vegetables can be conserved as seeds and preserved by timely planting.

African eggplant ranked third (33% of all household) among the most frequently purchased indigenous vegetables after amaranths (67%) and okra (37%). Furthermore, the degree of commercialization (in terms of produce sold on the market) is highest for African eggplant (82%) followed by other indigenous vegetables like nightshade (67%), okra and amaranth (65%), ethiopian mustard (63%), sweet potato (38%), pumpkin (32%), cowpea (11%), wild cucumber (4%) and jute mallow (0%). It also indicated that, among top ten indigenous vegetables, the net returns (in Tsh.) per ha is highest for African eggplant (1,331,176/=), followed by ethiopian mustard (1,290,704/=) (Weinberger and Msuya, 2004.)

1.1.5 Agronomy

Seed sowing is done in nursery beds along lines spaced 20 cm apart and covered with thin layer of soil. Seedlings should be thinned to 2 cm apart to avoid spindly plants.

Transplanting is done after five weeks or when the plants are 15 cm high. The recommended spacing is 75 cm X 75 cm or 60 cm X 90 cm. A fertile soil is recommended for good yields. However, it is recommended that, five tons of well decomposed manure per 1000 m^2 is incorporated in the field before transplanting. Two weeks later, side dress with 25 kg of 15:15:15 compound fertilizer per 1000 m^2. Additional 10 kg of fertilizer should be applied at the flowering stage and repeated after the first harvest. Irrigation is most critical during the flowering and fruit setting stages.

Pests and diseases are managed when occurs. Harvesting of fruits is done before the skin becomes tough and changes color.

1.1.6 Seed quality

As seeds develop in fruits they go through morphological, biochemical and physiological changes. Some of these changes are acquisition of germination ability, the development of desiccation tolerance and overcoming of seed dormancy (Samarah *et al*., 2004). Acquisition of ability to germinate in seeds has been reported to be attained at specific developmental stages in different crop species (Samarah *et al*., 2004). Germination incorporates those events that commence with the uptake of water by the quiescent dry seed and terminate with elongation of the embryonic axis (Bewley and Black, 1994).

Germination commences with the uptake of water by the dry seed, imbibitions and is completed when a part of the embryo, usually the radical, extends to penetrate the structures that surround it (Bewley, 1997).Many seeds do not germinate when placed in conditions which are normally regarded as favorable for germination, namely adequate

moisture, a suitable temperature and an atmosphere of normal composition (Mayer and Poljakoff, 1989). Nevertheless seeds can be shown to be viable as they can be induced to germinate by various special artificial treatments or under specific external conditions. Such seeds are said to be in a state of dormancy.

African eggplant seeds are among the seeds with low germination percent when placed under conditions normally regarded as favorable for germination. The minimum germination percentage set as standard for the crop is 70% (FAO,2010), however, this has not been achieved in areas where this crop is cultivated.

In seed production, the physical, physiological, phyto-sanitary and genetic qualities of the seed require attention so that farmers are provided with quality seed. Therefore, the purpose of this study is to determine the suitable methods of breaking seed dormancy; cardinal temperatures, chemicals and optimum harvesting stages of the crop in order to improve its germination and hence production for improving nutrition and increased income of the people.

1.2 Statement of research problem

Unsatisfactory seed germination of African eggplant is one of the limiting factor in production of this important indigenous vegetable. This has significant implication on the whole process of seed production and marketing for both seed producers and farmers as it will result into low production of this important vegetable. To improve production of seeds and hence production of this vegetable, it requires good quality seeds which germinate and grow into normal seedlings.

Therefore, the purpose of this research is to determine the suitable methods of breaking seed dormancy, optimum harvesting stage and cardinal temperatures for germination of African eggplant.

1.3 Justification

African eggplant is one of the most important indigenous vegetable in Tanzania where it contributes not only as a source of nutrients but also as source of income which improves the livelihood of people. Thus, sustainable production technologies are required so as to improve its production and hence increased consumption and income to the people.

1.4 Broad Objective

To enhance field emergence and crop stand of African eggplant by improving seed germination.

1.4.1 Specific Objectives

1. To determine the optimum temperatures and alternating temperature/light for maximum seed germination of African eggplant.

2. To determine the suitable chemical method of breaking seed dormancy in African eggplant.

3. To determine the optimum harvesting stage to obtain high quality African eggplant seeds.

1.5 Hypotheses

H_a1 - Quality African eggplant seeds require specific temperatures and alternating light/temperatures for germination.

H_01 - Quality African eggplant seeds does not require specific temperatures and alternating light/temperature for germination.

H_a2 - QualityAfrican eggplant seeds require chemical treatment for dormancy breaking

H_02 -QualityAfrican eggplant seeds does not require chemical treatment for dormancy breaking

H_a3 -QualityAfrican eggplant seeds require specific harvesting time

H_03 - Quality African eggplant seeds does not require specific harvesting time

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1Origin and Taxonomy of African eggplant

The Solanaceae family comprises about 2,300 species half of which belong to the genus *Solanum,* (Lester, 1982). This family is the source of many domesticated species. The *Leptostemonum* subgenus comprises more than 30% of the species of the genus. According to Sekara *et al.,* (2007), the appellation of eggplant involves 3 related *Solanum* species of the *Leptostemonum* subgenus, with two sections [Melongena (*Solanum melongena and Solanum macrocarpon*) and Oliganthes (*Solanum aethiopicum)*]. However, there are seemed to be uncertainty on *Solanum macrocarpon's* section because it has close relationships with *Solanuma ethiopicum* (Sekara*et al*., 2007.) The classification of non tuberoussolanum is still difficult due to the large number of species, the important intraspecific variability and the cross breeding of some species. Accordingly a large number of binomial names have been wrongly given to these species (Daunay and Lester, 1988.)

The main nontuberouscultivated species include *Solanum melongena* L; (brinjal), native to Southern India and widely grown in the world and generally referred to as *European aubergine.* African eggplants comprise different species, the most common of which are *Solanum aethiopicum L.*(scarlet eggplant) and *Solanum macrocarpon* L (Gboma) of west and central Africa origins; the latter is also grown in America and Asia (Abdoulaye, 2009).

Solanum aethiopicum L. is a phenotypically diverse species. It is a fruit and green leaf vegetable with hairy or glabrous leaves, bisexual partially self-pollinated flowers and

produce single or grouped fruits (trusses or short cymes) depending on subspecies and varieties (Seck, 1986).

The fruits are of varied color, shape and size (green, white, striped, multicolored and round to long, smooth, grooved or ribbed and small to very big); they are of bitter to sweet taste depending on their saponin content and consumed cooked or raw. At full maturity, they turn red to orange due to their carotene content. *Solanum aethiopicum* is reported to be highly nutritious than tomato and *S. melongena.* The leaves of *Solanum aethiopicum* are even more nutritious compared to the fruits(Abdoulaye ,2009).

Lester (1982, 1986); Lester and Seck (2004) clarified the taxonomy of several non tuberousSolanum. *S. aethiopicum*(scarlet eggplant) comprises 4 different groups or sub species; Gilo, Kumba, Shum and Aculeatum resulting from a domestication process from *S. anguivi* Lam, which has prickly hairy leaves and stems, flower trusses sometimes bearing over 10 small round to oblong small fruits (less than 1 to 1.5 cm in size); the fruits are green or striped (turning orange to red when fully mature).

Gilo, is very common in the humid tropics (Brazil, Africa), hairy, inedible leaves, variable fruits shape (round, elongated, egg-shaped or spindly, ribbed or smooth), color (dark and light green, white or striped) and size (from a few to over 100g).

Kumba has glabrous and large leaves, medium to ribbed fruits (5-10 cm in diameter),and edible leaves. This group is most commonly in the arid areas of tropical Africa. Other names are red African eggplant, orange African eggplant, scarlet African eggplant, or mini pumpkin tree (Porcher, 2009).

The Shum group is most generally grown for its glabrous edible leaves, it's very small slightly flattened, round or elongated fruits, though edible, are scarcely consumed.

The*Aculeatum* (*S.integrifolium*) plants have inedible leaves and fruits are rather used as ornamentals (hairy and prickly leaves and stems.) The fruits are of variable size and shape (round, flattened, ribbed and smooth) and color (dark and light green, purple). This group has been used as source of pest and disease resistance in breeding (Seck, 2000; Lester and Daunay, 2003).

The domestication process occurred in the following order(Lester, 1986); *S. anguivi*'*s* evolution resulted in *S. aethiopicum* group Gilo (wrongly referred to as *S. gilo* and *S. anomalum*, more common in savannahs and humid forests). This group evolved and generated the Kumba group which through reduction, gave rise to the Shum group. However, a different theory supports a possible Shum origin of the Gilo group(Sekara *et al.*, 2007.) The Aculeatum group wrongly called *S. integrifolium* (inedible) resulted from natural crosses between *S. anguivi* Lam and*S. aethiopicum* L.

The origin of different varieties is important as far as seed dormancy is concerned since different varieties have different ecological requirements depending on their origin and selection of these varieties during breeding may bring variation in different varieties.The variation in seed dormancy is ecologically significant for native plants and has resulted in contrasting ecotypes following many generations of selection (Allen and Meyer, 2002).

2.2 Seed quality and dormancy

Quality seeds can be defined as seeds suitable for sowing, germinate well and produce vigorous seedlings. Seeds are dormant when they fail to germinate under favorable environmental conditions and require to be exposed to some special treatments to overcome the dormancy (Copeland and McDonald, 1995).

A dormant seed does not have the capacity to germinate in a specified period of time under any combination of normal physical environmental factors that are otherwise favorable for its germination (Baskin and Baskin 2004a).

Whereas most vegetable species and commercially important cultivars are relatively free of dormancy, members of the Solanaceae are among the families with erratic germination due to seed dormancy (Carter and Vavrina, 2001; Leskovar *et al*., 1999, Nascimento *et al*., 2000). Seed dormancy is not merely a resting state in the absence of suitable conditions for germination, which is more correctly referred to as quiescence (Copeland and McDonald, 2001) but may be due to the requirement for a period of embryo growth and radicle emergence after the mature seed has been dispersed.

The possible causes of seed dormancy includes immaturity of embryo, impermeability of seed coat to water or gases, special requirements for temperatures, prevention of embryo development due to mechanical causes or the presence of substances inhibiting germination for example, abscisic acid (ABA) (Mayer and Poljakoff, 1989). Primary seed dormancy is more common in nature than secondary dormancy, and can be in the form of exogenous or endogenous dormancy. Exogenous dormancy is considered to be on the outside of the seed; associated with the seed's external covering structures such as the seed coat. Genetics and environmental factors can also modify the expression of

exogenous dormancy, especially for traits such as hard seed coat (Copeland and McDonald, 2001). Chemical exogenous dormancy due to germination inhibitors in the seed coat or fruit can also be observed in vegetable crops (Leskovar *et al*., 1999; Wien, 1997). Methods for breaking these dormancy mechanisms in nature include microbial action, freeze-thaw temperature cycles and ingestion by animals.

Laboratory techniques generally employ mechanical or chemical scarification processes to crack or partially remove the seed coat. Protocols (duration and compounds) used for treatments are critical to success, since seed damage or failure to break dormancy may result from excessive or insufficient treatment (AOSA, 1986; ISTA, 1993; McDonald and Copeland, 1997; Vivrette, 2001).

Endogenous primary dormancy can also be influenced by many environmental factors during seed development and maturation. Day length, temperature, seed position in the fruit or inflorescence, age of mother plant and plant or seed moisture status can be linked to dormancy levels in some species. Rudimentary embryos and the need for embryo after-ripening is one form of physiological dormancy.

Physiological dormancy is linked to the osmotic effects of high sugars or salts in the seed or fruit (for example beet). These osmotic effects may prevent full imbibitions, thereby preventing or slowing germination (Copeland and McDonald, 2001). Methods for breaking endogenous dormancy rely on leaching, mechanical or chemical scarification and stratification to adjust inhibitor-promoter balance (AOSA, 1986; ISTA, 1993). Other species my benefit from various chemical or growth regulator treatments, with or without light. Secondary dormancy (e.g thermodormancy,

photodormancy, skotodormancy) are also observed in some vegetable species.If lettuce seed (most cultivars) is subjected to temperatures of 30^{o}C or above during imbibition, it becomes dormant and is delayed in germination (Gray, 1977; Wien, 1997).

Seeds dormancy is an important factor affecting germination of eggplant seeds (*Solanum melongena*) harvested during maturation stages. Thus, the stage of seed maturity at harvest may affect seed dormancy and germination.

For seed production of *Solanum melongena*, fruits are normally harvested at full maturity, which is about 50-60 days after anthesis depending on cultivar, climate and growing conditions(Agbo and Nwosu, 2008). In many species of plants the seeds when shed from the parent plant, will not germinate. Such seeds will germinate under natural conditions, if they are kept for certain period of time. These seeds are said to require a period of after-ripening (Mayer and Paljakoff, 1989). After-ripening, a period of usually several months of dry storage at room temperature of freshly harvested, mature seeds is a common method used to release dormancy (Bewley,1997).

2.3 Factors influencing seed dormancy and germination

2.3.1 Influence of light on seed dormancy and germination

Several environmental factors function as determining factors in germination (Bewley and Black 1994), seed germination is affected by temperature, light and other environmental factors. Combination of factors can restrict germination to the most favorable, and often more predictable, time of the year, and one factor alone is often insufficient to produce germination. Light interacts with temperature and water to regulate germination (Grime *et al.*,1981, Bell 1999; De Villiers *et al.*, 2002).

The light requirement is especially common in small seeded species (Plummer and Bell, 1995; Milberg *et al.*,2000; Schutz *et al.*,2002), where an ability to sense the quality of light is important because small seeds have insufficient energy (carbon/nutrient) reserves to emerge from depth, allowing them to remain dormant when buried or when under vegetation (Fenner, 1980; Pons, 1991). Ochuodho (2005) reported that, the germination of Cleomegynandra seeds at 20^{o}C was inhibited by light, but it was improved at 20^{o}C in darkness.

There was no photo inhibition when seeds were germinated at constant 30^{o}C or alternating 20/30^{o}C (16 h night and 8 h day) for 10 days. Some species that do not or only slightly become secondarily dormant even exhibit no or only a low light requirement for germination (Baskin *et al*.,1993).

Once primary dormancy is lost in response to prevailing environmental conditions, secondary dormancy will soon start to be induced if the conditions required to terminate dormancy and induce germination are absent (e.g light and/ or nitrate) (William and Gerhard, 2006). Hilhorst (1990) suggested that, the induction and breaking of secondary dormancy was phytochrome controlled in light requiring seeds. In light requiring species, *Sisymbrium officinale* and *Arabidopsis*, light plays an important role in the biosynthesis of GA and also increases the sensitivity of seeds to GA (Hilhorst *et al*.,1986; Hilhorst and Karssen, 1988; Baskin and Baskin, 1998; Yamaguchi and Kamiya, 2002).

Phytocrome stimulates or inhibits germination according to the level of red or far red in the light. Generally, light with high levels of far-red light (light filtered through plant canopy) inhibits germination, while light with high levels of red light stimulates

germination (Gorski, 1975; Taiz and Zeiger, 2002). Some species are affected by exposure for long periods to induce germination (Bewley and Black, 1994; Taiz and Zeiger, 2002).

Light requirement for germination is one of the main traits associated with formation of a persistent soil seed bank, as well as dormancy mechanisms that extend or delay germination and gap detection through diurnally fluctuating temperatures (Baskin and Baskin 1989; Pons 1991).

Physiological dormancy is a major constraint in African eggplant of which the seeds have low germination unless they are conserved for 4 to 5 months, which requires suitable facilities (Abdoulaye, 2009.)Physiological dormancy is linked to seed metabolic rates, regulated by the presence of endogenous growth promoters and inhibitors (e.g. phenolics, cyanogenic compounds, ABA, GA's, cytokinins).These endogenous promoters and inhibitors will also interact with environmental factors such as light and temperature (Bewley and Black, 1994).

2.3.2 Influence of Temperature on seed dormancy and germination

Temperature is an important factor in seed germination and affects dormancy and germination rate (Alvarado and Bradford, 2002). The effects of temperature on germination are considered in terms of cardinal temperatures (Yan and Hunt, 1999). Cardinal temperatures (minimum, optimum and maximum) are the range of temperature in which seeds of particular species are able to germinate. Minimum temperature is the lowest temperature in which a seed is able to germinate. Optimum temperature is a temperature in which the highest percentage of the seed germinates at the shortest

period of time and maximum temperature is the highest temperature in which the seed can germinate (Alvarado and Bradford, 2002). Commander *et al.*, (2008) reported that, seeds of *Solanum orbiculatum* treated with smoke (karrikinolide) germinated to a high percentage over the temperature range of 10^{o}C to 30^{o}C.

This apparent broad temperature range for germination suggests that some *Solanum*species may be able to germinate throughout the year, responding to moisture cues rather than temperature cues (within their normal seasonal range), and enabling germination at any time during the year (Ahmed *et al.*, 2006).

After prolonged inhibition of germination due to lack of proper conditions for germination (e.g low temperatures, darkness, and deep burial) (Dyer, 1995; Benvenuti *etal.*, 2001), seeds may gradually enter a state of secondary dormancy, which often resembles primary dormancy (Hilhorst and Karssen, 1992).

Non-dormant seeds germinate over a wide range of temperatures. Those germinating only under a limited range of environmental conditions are called conditionally dormant, and those germinating at none of the temperatures are dormant (Baskin and Baskin, 1985). The cardinal temperatures for germination of African eggplant seeds is not known, hence this study is designed to come up with a range of temperatures at which seeds of this particular crop will germinate. Del Monte (1997) found that, the optimum temperature for germination of *Solanum nigram* was between 25^{o}C and 30^{o}C. Jurado and Westoby (1992) found that, germination of a *Solanum species* from Australia was higher at 28^{o}C, than at 12^{o}C and 20^{o}C. Horowitz and Givelberg (1982)

reported that,*Solanum nigrum* seeds germinated to 98% at temperature range between 20^0C and 35^0Cin light with optimum temperature of 25^0C.

Temperature is often regarded as the single most important environmental factor because of its role in breaking dormancy (Bouwmeester and Karssen, 1992, Vleeshouwers*et al*., 1995) and determining germination success (Baskin and Baskin, 1989).Temperature, nutrient, moisture and light availability, light quality, and position held by the seed within the inflorescence or the age of the maternal plant at the time of embryogenesis have been shown to impact seed dormancy and germination (Gutterman *et al*., 1992). Understanding of these factors which affect seed quality during seed production of African eggplant is important.

Extreme environmental conditions experienced at the time of seed development, such as high temperatures and water-stress, often result in low seed dormancy and, subsequently, high germination (Allen and Meyer, 2002). Conversely, exposure to low temperatures typically results in a prolonged developmental period that allows the seed coat to further develop, which leads to greater seed dormancy (Allen and Meyer 2002). Seeds of African eggplant may have high or low dormancy depending on conditions experienced during seed development and maturation.

In many seeds, germination is promoted by alternating temperature changes which may be either diurnal or seasonal (Mayer and Poljakoff, 1989). Barrosleal *et al*. (1993) found that, alternating temperature of $20/30^o$C enhanced germination percentage in *Solanum americanum*.Seed dormancy can be broken by alternating temperatures (Prober t*et al*., 1986; Benech *et al*., 1990).

Roberts and Locker,(1978) reported that *Solanum nigrum* seeds germinated rapidly at alternating temperature of 25/30^{0}C.It was reported that alternatingtemperature regimes can be more effective in stimulating germination than one constant temperature and seeds of various species require alternating temperatures to optimize their germination (Baskin and Baskin, 1998; Neuffer and Hurka, 1986).Fluctuating temperatures promote seed germination in comparison with constant temperatures (Huarte and Benech, 2005). Fluctuating temperatures, chilling pre-treatment and light were all found to improve germination of *S. nigrum* seeds (Bithell *et al*., 2002).Environmental conditions, particularly alternating temperature, regulates seed germination and dormancy by affecting the plant hormone balance of GA and ABA biosynthesis and catabolism, which will determine the dominant hormone (Ali-Rachedi *et al.*, 2004; Cadman *et al*., 2006). Temperature in the field regulate seed germination in two ways: (1) Breaking dormancy by fluctuating temperature (Benech *et al*., 1990), and (2) determining the germination rate of seeds after dormancy has been broken (Garcia *et al*., 1982).

Del Monte1 and Tarquis (1997), reported that alternating temperatures release dormancy by reducing base temperature (Tb) instead of reducing the amount of heat needed to achieve 50% germination response proposed by Ellis and Barret (1994) and Duran *et al.*(1995).

Temperature affects germination not only directly by fulfilling the specific germination requirements of different species, but also indirectly by changing the level of seed dormancy (Bouwmeester and Karssen, 1992).Studies indicates that, the optimum temperatures for growth of the crop is between 23^{o}C and 35^{o}C during the day and 18-25^{o}C during the night, however, no studies on the effect of alternating temperatures on

African eggplant seeds germination. This study is therefore designed to come up with optimum alternating temperature for germination of the crop.

2.3.3 Effect of Potassium nitrate on seed dormancy and germination

Many nitrogen containing compounds, including NO gas, nitrite (NO_2^-), nitrate(NO_3^-), nitrogen dioxide, ammonia, azide and cyanide promote dormancy release and seed germination in many species, possibly as a means of sensing soil Nitrogen availability (Bethke *et al*., 2007). Nitrate is an important nitrogen source for plants, but also a signal molecule that controls various aspects of plant development such as dormancy release.Even nitrate provided during seed development via the maternal plant leads to lower dormancy (Alboresi *et al.,* 2005).Endogenous nitrate concentration in seed is directly related to the parent plant'sexposure to exogenous nitrate (Saini *et al*., 1985). Potassium nitrate is linked to relieving light dormancy by increasing sensitivity to light in many species (Bewly and Black, 1994). Light has been shown to increase germination of *Chenopodium album* (Jursik et al., 2003) particularly in combination with nitrate (Bouwmeester and Karssen, 1993).

Light and nitrate interaction is alsonoticeable when studying the seeds whose parent plants were exposed to high nitrate (Saini, 1985).Exogenous nitrate can affect the requirement for light to promote *A. thaliana* seed germination (Barak *et al*., 2002), and their initial level of dormancy is influenced by the nitrate regime fed to the mother plant (Alboresi *et al*., 2005).Nur *et al.* (2005) noted that, low nitrate concentration of 0.1% was more effective than higher concentration (above 0.1 %) in breaking dormancy in *Solanumstramonifolium* and *Solanumtorvum* and GA_3 treatment at 0.01% was able to increase germination of all dormant accessions to almost 100%. Saini *et al*. (1985)

reported that, Potassium nitrate concentrations of 0.1 % recorded higher germination. Studies on nitrate and light interactions to improve seed germination of African eggplant have not been reported. Therefore, in this study, the optimum potassium nitrate level for improving germination of African eggplant will be determined.

2.3.4 Effect of Giberallic Acid (GA_3) on seed dormancy and germination

GA_3 treatment of dormant *Arabidopsis thaliana* seeds caused transient increase in ABA concentration (Ali-Rachedi *et al*., 2004), suggesting that in dormant seeds a feedback mechanism exists that maintains a high ABA: GA_3 ratio. Cadman *et al.(*2006) showed that, dormancy may depend on an intrinsic balance of GA_3 and ABA biosynthesis and catabolism, which will determine the dominance of either of the hormones.

Ali-Rachedi*et al*. (2004) and Cadman *et al. (*2006) reported that, dormancy release involves a net shift to increased GA_3 biosynthesis and ABA degradation resulting in low ABA: GA ratios. The transition from the dormant to the non-dormant state of many seeds is characterized by decrease in ABA sensitivity and increase in GA_3 sensitivity (Chiwocha *et al*., 2005).

Gibberellins are thought to act via mechanisms that include promoting growth potential of the embryo (Kucera *et al.,* 2005), weakening endospermic cells (Groot and Karssen1987; Groot *et al.,* 1988; Debeaujon and Koornneef, 2000) and replacing after-ripening requirements (Baskin and Baskin, 2004a). GA_3 has been observed to promote germination of other physiologically dormant seeds (Baskin and Baskin 1998, 2004b).According to Aboulaye 2009, GA_3 improved germination of eggplant seeds ofKumba group of West Africa. This study is designed to come up with optimum GA_3

concentration for improving seed germination of two varieties of African eggplant which are commonly produced in Tanzania, namely Tengeru white and DB3.

2.3.5 Influence of maturity stage on seed dormancy and germination

An important aspect of seed production is the correct determination of physiological maturity and the ideal harvest time (Marcos, 2005). Agbo and Nwosu (2008) reported that, seeds extracted from full red fruits recorded higher germination percentages than seeds harvested from light green, green, sign of ripening (yellow red) and greenish red fruits. Harada (1997) pointed out that, the last two stages of seed development encompass the embryo maturation stage, when the embryo increases in weight and the desiccation stage, when there is marked decrease in water content.

Potential seed quality is established at physiological maturity when 100% of the seeds germinate and produced normal seedlings with maximum vigor (Hilhost and Troop, 1997).Yogeesha *et al.* (2006) had shown that a strong relationship exists between seed dormancy and ABA contents of seeds of *Solanum melongena* species. Free ABA is highest in developing seeds and is generally low or even undetectable in mature seeds (Black, 1991).

ABA found in seeds of many species promotes maturation and dormancy, synthesis of certain storage proteins and inhibits germination (Bewly and Black, 1994).

Generally, ABA rises in concentration during seed development, reaches 1 or 2 peaks, then usually declines rapidly at the time of seed dry down (Bewley and Black, 1994). Yogeesha et al. (2006) reported the presence of inhibiting hormones in some cultivars of *Solanum melongena*. Agbo and Nwosu (2008) reported that, for seed production of

Solanum melongena, fruits are normally harvested at full maturity, which is about 50-60 days after an-thesis depending on cultivar, climate and growing conditions.

Passam *et al*.(2009) concluded that, the optimum time of harvest for seed production is 55 days after anthesis (DAA) for two eggplant varieties, Emi and Tsakoniki. Bewley and Black(1994) reported that, tomato seeds takes about 60 days after pollination(DAP) to reach full maturity, but germinate at 90% levels by about 40 DAP. According to *Passam et al.*(2009) seeds extracted from fruits that were harvested between 25 DAA and 35 DAA did not germinate, whereas seeds extracted from fruits harvested at 45 DAA showed high germination which decreased after storage at 25^{o}C for three months.*Solanum species* seeds have a certain period of time with reduced ability to germinate. For example, buried seed of *S. nigrum* remained dormant for at least 39 years in Britain (Edmond and Chweya, 1997). Abdoulaye (1992) reported that, embryo dormancy is a major constraint in African eggplant and their fresh seeds can germinate only after storage for 4-5 months under suitable conditions (cold chambers). Acquisition of ability to germinate in seeds has been reported to be attained at specific developmental stages in different crop species (Agbo and Obi, 2008). Thus, the stage of seed maturity at harvest may affect seed dormancy and germination.

Seed dormancy in cultivated plants not only causes problems in actual agricultural production but also complicates assessment of seed quality (Geneve, 1998).

Therefore, problem of seed dormancy require attention in areas of seed production (technology) where study of seed dormancy in many agricultural seeds is an important input. Although several researches have been conducted on seed dormancy in various

solanum species, no research has been done on optimum harvesting stages and cardinal temperatures for germination of *Solanum aethiopicum*. This study was therefore designed to come up with various ways of improving seed germination of African eggplant by subjecting the seeds to various temperatures, light durations, alternating temperatures/light, chemical treatments ($KNO_{3,}GA_3$) and harvesting the fruits at different maturity stages. The information gained from the study should form the basis for advice to producers to have seedling emergence and good crop stand which is likely to result into high yield, hence more income for producers.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1: Seed sources and Experimental sites

Seeds were sourced from Agricultural Seed Agency (ASA) horticultural site located at Tengeru, about 15 km East of Arusha city. The average rainfall in this area is 913 mm per annum, the maximum and minimum temperatures are 21^{O}C and 11^{O}C respectively and the altitude range between 485-1660 m (Jim *et al.*, 2008). The reasons for selecting this area were; first, the crop is popular in this region where most of the small scale eggplant producers are found. Secondly, most of the seed companies which deal with this crop are situated in Arusha. Laboratory experiments were set at Kenya Forest Research Institute (KEFRI) at Muguga, Nairobi.

3.1.1: Seed source one experiment

Seeds of two varieties of African eggplant, Tengeru white and DB3 was sourced from ASA Tengeru. The seeds were sowed in a nursery for 50 days and thereafter transplanted to the field in a spacing of 75cm X75 cm in an area of $240m^2$. Each variety was planted into two plots, each $60m^2$. Each plot has 13 rows with 8 plants each. NPK (20:10:10) fertilizer was applied at the rate of 200kgs/ha during transplanting, followed by splits application of Urea (46% N) at the rate of 90kg/ha at 30 days interval from transplanting.

Harvesting of fruits was done when the fruits were red ripe, yellow red and yellow green. Seeds were extracted by cutting the fruits by knives and remove seeds by hands. Seeds were fermented for 24 h to release the mucous and then washed and sun dried for

three days. Seeds were packed in clean plastic bags, ready for germination test at the laboratory.

3.1.2: Seed source two experiment

In the following season, the above experiment was repeated but at this time, the crop was monitored daily to examine days to 50% flowering and 50% fruiting for both varieties. Fruits were harvested when full red at different maturity stages as follows at 30, 44, 58 and 72 days after 50% flowering. Seeds were extracted and processed the same way as in (3.3.1) above.

3.2: Data collection

The following data were recorded from the field; Days to 50% flowering from transplanting date which were 41 days for DB3 and 48 days for Tengeru white. Days to 50% fruiting which were 48 days for DB3 and 55 days forTengeru white. Days to first harvest, this was 30days from transplanting. Harvesting was done after every two weeks (14days) from first harvest that is 30 days 44 days, 58 days and 72 days. Fruits were harvested when they were fully red. All data were collected from 40 selected plants per plot, leaving the border rows plants.

Also, 1000 seed weight was determined for both varieties (appendix 13 and14) in eight replicates. Each replicate contained 100 seeds. Average seeds weight of 100 seeds was calculated.

1000 seeds weight was calculated by multiplying the average seed weight of 100 seeds by 10. Also, number of seeds per kg was calculated by the following formula:-

$$Noofseedperkg = \frac{(No.ofseedsinreps \times 1000)}{\sum X}$$ ---------- Equation 1

Where ∑X = total sum of the eight replicates.

3.3: Laboratory tests

Sample of seeds for all varieties were taken to the laboratory for conducting germination test according to ISTA standards (ISTA, 1993). According to ISTA, the minimum submitted sample size for germination test of eggplant is 15 grams. The working samples of 400 seeds per treatment wereobtained from the submitted sample.

3.3.1:Germination test for source one seed

Top of paper method was used for seeds from experiment one. Two layers of filter paper were placed in the petridishes. Seeds were surface sterilized by soaking them into 1% solution of sodium hypochlorite for ten minutes, then rinsed with distilled water and dried on papers. Four replications of 100seeds were counted and placed into their respective petridishes for each treatment.The Petridishes were covered with their lids to minimize evaporation and placed into their respective growth chambers calibrated to various temperature treatments.

3.3.2: Treatments for source one seeds

Treatments for source one seeds were different temperatures at 15^{o}C, 20^{o}C, 25^{o}C, 30^{o}C and 35^{o}C in 12 h light/12 h dark. Alternating temperature 30/20^{o}Cand 30/25^{o}Cin 24 h continuous light.

Also seeds of DB3 seeds were treated with different chemical concentrations (GA_3 at 0.01%, 0.02% and 0.03%) and (KNO_3at 0.1%, 0.2% and 0.3%) and germinated at

alternating temperatures 30/25^{o}C under continuous darkness. Seeds were incubated for 20 days while monitoring germination count daily.

For source one seeds, after obtaining results, the temperature which gave highest germination (30/25^{o}C) in 24 hours light was selected for setting another experiment whereby, only DB3 seeds were used.Tengeru white seeds were not repeated after showing good germination percentage (87%) under alternating temperature (30/25^{o}C) (24 hrs continuous light). In thisexperiment, different chemical concentrations were applied and experiment was set on 24 hours continuous light.Different concentrations of GA_3 (0.05%, 0.08%, 0.1% & 0.2%) were prepared. Seeds were prepared as in first experiment above and treated by moistening them with GA_3concentrations. Treatments were GA_3at 0.05%, 0.08%, 0.1% and 0.2 % and seeds were placed in incubator for 20 days and germination count was recorded on day 5, 8, 13, 17 and 20 respectively.

3.3.3: Experimental design for source one seeds

Treatments were completely randomized (CRD) in the germination chamber into four replications for both varieties for seeds from source one experiment.

3.3.4: Data Analysis for source one seeds

The data was subjected to analysis of Variance (ANOVA) using GENSTAT software version 12 and the mean separations was done using Tukey at P = 0.001.

3.4: Germination test for seeds from experiment two

3.4.1: Moisture content determination

The purpose of this experiment was to determine the initial moisture content of source two seeds after drying on sun for three days. Initial moisture content was carried out in

duplicate on two independently drawn working samples for source two seeds. Empty containers along with cover were weighed. The sample was mixed thoroughly and two small portions of seed samples were weighed. After weighing, the lid was removed and the open container was kept in the oven set at 103^{o}C for 17 h. At the end of drying period, containers were closed by their lids.

The containers were transferred into a desiccator and allowed to cool. Samples were weighed again, data recorded (Appendix 12) and moisture content calculated using the following formula:

$$M = \frac{M2-M3}{M2-M1} \text{ X } 100 \ldots\ldots\ldots\ldots \text{Equation 3}$$

Where M = Seed moisture content

M1 = Weight of the empty container with its cover

M2 = Weight of the container with its cover and seeds before drying

M3 = Weight of the container with its cover and seeds after drying

For the experiment involving seeds from experiment two, the growth media was agar. Agar was mixed with water at the ratio of 10gms of agar to 1litre of water and boiled. The media was poured into petridishes and left to cool ready for sowing seeds. Seeds were prepared as in experiment one above.

Seeds were treated withGA_3 and KNO_3 at (0.1%, 0.2% and 0.3%) concentrations. The experiment was set under one alternating temperature (30/25^{o}C) and two light regimes

thatwere 24 h in continuous darkness and 24 h in continuous light. The incubation period was 20 days and germination count was done after every one day interval from day 6 to 20,that was day 6, 8, 10, 12, 14, 16, 18 and 20. Seeds protruding about 1 mm out of seed coat were considered as germinated seed. This experiment involved seeds from both varieties; Tengeru white and DB3.

3.4.1: Experimental design for seeds from source two

Treatments were completelyrandomized (CRD) in the germination chamber into two replications for bothvarieties.

3.4.2: Treatments for source two seeds

Seeds harvested at different maturity stages, 30, 44, 58 and 72 days after anthesis were treated withGA_3at different concentrations of 0.1%, 0.2%, 0.3% and KNO_3 at different concentrations of 0.1%, 0.2% and 0.3%.

3.4.3: Data Analysis for source two seeds

The data was subjected to analysis of variance (ANOVA) using GENSTAT software version 12 and the mean separations was done using Tukey at P = 0.001.

3.5: Germination percentage calculation

Daily germination percentage was calculated as follows:

$$GT = (NT \times 100)/N$$ ……Equation 2. Where

GT = germination percentage
NT= number of seeds that actually germinated and N= no. of seeds used in bioassay.

CHAPTER FOUR

4.0 RESULTS

4.1: Temperature effects on seed germination

4.1.1: Influence of constant temperatures on germination of African eggplant seeds

Seeds of Tengeru white germinated in a wide range of temperatures from 15^{o}C to 30^{o}C, and recorded the highest germination percentages of73.5% at 25^{o}C followed by 70.8% at 20^{o}C. DB3 exhibited very low germination percentage of 0.4% at 30^{o}C and 0.1% at 25^{o}C which is almost zero germination and failed to germinate at constant temperatures of 15^{o}C, 20^{o}C and 35^{o}C (Figure 1.)There was a decrease in germination percentages with further increase in temperatures to 35^{o}C and germination failed to take place at temperature 35^{0}C for both Tengeru white and DB3 seeds.

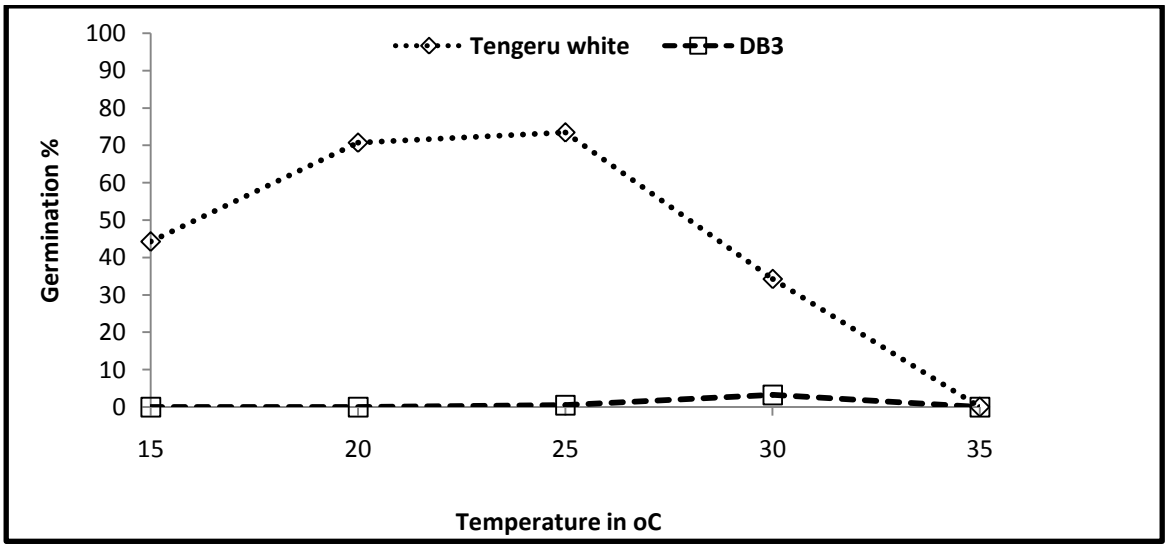

Figure 1: Germination% of A.egg plant under various temperatures (12hrs light/12 hrs darkness)

Tengeru white seeds germinated earlier with more than 50% germination after 7 days of incubation while DB3 germinated later with 1.5% germination on day 10(Figure 2).There was no germination recorded for DB3 variety for the whole incubation period of 20 Days at constant temperature 15^{o}C,20^{o}C and 35^{o}C.

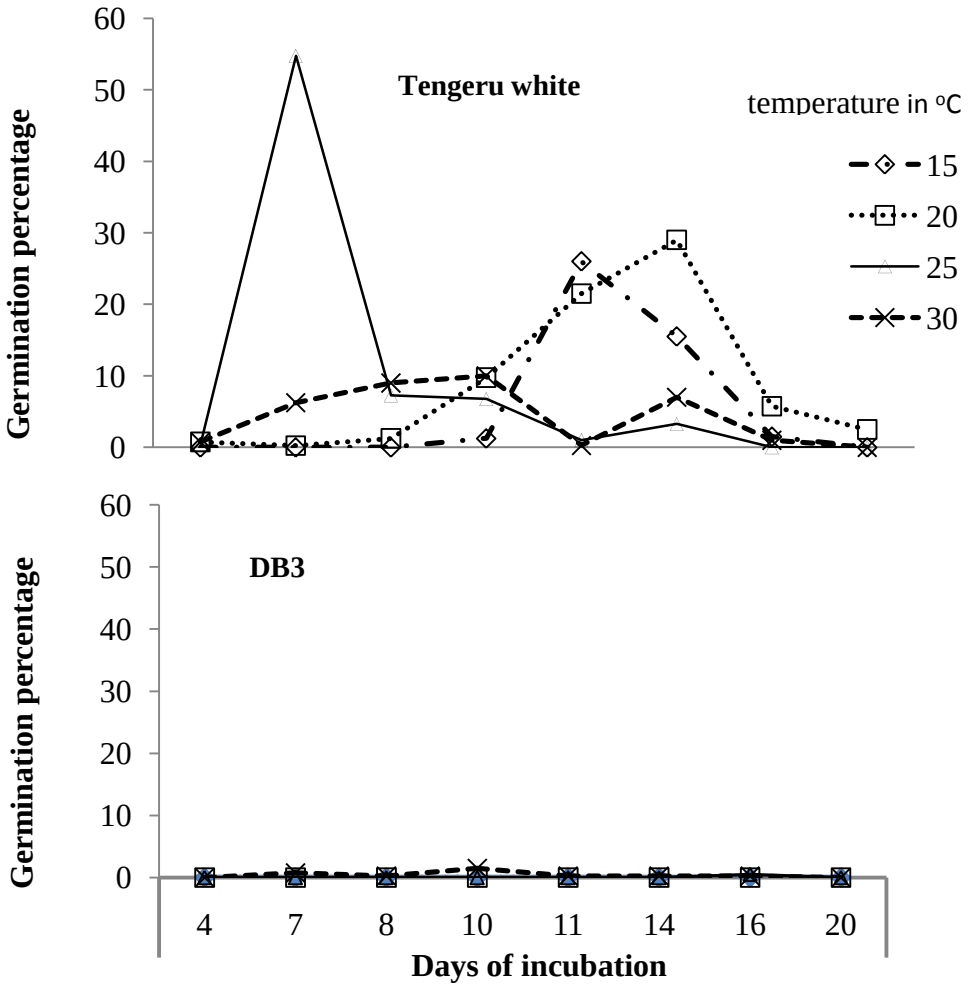

Figure 2: Germination percentages of Tengeru white and DB3 seeds at different temperatures under 12 h light/12 h darkness

The first count under temperature regime of 15^{o}C was recorded on day 10 and the highest germination percentage (26%) on day 11 while the lowest was 0 for Tengeru white (Figure 2).The two varieties germinated at different constant temperature (Figure 2) whereby, the optimum germination temperature for Tengeru white was 25^{o}C while the maximum and minimum temperatures were 30^{o}C and 15^{o}C respectively. On the other hand, DB3 recorded very low germination between temperatures 30^{o}C and 25^{o}C.

Germination under temperature regime 20^{o}C occurred earlier than at 15^{o}C (Figure 2). The first count of 0.8% was observed on day 4 while the highest germination of 29% occurred on day 14 and the lowest on day 7. As in temperature 15^{o}C, DB3 did not germinate under this temperature. The highest germination under temperature 25^{o}C was recorded earlier on day 7 (54.8%) and there was no germination after day 14 for Tengeru white while DB3 germinated to 0.5% on day 16. Days, variety and their interactions were highly significant at $P = < 0.001$ indicating the usefulness of the temperature on increasing mean germination percentages during the incubation period. DB3 recorded very low mean germination of 0.4% under temperature 30^{o}C and did not germinate at the constant temperatures 15, 20 and 25. Germination percentage for Tengeru white was highest (10%) on day 10.

4.1.2: Influence of alternating temperatures on germination of African eggplant seeds

Seeds of both varieties were germinated under two alternating temperatures, 30/25^{o}C and 30/20^{o}C in continuous light to determine the best alternating temperature for germination of the crop. Generally, there was high germination percentage under alternating temperatures compared to constant temperatures. Tengeru white recorded the highest germination percentage of 87% at alternating temperature 30/25^{o}C followed by 72.75% at alternating temperature 30/20^{o}C under 24 h continuous light (Table 1.)

DB3 seeds on the other hand, recorded the lowest germination compared to Tengeru white, whereby, the maximum germination of 21% for this variety was recorded at alternating temperature 30/25^{o}C in continuous light, followed by 3.3% at alternating temperature 30/20^{o}C. Germination percent was highest, 28.3 %on day 7 followed by 27 % on day 8 and 11 % on day 10 for Tengeru white. DB3 recorded highest germination of 1.8 % on day 14 followed by 0.5 % on day 7 and 8 respectively. Alternating temperatures and their interactions were highly significant at P = 0.001 level of significance on improving germination percentages.

Table 1: Germination percentages at 30/25^{o}C and 30/20^{o}C in continuous light (24 h).Seeds extracted from full red fruits

Alternating temperature	Days	T. White	DB3	
30/25^{o}C	4	3.5	0.0	
	7	69.0	0.0	
	8	4.8	0.3	
	10	5.0	11.0	
	11	1.3	5.3	
	14	1.8	4.5	
	16	1.0	0.0	
	20	0.8	0.0	
Final germination %		87.0	21.0	
	mean	10.9	2.6	
T30/20^{o}C	4	0.5	0.0	
	7	28.3	0.5	
	8	27.0	0.5	
	10	11.0	0.3	
	11	3.0	0.3	
	14	2.8	1.8	
	16	0.0	0.0	
	20	0.0	0.0	
Final germination %		72.6	3.4	
	mean	9.1	0.4	
	Days	Temperature	Variety	Variety*temperature
L.S.D	1.341	1.255	0.671	1.774
CV%	38.40%			

Highest mean germination percentage of 10.9% was recorded for Tengeru white under temperature regime30/25^{o}Cwhile the highest mean germination percentage under temperature 30/20^{o}C was 9.1% (Table 1). Both varieties recorded higher mean germination percentages under alternating temperature 30/25^{o}C (24 h light) whereby Tengeru white recorded more than 50% germination on day seven as compared to alternating 30/20^{o}C (24 h light) where it recorded only 28.3% germination on the same

day. DB3 on the other hand, recorded higher mean germination percentage (2.62%) under alternating 30/25^{o}C

(24 h light) as compared to 0.4% under alternating 30/20^{o}C (24 h light).Germination percentages of both varieties at different days were statistically different at P = < 0.001.

4.2 : The suitable chemical method for improving seed dormancy in African eggplant.

From Table 2, Germination percent of DB3 seeds treated with GA_3 and KNO_3 were highly significant at P = 0.001. GA_3 showed higher germination percent than KNO_3 and the highest germination percentage of 35.4% was attained under 0.03% of GA_3 concentration. Control which was not treated with any chemical recorded the germination percent of 2.2%. On the other hand, seeds treated with KNO_3 recorded higher germination of 13% at lower concentration of 0.1% compared to control which was 2.2% and lower germination of 6.4% under higher concentration of 0.3%. Interactions between days and chemicals, harvesting stages and days, were all highly significant at $p \leq 0.001$ on influencing germination percentages (Apendix 11).

Table 2: Germination percent of DB3 seeds under different chemical concentrations at 30/25^{o}C in 24 h continuous darkness (seeds extracted from full red fruits)

	Chemical concentration (%)						
Day	Control	GA3 0.01	GA3 0.02	GA3 0.03	KNO3 0.1	KNO3 0.2	KNO3 0.3
5	0.1	1.9	1.5	8.0	3.5	0.1	0.4
7	0.4	3.0	8.6	18.8	6.6	2.5	1.9
9	1.1	1.6	7.5	6.5	0.6	3.1	3.3
12	0.6	3.5	3.5	2.0	1.9	2.8	0.5
14	0.0	0.1	0.4	0.1	0.4	1.0	0.3
Final germination	2.2	10.1	21.5	35.4	13	9.5	6.4

	Days	Chemical	Days*chemical
L.S.D	0.55	0.61	1.37
% C.V	34.2		

Seeds extracted from red fruits when treated with GA_3 concentration of 0.03% increased germination from 2.2% (control) to 35.4%. On the other hand, seeds extracted from yellow green fruits showed almost zero germination percentage(Figure 2.) DB3 seeds recorded higher germination percentage when treated with GA_3 than when treated with KNO_3 at higher concentration of 0.03% indicating that, further increase in concentration could further increase germination, hence, in the following experiment, Gibberellic Acid concentrations were increased to 0.05%, 0.08%, 0.1% and 0.2% at alternating 30/25^{o}C in continuous light. Different GA_3 concentrations were highly significant at $P < 0.001$ on influencing germination percentage of African eggplant (Table 3).

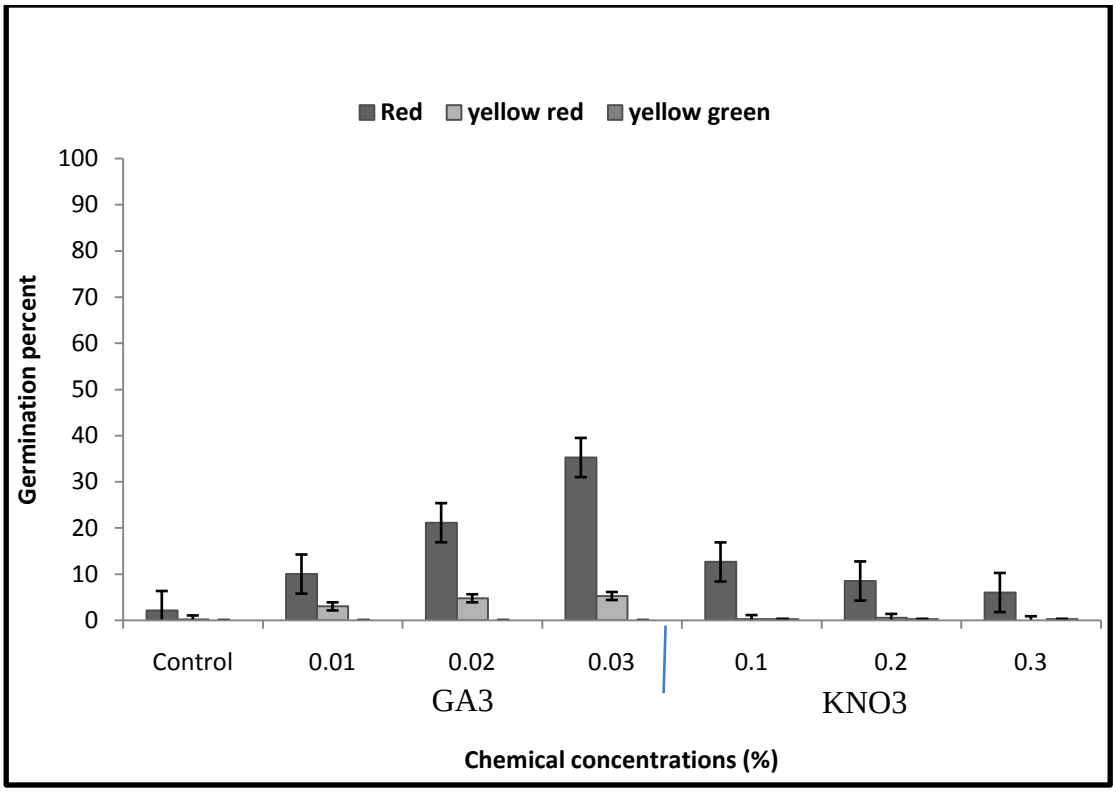

Figure 3: Germination percent of DB3 seeds at different harvesting stages and chemical concentration at 30/25^{o}C under 24 h continuous darkness.

The highest mean germination of 13.7% was recorded for the seeds treated with 0.1% of gibberellic acid while the seeds without chemical treatment (control) recorded the lowest mean germination of 3.26%. Increased concentration of GA_3 to 0.2% lowered mean germination significantly from 13.7% to 11.8%. Higher mean germination of 13.8% was recorded on day eight and lowest of 7.8% on day five. Germination percentages increased significantly with increase of GA_3 concentrations from 0.03% (Table 2) to 0.05%, 0.08% and 0.1% (Table 3).

Table 3: Germination of DB3 seeds under different GA_3 concentrations at 30/25^oC in 24 h continuous light (seeds extracted from full red fruits)

	GA_3 concentration (%)				
Days	Control	0.05	0.08	0.1	0.2
5	3.4	7.4	9.8	11.7	6.9
8	2.8	11.9	15.6	19.1	19.7
13	4.0	8.1	10.8	16.8	13.1
17	4.3	7.3	5.5	10.5	10.0
20	1.9	5.7	7.4	10.4	9.4
Total germination	**16.4**	**40.4**	**49.1**	**68.5**	**59.1**
mean germination %	3.3	8.1	9.8	13.7	11.8
		L.S.D	C.V%		
Days		0.942	32.3		
Chemical		0.942			
Days*chem		2.104			

4.3: Influence of light on germination of African eggplant seeds

Exposure to light of DB3 seeds harvested 72 DAA increased germination significantly at $P \leq 0.001$ to 42.5% compared to 33.6% under darkness. Tengeru white on the other hand, recorded higher germination under light compared darkness for the seeds harvested 72 DAA. Generally, germination percentages for both varieties were higher under light compared to one under darkness (Table 4). The lowest germination percent was observed for seeds harvested between 30 days and 44 days after anthesis and placed under darkness.

Table 4: Effect of light on germination of DB3 and Tengeru white seeds harvested at different maturity stages and germinated at 30/25^{o}C.

Maturity stages (DAA)	DB3		Tengeru white	
	Light	dark	Light	dark
30	0.1	0.0	0.2	0.0
44	7.8	7.7	0.0	0.0
58	31.2	31.0	51.5	34.6
72	42.5	33.6	85.6	75.1
	Light	Variety	Maturity stage	
L.S.D	1.83	1.83	2.59	
%CV	36.40			

Light was highly significant at P=0.001 on influencing germination percentages of African eggplant seeds and higher germination percentages were recorded for seeds placed under light as compared to those in darkness for both varieties (Table 5). Light interacted with GA_3 at 0.1% to improve germination of DB3 seeds from 18% (control) to 29% compared with 16% (control) to 25% under darkness. Tengeru white seed germination on the other hand, was improved from 35% (control) to 38% at GA_3 0.3% under light compared with germination improvement from 31% (control) to 35% at GA_3 0.2% although germination under these GA_3 concentrations were not statistically significance.

Table 5: Light interacting with chemical and variety to influence germination% under alternating temperature 30/25^{o}C (24 h continuous darkness and 24 h continuous light).

Variety	Chemical	Light regime		
		Darkness	Light	Mean
DB3	Control	16	18	17
	GA_3 0.1	24	26	25
	GA_3 0.2	21	27	24
	GA_3 0.3	25	29	27
	KNO_3 0.1	19	20	20
	KNO_3 0.2	16	16	16
	KNO_3 0.3	20	20	20
	Mean	20	22	21
Tengeru white	Control	31	35	33
	GA 0.1	22	25	24
	GA 0.2	34	34	34
	GA 0.3	27	38	33
	KNO_3 0.1	22	35	29
	KNO_3 0.1	13	34	24
	KNO_3 0.3	23	37	30
	Mean	25	34	30

	Light	Variety	Chemical	Light *variety	Chemical *variety
L.S.D	1.83	1.83	3.424	2.588	4.842
% C.V	36.4				

4.4: The optimum harvesting stage for African eggplant seeds

The two varieties attained 50% flowering at different days whereby, DB3 reached 50% flowering on day 41 after transplanting while Tengeru white reached 50% flowering on day 48 (table 8). Both varieties and days to 50% flowering were highly significant at P=

0.001 level of significance. From Table 6, it was recorded that, DB3 attained 50% fruiting 48 days after transplanting while Tengeru white attained 50% fruiting 55 days after transplanting. Variety, days to 50% fruiting and their interaction were highly significant at P= 0.001 level of significance.

Table 6: Days to 50% flowering and fruiting

Flowering and fruiting	Variety	Days to flowering and fruiting								
		30	37	41	44	48	51	55	58	65
Flowering	DB3	5	15	21	26	30	36	-	-	-
	Tengeru white	2	6	10	17	20	30	-	-	-
Fruiting	DB3	-	3	-	13	20	24	30	37	39
	Tengeru white	-	2	-	5	5	13	20	28	38
	Variety	L.S.D	%CV							
		1.71	16.1							

Seeds of both varieties attained maximum weight at different physiological maturity stages. It was revealed that, DB3 attained its maximum weight (2.34gm) 44 days after anthesis while Tengeru white attained its maximum weight (1.88gm) 72 days after anthesis (Figure 4.)After maximum seed weight, Tengeru white loses water very fast as compared to DB3. It was noted that, seeds of Tengeru white attained higher germination percent (84%) without chemical treatment at its maximum weight of (1.88gm) while DB3 attained (31%).

These differences in germination percentages of the two varieties might have been attributed by their different physiological behavior (Figure 5). DB3 did not attain maximum germination at its maximum seed weight as compared to Tengeru white.

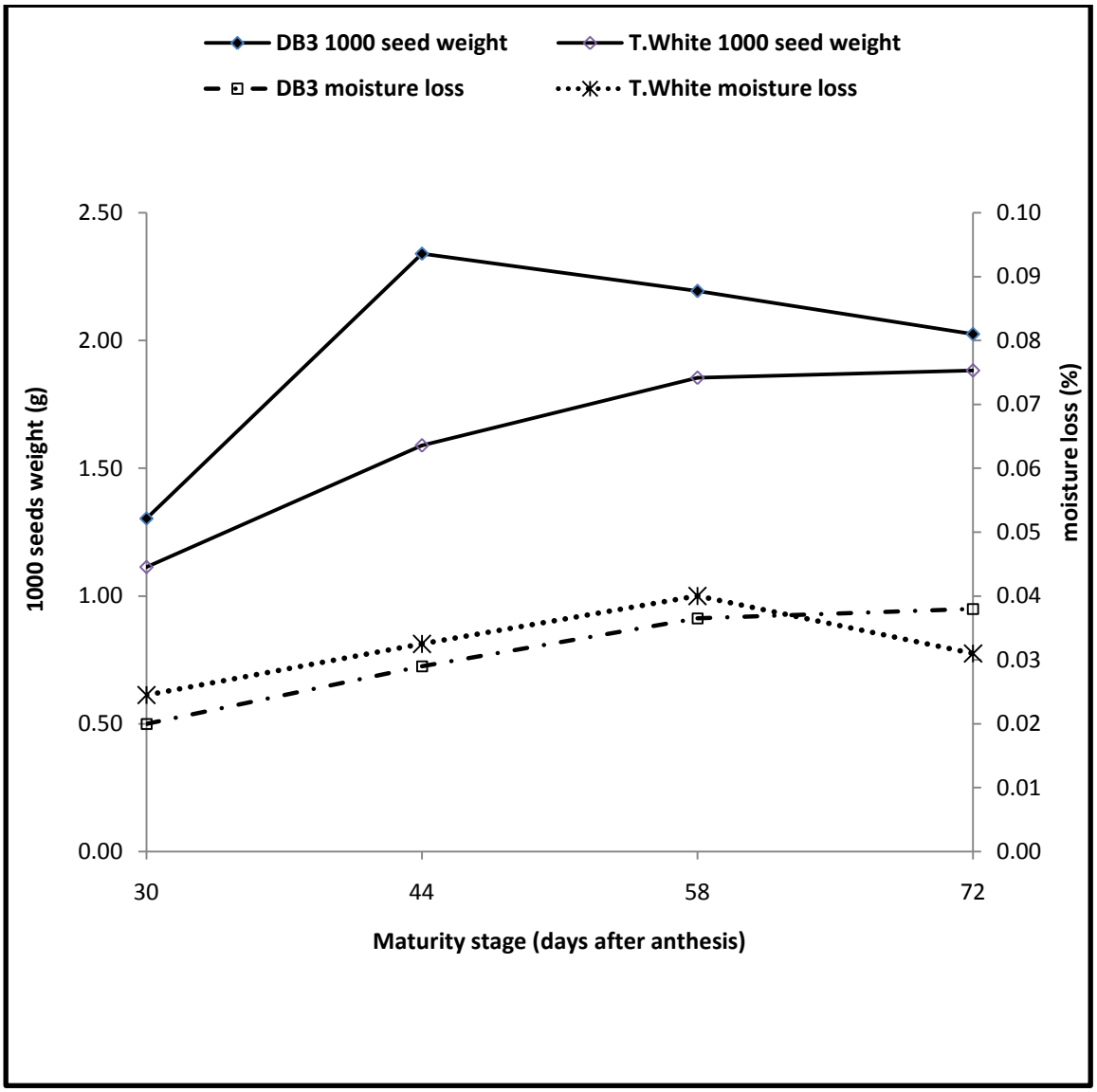

Figure 4: 1000 seed weight and percentage moisture content for DB3 and Tengeru white seeds at different physiological maturity stages.

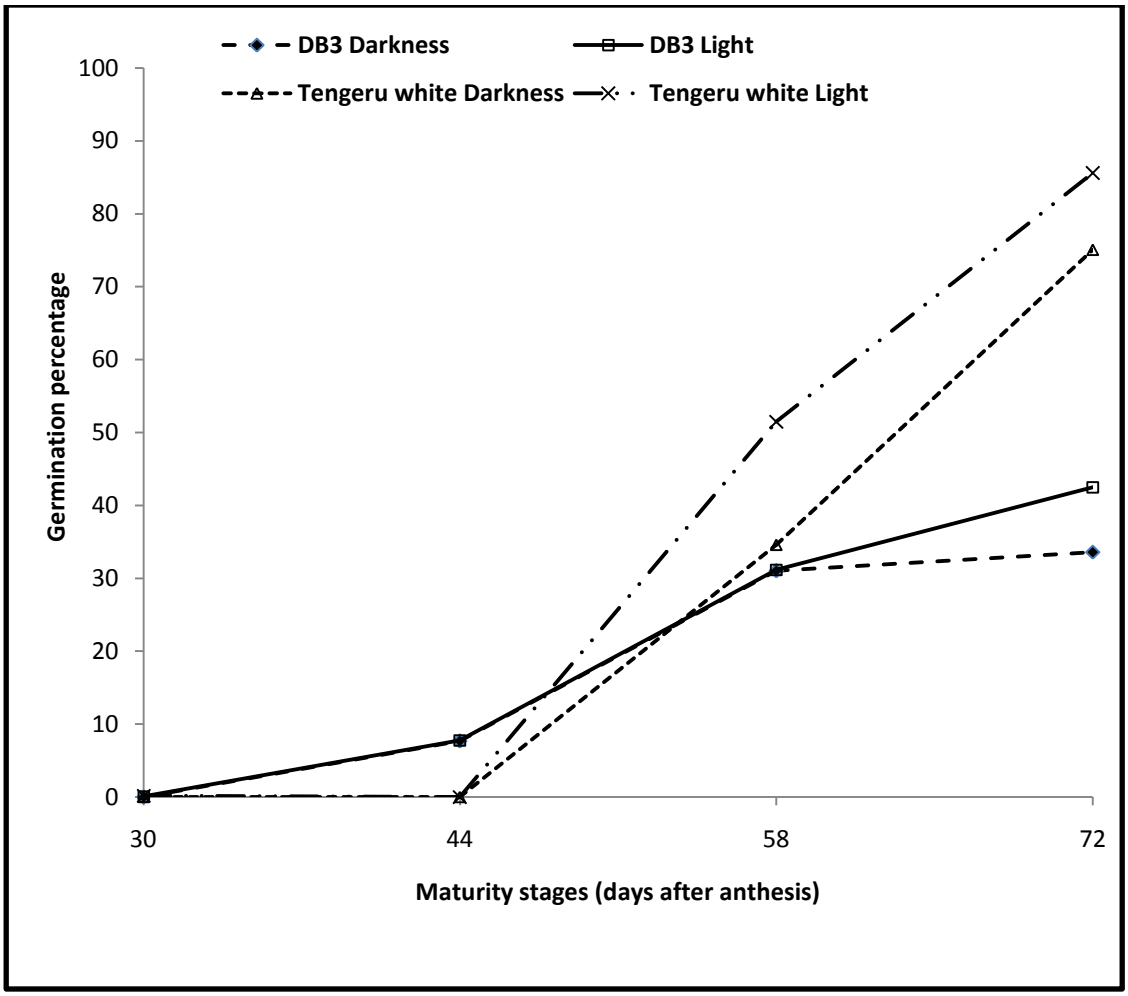

Figure 5: Germination percentages of Tengeru white and DB3 seeds harvested at different maturity stages at alternating temperature 30/25^{o}C

It was noted that, Tengeru white and DB3 seeds harvested at physiological maturity, 72 days after anthesis attained higher germination percentages when germinated under light as compared to darkness. Generally, lower germination percentages were recorded for seeds harvested between 30 days and 44 days after anthesis for both varieties (Figure 5.)

Table 7: Seeds of different maturity stages interacted with GA_3 and KNO_3 at 30/25^{o}C in 24 h continuous light.

		Maturity stages (DAA)				
Variety	Chemical	30	44	58	72	Mean
DB3	Control	0.0	5.8	29.7	31.5	16.8
	GA_3 0.1	0.0	11.0	34.5	54.0	24.9
	GA_3 0.2	0.0	14.0	36.0	45.5	23.9
	GA_3 0.3	0.0	6.0	41.0	60.0	26.8
	KNO_3 0.1	0.0	7.5	29.5	40.0	19.3
	KNO_3 0.2	0.0	8.5	24.0	30.0	15.6
	KNO_3 0.3	0.5	10.5	30.0	38.0	19.8
Tengeru white	Control	0.0	0.0	48.0	84.0	33.0
	GA_3 0.1	0.5	0.0	32.0	61.5	23.5
	GA_3 0.2	0.0	0.0	40.0	96.5	34.1
	GA_3 0.3	0.0	0.0	45.0	86.0	32.8
	KNO_3 0.1	0.0	0.0	33.0	81.0	28.5
	KNO_3 0.2	0.5	0.0	43.0	50.0	23.4
	KNO_3 0.3	0.0	0.0	35.5	85.0	30.1
	Chemical	Variety	Maturity stages	chemical*variety	chemical* maturity stages	
L.S.D	3.42	1.83	2.59	5.29	7.48	
%C.V	36.40					

It was observed that, both DB3 and Tengeru white seeds harvested 72 DAA and treated with GA_3 attained higher germination percentages than seeds harvested between 30 and 44 DAA and treated with similar GA_3 concentration. GA_3 and KNO_3at different concentrations interacted with harvesting maturity stages and varieties to influence germination percentages at $p \leq 0.001$ (table 7). GA at 0.1% increased the mean germination percentage of DB3 significantly from 16.8% to 24.9%.

Although Tengeru white seeds attained highest mean germination of 34.1% at 0.2 % of GA_3 compared to 33% for control, the increment was not statistically significant from 0.1% of GA_3. On the other hand, DB3 attained highest mean germination of 26.8% at 0.3% of GA_3 compared to (24.9%) at 0.1% of GA_3. However, this higher (26.8%) mean germination percentage was not statistically different from the one recorded at 0.1% concentration of GA_3.Further increase of KNO_3 concentration to 0.2% reduced mean germination percentages for DB3 from 19.25% to 15.6%.The highest mean germination percentage of 19.8% at 0.3% of $KNO_3$was not statistically significant from the one recorded at 0.1% of KNO_3.

CHAPTER FIVE

5.0 DISCUSSION

5.1: The optimum temperatures and alternating temperature/light for germination of African eggplant seeds

5.1.1: Constant temperatures improves germination of African eggplant seeds

From the results, seeds of different varieties of eggplant showed variation in germination under different temperature regimes. Tengeru white germinated in a wide range of constant temperatures from 15^{o}C to 30^{o}C with optimum temperature being 25^{o}C implying that, the seeds of this crop are non-dormancy.Non-dormant seeds germinate over a wide range of temperatures. Those germinating only under a limited range of environmental conditions are called conditionally dormant, and those germinating at none of the temperatures are dormant (Baskin & Baskin, 1985).This apparent broad temperature range for germination suggests that some *Solanum* species may be able to germinate throughout the year, responding to moisture cues rather than temperature cues and enabling germination at any time during the year (Ahmed *et al.*,2006).

DB3 seeds on the other hand, attained very low germination percentage with constant temperatures between 25^{o}C and 30^{o}C. This suggests that, DB3 seeds may have higher dormancy when germinated under constant temperatures. The two varieties have different cardinal temperatures requirements suggesting that, these two varieties might have different origins. Variation in germination probably was attributed by selection of these varieties during breeding. The variation in seed dormancy is ecologically

significant for native plants and has resulted in contrasting ecotypes following many generations of selection (Allen and Meyer, 2002).

After prolonged inhibition of germination due to lack of proper conditions for germination (e.g. low temperatures, darkness, and deep burial) (Dyer, 1995 andBenvenuti *etal.*, 2001), seeds may gradually enter a state of secondary dormancy, which often resembles primary dormancy (Hilhorst andKarssen, 1992).

Seeds of different crop species have a minimum, optimum and maximum temperatures at which they will germinate (Alvarado and Bradford, 2002.) For African eggplant, these temperatures were found to be 15^oC, 25^oC and 30^oC respectively for Tengeru white whereas for DB3 the minimum was 25^oC and optimum was 30^oC. DB_3 germinated only at 25^oC and 30^oC. Del Monte (1997) reported similar results for *Solanum nigrum*. Jurado and Westoby (1992) found that, germination of a *Solanum* species from Australia was higher at 28^oC, than at 12^oC and 20^oC.Horowitz and Givelberg (1982) reported that,*Solanum nigrum* seeds did not germinate in the dark but under light germinated to 98% at temperature between 20^oC and 35^0C with optimum of 25^0C.

Temperature is often regarded as the single most important environmental factor because of its role in breaking dormancy (Bouwmeester and Karssen 1992, Vleeshouwers *et al*., 1995) and determining germination success (Baskin and Baskin, 1988).Temperature, nutrient, moisture and light availability, light quality, and position held by the seed within the inflorescence or the age of the maternal plant at the time of embryogenesis have been shown to impact seed dormancy and germination

(Gutterman,1992).For African eggplant seeds, light availability was found to be useful for improving germination of both varieties. DB3 attained very low germination under Constant temperatures (15^{o}C, 20^{o}C, 25^{o}C, 30^{o}C and 35^{o}C) but improved germination under alternating temperatures 30/25^{o}C.

The lower germination percentages of African eggplant seeds partly may have been attributed by the conditions experienced in the field during seed development and maturation. Seeds were harvested during the rainy season which was between March and May; hence there was no water stress and temperatures were below 25^{o}C. Extreme environmental conditions experienced at the time of seed development, such as high temperatures and water-stress, often result in low seed dormancy and, subsequently, high germination (Allen and Meyer, 2002). Conversely, exposure to low temperatures typically results in a prolonged developmental period that allows the seed coat to further develop, which leads to greater seed dormancy (Allen and Meyer, 2002).

5.1.2:Alternating temperatures releases dormancy of African eggplant seeds.

Results indicated that, Tengeru white seeds attained higher germination (87%) under alternating temperature 30/25^{o}C in continuous light while under similar conditions DB3 attained 21%. Seeds of both varieties harvested at physiological maturity stages recorded higher germination percentages under continuous light at alternating 30/25^{o}C (Table 4). The higher germination percentages under alternating temperatures suggest that, alternating temperatures were able to release dormancy in African eggplant seeds. Roberts *et al.*,(1978) reported that *Solanum nigrum* seeds germinated rapidly at an alternating temperature of 25/30^{0}C.It was reported that alternating temperature regimes can be more effective in stimulating germination than one constant temperature and

seeds of various species require alternating temperatures to optimize theirgermination (Baskin and Baskin, 1998). Fluctuating temperatures promote seed germination in comparison with constant temperatures (Huarte andBenech, 2005).

Fluctuating temperatures, chilling pre-treatment and light were all found to be required for germination of *S. nigrum* seeds (Bithell *et al*., 2002).Many seeds only germinate if they experience daily temperature shifts. This would normally occur on or near the soil surface, as the soil warms up during the day and cools at night. When the seeds of African eggplant were subjected to various alternating temperatures in both light and darkness to mimic the real environmental conditions, higher germination percentages was recorded at all alternating temperatures as compared to constant temperatures. Environmental conditions, particularly alternating temperature, regulates seed germination and dormancy by affecting the plant hormone balance of GA_3 and ABA biosynthesis and catabolism, which will determine the dominant hormone (Ali-Rachedi *et al*., 2004; Cadman *et al*., 2006). There are at least two possible ways by which environmental changes affect seed germination via GA_3: (1) the environmental signal regulates the level of endogenous GA_3, and (2) it affects the ability of cells to respond to the hormone.

Temperature in the field affect seed germination in two ways: (1) Breaking dormancy by fluctuating temperature (Benech*et al*., 1990), and (2) determining the germination rate of seeds after dormancy has been released (Garcia *et al*., 1982).

Temperature affects germination not only directly by fulfilling the specific germination requirements of different species, but also indirectly by changing the level of seed dormancy (Bouwmeester and Karssen, 1992).

5.1.3:Influence of light regime on seed germination of African eggplant seeds.

Light is one of the environmental factors affecting seed germination, other factors being water and temperature. These factors do not work in isolation, thus, there is interaction among these factors to influence seed germination of a given crop.

Combination of factors can restrict germination to the most favorable and often more predictable and one factor alone is not sufficient to produce germination.

For African eggplant,results indicated that, the mean germination percentages of the seeds harvested at different physiological maturity stages and exposed to continuous light for 24 hours were higher compared to those in darkness in both varieties. Thissuggest that, these varieties of African eggplant has a light requirement for germination. Effect of light indicates the evidence of phytochrome mediated germination and dormancy of eggplant seeds. Light activates phytochromes that stimulate production of endogenous gibberellins to promote germination. Hilhorst (1990) suggested that, the induction and breaking of secondary dormancy was phytochrome controlled in light requiring seeds. In light requiring species such as*Sisymbrium officinal e*and *Arabidopsis,* light plays an important role in the biosynthesis of GA_3 and also increases the sensitivity of seeds to GA_3 (Hilhorst *et al*., 1986; Hilhorst and Karssen, 1988; Baskin and Baskin, 1998; Yamaguchi and Kamiya, 2002). Phytocrome stimulates or inhibits germination according to the level of red or far-red in the light.

Light interacted with both varieties, chemicals and harvesting stages to influence germination percentages (Table 4.) Light also interact with temperature and water to

regulate germination. Response to light of African eggplant seeds may be attributed by its small size. Smaller seed size has been shown to be light sensitive during germination (Grime *et al*., 1981, Pons, 1991and Milberg *et al*., 2000).

Light requirement is especially common in small seeded species where an ability to sense the quality of light is important because small seeds have insufficient energy reserves to emerge from depth (Plummer and Bell, 1995; Milberg *et al.*,2000; Schutz *et al.*,2002).The lower germination percentage in absence of light demonstrate its importance to germination of eggplant seeds. The lower germination under darkness, suggest that, seeds of African eggplant posses primary dormancy that requires light to be broken.

Baskin and Baskin (1998) suggested that, light requiring seeds of some species may enter dormancy during imbibitions in darkness for extended period hence skotodormancy. Some species that do not or only slightly become secondarily dormant even exhibit no or only a low light requirement for germination (Baskin *et al*.,1993). Thus it is possible that, the dark treatment triggered loss of photosensitivity hence secondary dormancy in these seeds of eggplant.A seed that loses primary dormancy may acquire secondary dormancy if the prevailing conditions such as light and/ or nitrate do not favor germination (William and Gerhard, 2006).

Generally, light with high levels of far-red light (light filtered through plant canopy) inhibits germination, while light with high levels of red light stimulates germination (Gorski, 1975; Taiz and Zeiger, 2002). While some species are affected by exposure for

long periods to induce germination (Bewley and Black, 1994; Taiz and Zeiger, 2002) other species are affected by brief exposure to induce germination. Results indicated that, light has effect on germination of African eggplant, however, light quality studies have not been reported, hence further research should be done to determine light quality for this crop. In this study, seeds of African eggplant were exposed to continuous white light (florescent tube light.)

5.2: Suitable chemical treatments for improving germination of African eggplant seeds

Gibberallic acid (GA_3) and Potassium nitrate (KNO_3) at different concentrations were involved for improvement of seed germination of African eggplant.

5.2.1: Potassium Nitrate (KNO3) improves African eggplant seeds germination

Nitrate is an important nitrogen source for plants, but also a signal ion that controls various aspects of plant development. Besides the basic requirement for water, oxygen and appropriate temperature, the seed may also be sensitive to other factors such as light and nitrate. Results indicated that, DB3 seeds exhibited higher germination at lower concentration of potassium nitrate (0.1%) and lower germination at higher concentration (0.3%) in both light and darkness.

This suggests that, seed germination of African eggplant can be regulated by exogenous application of nitrate at lower concentrations. Nur*et al*., (2005) obtained similar results for *Solanum stramonifolium* and *Solanum torvum.*Highly stimulatory KNO_3 concentrations have been reported as 0.1 M *(*Saini *et al*., 1985.)

Many nitrogen-containing compounds, including NO gas, nitrite ($NO2^-$), nitrate($NO3^-$), nitrogen dioxide, ammonia, azide, and cyanide, break dormancy and promote seed germination in many species, possibly as a means of sensing soil N availability (Bethke*et al*., 2007). Even nitrogen provided during seed development via the maternal plant leads to lower dormancy (Alboresi *et al.*, 2005).Potassium nitrate improved germination of African eggplant seeds significantly at $P \leq 0.001$ for the seeds germinated under continuous light suggesting that, nitrate in presence of light regulate seed germination of African eggplant. Potassium nitrate is linked to relieving light dormancy by increasing sensitivity to light in many species (Bewly and Black, 1994). Light has been shown to increase germination of *Chenopodium album* particularly in combination with nitrate (Bouwmeester and Karssen, 1993; Moravcova and Dostalek, 1989). A light and nitrate interaction is also observed in the seeds whose parent plants were exposed to nitrate (Saini, *et al*., 1985).Exogenous nitrate can affect the requirement for light to promote *A. thaliana* seed germination (Barak *et al*., 2002), and their initial level of dormancy is influenced by the nitrate regime fed to the mother plant (Alboresi *et al*., 2005). Therefore nitrates are required for germination and so could be said to directly affect dormancy rather than just promote germination.

5.2.2: Gibberallic Acid (GA_3) enhances seed germination of African eggplant.

The maximum germination was attained at 0.1% and further increase in GA_3 concentration lowered germination. These results suggest that, seeds were characterized by high level of dormancy, possibly caused by high level of ABA. GA_3 treatment of dormant *Arabidopsis thaliana* seeds caused transient increase in ABA concentration (Ali-Rachedi*et al*., 2004), suggesting that in dormant seeds a feedback mechanism

exists that maintains a high ABA: GA_3 ratio. Thus, the net result of dormant state is characterized by increased ABA biosynthesis and GA_3 degradation. Ali-Rachedi*et al*., (2004) and Cadman *et al*.,*(*2006) showed that, dormancy may depend on an intrinsic balance of GA_3 and ABA biosynthesis and catabolism, which will determine the dominance of either of the hormones.

When GA_3 level was increased to 0.1%, increased germination was recorded, suggesting that, dormancy release was a result of increased GA_3 and suppression of ABA.

Ali-Rachedi*et al*., (2004) and Cadman *et al*.,*(*2006) reported that, dormancy release involves a net shift to increased GA_3 biosynthesis and ABA degradation resulting in low ABA: GA_3 ratios. The transition from the dormant to the non dormant state of many seeds is characterized by decrease in ABA sensitivity and increase in GA_3 sensitivity (Chiwocha *et al*., 2005). Gibberellins are thought to act via mechanisms that include promoting growth of the embryo (Kucera *et al.*,2005), weakening endospermic cells (Groot and Karssen, 1987; Groot *et al.*,1988; Debeaujon and Koornneef, 2000) and replacing after-ripening requirements (Baskin and Baskin, 2004a).

GA_3 induced higher germination percentages under light conditions and suggest that, GA_3 reduces inhibitor or increases promoter level. According to Abdoulaye (2009), fresh seeds of African eggplants can have different physiological behaviors after harvest. In particular, embryo dormancy is a key issue in most varieties of the Kumba group.

Germination of DB3 was more improved by GA_3 indicating that, seeds of this specie exhibit physiological dormancy, as GA_3 has been observed to promote germination of other physiologically dormant seeds (Baskin and Baskin 1998, 2004a).

To improve germination, dormant varieties of African eggplant need soaking of seeds in solution of gibberellic acid (GA_3, 500 ppm, 24 h) (Abdoulaye, 2009). The higher concentration of 0.1% (1000ppm) usedin this experiment may be due to differences in dormancy levels caused by different varieties and environment in which seeds developed. Copeland and McDonald, (2001), reported that endogenous primary dormancy can also be influenced by many environmental factor during seed development and maturation.

Day length, temperature, seed position in the fruit or inflorescence, age of mother plant and plant or seed moisture status can be linked to dormancy levels in some species. A diverse range of dormancy mechanisms have evolved, in keeping with the diversity of climates and habitats in which they operate (Baskin and Baskin, 2004b). The environment in which African eggplant was grown may also have contributed to the dormancy level of the crop.

5.3: The optimum harvesting stage of African eggplant and its implication on seed germination

DB3 reached 50% flowering earlier on day 41 after transplanting as compared to 48 days for Tengeru white. Report by AVRD- RCA (2000), showed that, DB3 attained 50% flowering 41 days after transplanting while Tengeru white attained its 50%

flowering 53 days after transplanting. This suggests that, DB3 mature earlier than Tengeru white.Abdoulaye (2009) reported that, *Solanum aethiopicum* and *Solanam macrocarpon* plants generally start flowering about 70 days after sowing or 35 to 40 days after transplanting. Days to 50% flowering is important in determining the harvesting stage of African eggplant.

Pollination of flowers in a plant/plant population or the same inflorescence does not occur at the same time, therefore, seeds of the same plant/plant population mature at different time. An important aspect of seed production is the correct determination of physiological maturity and the ideal harvest time (Marcos-Filho, 2005).Apart from other factors that influence seed quality, seed maturation stage and desiccation stage are important factors which affect seed quality.

Seed development and maturation starts with fertilization. The process is controlled genetically and involves an organized sequence of changes from ovule to the point in which seed becomes independent from the mother plant. The whole process comprise of successive stages that can be viewed as preparation for successful seed germination. During seed development and maturation, synthesis and accumulation of nutrients reserves occurs, followed by reserve mobilization during germination, leading to resumption of embryo to produce seedling (Copland and McDonald, 2001.)

Both varieties showed higher germination percentages under light with or without chemical treatments when harvested between 58 DAA and 72 DAA. The highest germination was exhibited by 72 DAA suggesting that, seeds of Tengeru white and DB3 attained their physiological maturity stage 72 DAA. Agbo and Nwosu, (2008)

reported that, for seed production of *Solanum melongena*, fruits are normally harvested at full maturity, which is about 50-60 days after anthesis depending on cultivar, climate and growing conditions. Passam *et al.,* (2009) concluded that, the optimum time of harvest for seed production is 55 DAA for two eggplant varieties, Emi and Tsakoniki.

The low germination percentages between 30 and 44 DAA suggest that, at this maturity stage, seeds of this particular crop had not attained their maximum weight and hence physiological maturity. According to *Passam et al.*,(2009) seeds extracted from fruits that were harvested between 25 DAA and 35 DAA did not germinate, while seeds extracted from fruits harvested at 45 DAA showed high germination. Harada, (1997) pointed out that, the last two stages of seed development encompass the embryo maturation stage, when the embryo increases in weight and the desiccation stage, when there is marked decrease in water content.

During seed maturation there are significant changes in embryo size and weight due to accumulation of storage reserves until physiological maturity is attained. Potential seed quality is established at physiological maturity when 100% of the seeds germinate and produce normal seedlings with maximum vigor (Hilhost and Troop, 1997.)

The higher germination of seeds extracted from red fruits was possibly attributed to the physiological maturity of the seeds. Seeds extracted from yellow red stage and yellow green stage attained very low germination.

It is possible that, at these stages,seeds had not reached their physiological maturity. Similar results were obtained byAgbo and Nwosu, (2008) for *Solanum melongena*.The

low germination between 30 DAA and 44 DAA may also suggest that, the embryos may have been too immature to germinate.

DB3 recorded lower germination as compared to Tengeru white. This suggest that, DB3 has high dormancy level than Tengeru white and therefore, even though harvested at its physiological maturity stage, requires chemical treatments, especially GA_3 at 0.1% and light conditions to achieve higher germination percentages. However, seed embryo dormancy in DB3 require further research on the quality of light and genetic solutions to come up with non dormant variety.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1: Conclusions

Tengeruwhite germinated under a wide range of temperatures between 15^{o}C and 30^{o}C with optimum germination being 25^{o}C whereas DB3 had very lowgermination between 25^{o}C and 30^{o}C. Alternating temperature of 30/25^{o}C in continuous light for 24 hours induced higher germination than constant temperatures.

The effect of GA_3 on germination of DB3 was more compared to KNO3 i.e. produced higher mean germination percentages. The best GA_3 concentration for improving DB3 seeds germination was 0.1%.

Harvesting the fruits when they are red 72 days after anthesisproduces viable seeds with higher mean germination percentages for Tengeru white and DB3 respectively. Tengeru white can germinate well without any chemical treatment when harvested 72 DAA while DB3 needs treatment with GA_3

6.2: Recommendations

1. Tengeru white variety is recommended for seed production in wide environmental conditions.

2. For quality seed production, both varieties should be harvested for seeds at physiological maturity which is 72 days after anthesis.

3. For higher germination, both varieties should be sown in alternating temperatures of 30/25^{o}C under light regime. Under field conditions, this can be achieved by placing the seeds at shallow depths or near soil surface where seeds can get some partial light and warmth during the day.

4. To improve germination of DB3, it is recommended that, seeds should be moistened with 0.1% of GA_3 before sowing.

5. DB3 has higher seed dormancy compared to Tengeru white, therefore further research should be done, especially on breeding for non dormant traits and light qualities requirements to reduce the dormancy so as to improve germination.

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APPENDICES

Appendix 1. Anova tables for germination of seeds at constant temperatures

(a)15^{o}C.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	39.92	13.31	1.69	
Days	7	1350.61	192.94	24.47	<.001
Variety	1	489.52	489.52	62.08	<.001
days.variety	7	1350.61	192.94	24.47	<.001
Residual	45	354.83	7.89		
Total	63	3585.48			

(b)20^{o}C

Variate: % Germ.					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	10.67	3.56	0.63	
days	7	1628.23	232.61	41.04	<.001
variety	1	1251.39	1251.39	220.77	<.001
days.variety	7	1628.23	232.61	41.04	<.001
Residual	45	255.08	5.67		
Total	63	4773.61			

(C) 25^{o}C

Variate: % Germ					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	2.125	0.708	0.21	
days	7	4846.5	692.357	201.17	<.001
variety	1	1332.25	1332.25	387.09	<.001
days.variety	7	4883.25	697.607	202.69	<.001
Residual	45	154.875	3.442		
Total	63	11219			

(d) 30°C

Variate: % Germ					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	70.560	23.520	1.420	
days	7	291.940	41.710	2.520	0.028
variety	1	240.250	240.250	14.520	<.001
days.variety	7	211.250	30.180	1.820	0.106
Residual	45	744.440	16.540		
Total	63	1558.440			

Appendix 2. Anova table forgermination of seeds at alternating Temperatures

(a) 30/20°C.

Variate: % Germ					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	0.38	0.12	0	
days	7	2048	292.6	9.79	<.001
variety	1	1208	1208	40.4	<.001
days.variety	7	1997	285.2	9.54	<.001
Residual	45	1345	29.89		
Total	63	6598			

(b) 30/25°C

Variate: % Germ					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	3	11.38	3.79	0.15	
days	7	7358.25	1051.18	40.46	<.001
variety	1	1089	1089	41.92	<.001
days.variety	7	8620.25	1231.46	47.4	<.001
Residual	45	1169.12	25.98		
Total	63	18248			

Appendix 3. Analysis of variance fordays to 50% flowering.

Variate: no_of_plants_flowered					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
variety	1	744.19	744.19	67.27	<.001
Days to 50% flowering	5	4525.1	905.02	81.81	<.001
variety.days to 50%flowering	5	85.44	17.09	1.54	0.201
Residual	36	398.25	11.06		
Total	47	5752.98			

Appendix 4. Analysis of Variance for days to 50% fruiting.

Variate: fruited_plants					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
variety	1	840.88	840.88	83.64	<.001
Days to 50%_fruiting	6	8206.71	1367.79	136.05	<.001
variety.daysto 50% fruiting	6	302.00	50.33	5.01	<.001
Residual	42	422.25	10.05		
Total	55	9771.84			

Appendix 5. Analysis of variance for seeds harvested at different maturity stages.

Variate: %germination					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
chemical	6	2266.08	377.68	4.55	<.001
light regime	1	2035.04	2035.04	24.53	<.001
variety	1	13020.04	13020.04	156.96	<.001
Maturity stage	3	228797.5	76265.83	919.41	<.001
chemical.light_regime	6	642.54	107.09	1.29	0.261
chemical.variety	6	2824.71	470.78	5.68	<.001
light regime.variety	1	504.17	504.17	6.08	0.014
chemical.maturity stage	18	4737.42	263.19	3.17	<.001
light regime.week	3	1978.46	659.49	7.95	<.001
variety.maturity stage	3	34764.12	11588.04	139.7	<.001
chemical.lightregime.variety	6	1216.42	202.74	2.44	0.026
chemical.lightregime.maturity stage	18	1410.96	78.39	0.94	0.525
chemical.variety.maturity stage	18	4222.79	234.6	2.83	<.001
light_regime.variety.maturity stage	3	1194.33	398.11	4.8	0.003
chemical.light_regime.variety.maturity stag.	18	2334.08	129.67	1.56	0.069
Residual	272	22562.67	82.95		
Total	383	324511.3			

Appendix 6. Light regime interacting with different chemicals concentrations.

Chemical	CO	GA0.1	GA0.2	GA0.3	KNO30.1	KNO30.2	KNO30.3	mean GA	mean KNO3
Darkness	23.3	23.3	27.6	25.9	20.4	14.3	21.5	25.6	18.7
Light	26.4	25.1	30.4	33.6	27.4	24.8	28.4	29.7	26.8
Mean	24.9	24.2	29.0	29.8	23.9	19.5	24.9	27.6	22.8
Light.reg*chemical	L.S.D	%CV							
	4.842	36.4							

Appendix 7.Chemical interacting with variety on germination % of African eggplant.

Chemical	CO	GA0.1	GA0.2	GA0.3	KNO30.1	KNO30.2	KNO30.3	mean GA	mean KNO3
DB3	16.8	24.9	23.9	26.8	19.3	15.6	19.8	25.2	18.2
T. white	33.0	23.5	34.1	32.8	28.5	23.4	30.1	30.1	27.3
Mean	24.9	24.2	29.0	29.8	23.9	19.5	24.9	27.6	22.8
chemical.*var.	L.S.D	%C.V							
	4.842	36.4							

Appendix 8. Light regime interacting with varieties of African eggplant germination %.

L.regime	Variety		
	DB3	T. white	Mean
Darkness	18.1	27.4	22.7
LIght	20.4	34.3	27.4
Mean	19.2	30.9	25.0
L.regime*Variety	L.S.D	%CV	
	2.588	36.400	

Appendix 9.Variety interacting with different physiological maturity stages.

VARIETY	30 DAA	44 DAA	58 DAA	72 DAA	MEAN
DB3	0.0	7.7	31.1	38.0	19.2
Tengeru white	0.1	0.0	43.0	80.3	30.9
mean	0.1	3.9	37.1	59.2	25.0
var* week	L.S.D	%C.V			
	3.660	36.400			

Appendix 10: Germination % at different maturity stages and chemical treatment.

		Days					
Harvesting stage	chemical	5	7	9	12	14	total germ%
Red	Control	0.1	0.4	1.1	0.6	0.0	2.1
	GA 0.01	1.9	3.0	1.6	3.5	0.1	10.1
	GA 0.02	1.5	8.6	7.5	3.5	0.4	21.5
	GA 0.03	8.0	18.8	6.5	2.0	0.1	35.4
	KNO3 0.1	3.5	6.6	0.6	1.9	0.4	13.0
	KNO3 0.2	0.1	2.5	3.1	2.8	1.0	9.5
	KNO3 0.3	0.4	1.9	3.3	0.5	0.3	6.3
yellow red	Control	0.0	0.0	0.0	0.2	0.0	0.2
	GA 0.01	0.3	0.3	2.0	0.5	0.0	3.0
	GA 0.02	0.0	0.5	1.5	2.8	0.0	4.8
	GA 0.03	0.3	2.3	2.0	0.8	0.0	5.3
	KNO3 0.1	0.0	0.0	0.0	0.3	0.0	0.3
	KNO3 0.2	0.0	0.0	0.3	0.3	0.0	0.5
	KNO3 0.3	0.0	0.0	0.0	0.0	0.0	0.0
yellow green	Control	0.0	0.0	0.0	0.0	0.0	0.0
	GA 0.01	0.0	0.0	0.0	0.0	0.0	0.0
	GA 0.02	0.0	0.0	0.0	0.0	0.0	0.0
	GA 0.03	0.0	0.0	0.0	0.0	0.0	0.0
	KNO3 0.1	0.0	0.0	0.0	0.3	0.0	0.3
	KNO3 0.2	0.0	0.0	0.0	0.3	0.0	0.3
	KNO3 0.3	0.0	0.0	0.0	0.3	0.0	0.3

Harv.stage	chem.	Days	Harv* chem.	Harv.*Days	Chem.* Days	Harv.*chem.* Days
S.E.D	0.2322	0.3371	0.3002	0.6046	0.5192	0.7538	1.352
%C.V	32.5						

Appendix 11:Moisture content of dried seeds.

	M1	M2	M3	**M2-M3**	M2-M1	MC%	MC%	Approx MC%
30 DAA TW R1	2.09	2.47	2.45	**0.02**	0.38	6.08	6.46	6.00
30DAA TW R2	2.08	2.44	2.42	**0.02**	0.37	6.83		
30 DAA DB3 R1	1.95	2.31	2.29	**0.02**	0.36	5.77	5.78	6.00
30 DAA DB3 R2	1.98	2.33	2.31	**0.02**	0.35	5.80		
44 DAA TW R1	2.07	2.44	2.41	**0.03**	0.36	7.14	7.81	8.00
44 DAA TW R2	2.10	2.56	2.52	**0.04**	0.46	8.48		
44 DAA DB3 R1	2.06	2.59	2.55	**0.04**	0.53	7.05	7.22	7.00
44 DAA DB3 R2	2.04	2.58	2.54	**0.04**	0.54	7.39		
58 DAA TW R1	2.12	2.63	2.59	**0.04**	0.51	7.72	7.67	8.00
58 DAA TW R2	2.08	2.65	2.61	**0.04**	0.58	7.63		
58 DAA DB3 R1	2.08	2.55	2.52	**0.03**	0.47	7.45	7.10	7.00
58 DAA DB3 R2	2.08	2.51	2.48	**0.03**	0.43	6.76		
72 DAA TW R1	2.08	2.58	2.54	**0.04**	0.50	8.27	8.48	8.00
72 DAA TW R2	2.06	2.52	2.48	**0.04**	0.46	8.70		
72 DAA DB3 R1	2.12	2.62	2.58	**0.04**	0.50	7.63	7.78	8.00
72 DAA DB3 R2	2.10	2.52	2.49	**0.03**	0.42	7.93		

Appendix 12: Seed weight for Tengeru white.

REPS	30 DAA	44 DAA	58 DAA	72 DAA
R1	0.11	0.16	0.18	0.19
R2	0.11	0.15	0.18	0.19
R3	0.11	0.16	0.19	0.18
R4	0.11	0.16	0.19	0.19
R5	0.12	0.17	0.19	0.19
R6	0.11	0.15	0.18	0.18
R7	0.11	0.15	0.19	0.19
R8	0.11	0.16	0.19	0.18
Sum	0.89	1.27	1.48	1.51
Average	0.11	0.16	0.19	0.19
No of seeds/kg	112233.45	78678.21	67430.88	66401.06
1000seeds wt(gm)	1.11	1.59	1.85	1.88

Appendix 13: Seed weight for DB3.

REPS	30 DAA	44 DAA	58 DAA	72 DAA
R1	0.13	0.23	0.23	0.20
R2	0.14	0.22	0.21	0.20
R3	0.13	0.24	0.21	0.21
R4	0.13	0.24	0.22	0.20
R5	0.12	0.23	0.22	0.21
R6	0.13	0.24	0.21	0.20
R7	0.13	0.24	0.22	0.20
R8	0.13	0.24	0.22	0.21
SUM	1.04	1.87	1.76	1.62
Average	0.13	0.23	0.22	0.20
No. of seeds/kg	95877.28	53418.80	56980.06	61728.40
1000seeds wt (gm)	1.30	2.34	2.19	2.03