EFFECT OF DIFFERENT PRIMING AGENTS ON GERMINATION, EMERGENCE AND YIELD PERFORMANCE OF BAMBARA GROUNDNUT LANDRACES

BY

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APPROVAL

This dissertataion of Priscilla Katawa Mwale has been approved as meeting the requirements for the award of the degree of Master of Science (Agronomy) by the University of Zambia.

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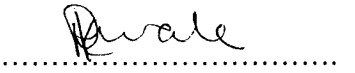
DECLARATION

I, Priscilla Katawa Mwale hereby declare that this dissertation represents my own work and that it has not previously been submitted for a degree at this or another University.



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Signature

DEDICATION

Dedicated to my children, John (Jr) and Mwisa; Celestine my granddaughter for their perseverance when I was away from home.

ABSTRACT

Bambara groundnut (*Vigna subterranean* (L.) Verde.) is an indigenous African leguminous crop, cultivated mainly by small- scale farmers in Zambia. The crop is grown predominantly for human consumption although it has potential for use in animal feeds and in many farming systems for soil amendments and rotation. However, its full potential has not been exploited in Zambia. Most varieties of the crop under cultivation in Zambia are characterized by low yields, poor agronomic characteristics and poor response to improved conditions. In addition, it exhibits slow and uneven germination both of which may lead to poor establishment and low yields. This problem has been overcome by priming in other crops.

Therefore, the objectives of this study were to determine the effects of different priming agents and priming temperature on germination rate, emergence and yield performance of different landraces of Bambara groundnuts. Three Bambara groundnut landraces, identified by colour, were used in evaluation of the response to priming. A split- split plot design was used with three landraces (Brown, Red and Cream), two priming temperatures ($10^{O}C$ and $15^{O}C$) and three priming agents (Polyethylene glycol, Potassium Nitrate and Potassium dihydrogen phosphate) and No priming (control).

The germination parameters measured were time to 50% germination, rate of germination, final germination and germination synchrony. Time to 50% germination was reduced by priming in KNO_3 and KH_2PO_4 but PEG had no effect. Germination

rate was improved in KH_2PO_4 while KNO_3 and PEG had no effect. Final germination percentage was not improved across landraces and priming agents. Priming had no effect on the germination synchrony. The above results indicate that the different priming agents could not improve the germination of Bambara groundnut landraces. The emergence parameters were similar to those for germination.

Different priming agents did not improve time to 50% emergence of Bambara groundnuts. Similarly emergence rate, final emergence percentage and emergence synchrony was not improved.

The yield attributes measured were number of stems per plant, number of branches per plant, number of nodes per plant, number of pods per plant, harvest index, 100 seed weight and grain yield. Priming across priming agents had significant effect on the 100 seed weight, harvest index and number of nodes per plant. Despite the differences in yield attributes, grain yield of Bambara groundnut was not affected by priming. This shows that Bambara groundnut is a stable crop but affected by the environment as reported in earlier studies of stability in 1992/93 season.

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CHAPTER 1

1.0 INTRODUCTION

Bambara groundnut (*Vigna Subterranea* (L.) Verdc.) is an indigenous African leguminous crop. Its common English name is derived from the Bambara, a tribe of Mali. Bambara groundnut has been cultivated in the tropical regions of Sub – Saharan Africa and in Madagascar for many centuries (Linnemann and Azam – Ali, 1992). The crop ranks third among the pulses after groundnuts (*Arachis hypogea L*) and cowpeas (*Vigna unguiculata* (L.) (Linnemann,1991).

In Zambia, the crop is cultivated by small scale farmers especially those in Eastern and Western parts of the country (Begemann,1988). It is either planted as a sole crop on flat land and / or on ridges. It may also be grown as an intercrop with pearl millet (*Pennicetum typhoides L.*), sorghum (*Sorghum bicolor L*), maize (*Zea mays L.*) or even vegetables such as okra (*Hibiscus esculentus L.*) or/ and pumpkins (*Cucurbita moschata L.)* (Doku, 1967; Doku and Karikari, 1971a; Ezueh, 1977; Haque,1980; Linnemann, 1990). Bambara groundnuts are predominantly grown for human consumption, although it has a potential for use as animal feed. The seeds of Bambara groundnuts are often described as complete food, as they contain protein (22.2%), carbohydrates (63.56%), fat (6.6%), cellulose (4.4%), phosphorus (0.28%), and Iron (0.0049%) in sufficient proportions to provide a nutritious food (Ferrao et al. 1987). Immature seeds are cooked as an early source of food during the rainy season, while

the mature seeds when dried are cooked or pounded into flour which can be used when needed (Linnemann , 1991).

The crop has also been found to fix atmospheric nitrogen for the subsequent crop in the rotation and thus improve soil fertility (Brooks, et al., 1988; Dadson , et al., 1988; Mukurumbira, 1995). This makes the crop an important consideration in any farming system for sustainable agricultural development. The crop has also been found to be fairly resistant to pests and diseases. In many dry, hostile environments, Bambara groundnut is able to produce some yield, where groundnuts and other non - drought tolerant legumes may fail completely (Nyamudeza, 1989; Lewitt, 1990).

The above mentioned benefits, notwithstanding the potential of the crop has not been exploited in Africa especially south of the Sahara. Most of the work on Bambara groundnut has been done in West Africa. The limited research, indicates that Bambara groundnut is a promising crop which has largely been neglected by national and international agricultural researchers. Previous research on the physiology and agronomy of Bambara groundnut has been carried out on a short – term, trial and error basis, mainly owing to the limited funds available for research on underutilized crop species (Linnemann and Azam – Ali, 1992). The problem of funds is more critical in resource - poor countries like Zambia.

Most genotypes of the crop under cultivation in Zambia are characterized by low yields, poor agronomic characteristics and poor response to improved conditions (Begemann, 1988). The crop does not yield more than 500 kg /ha (Mbewe and Mwala ,1995). In addition, it exhibits slow and uneven germination (Zulu , 1989;

Zengeni and Mupamba , 1995), both of which may lead to poor establishment and low yields. Sowing seed that does not have the capacity to produce an abundant crop of the required cultivar is the greatest hazard in crop production (Mupamba, pers. communication ,1995).[1]

Despite the recognition of the problem of germination in Bambara groundnuts, little effort has been made to investigate the causes of poor germinability in the crop. Most work has been done on storage and viability of the crop in relation to germination and emergence. In certain landraces, the presence of seed dormancy has been a cause of conflicting results.

Nkumba (1992), tried to break the seed dormancy to achieve uniform emergence by soaking the seeds in water overnight before planting. Zengeni and Mupamba (1995) observed improved germination of 83.13% on paper and 77.17% in sand by keeping the medium at field capacity moisture content. But the germination and emergence in the field was as low as 45%. This was attributed to low temperature and longer period required to assess germination despite daily irrigation to field capacity.

In other crops such as vegetables, maize, sunflower and pastures, germination and seedling emergence have been improved by priming of the seeds, where priming refers to the exposure of quiescent seeds to a solution or matricum of low water potential that permits seed hydration without seed germination (Bradford , 1986). This seed treatment can improve seed germination and seedling emergence particularly under adverse seed bed conditions such as low temperature (Pill and Finch – Savage,

[1] Mupamba, J. (Ms), National Tested Seeds, Bentley House, Harare, Zimbabwe

1988); reduced water availability (Frett and Pill , 1989); or salinity (Wiebe and Muhyadin, 1987).

Therefore, the objective of this study is to determine the effect of different priming agents and priming temperature on the germination rate, emergence and yield performance of different landraces of Bambara groundnuts.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Growth and development of Bambara groundnut.

Bambara groundnut is an indeterminate herbaceous annual plant with submerged stems formed by downward compression of a more branched plant. It shows wide variation in growth habit but may be classified into two broad groups: open or spreading types with long trailing stems, and compact or bunched types with short trailing trailing stems (Doku and Karikari, 1971).

Bambara groundnuts show hypogeal type of germination which after exposure of the first internodes, the development of the main axis appears to cease. A whorl of leaves is produced from the second node shoots grow out from axials (Azam- Ali, 1988). The hypogeal germination of the cultivated forms usually takes 7 to 15 days.

Flowering starts 28 to 55 days after sowing and may continue until senescence sets in (Doku and Karikari, 1970; Linnemann and Azam- Ali, 1992). Bambara groundnut can develop pods on or beneath the soil surface. Reproductive development is not completely inhibited by light, unlike groundnuts where pegs have to penetrate the soil surface before further development takes place (Nishitani. and Inuouge, 1981). The pod develops first, reaching mature stage in 30 days after fertilization, while the seed develops in the subsequent 10 days. Fruit development has been reported to be affected by photoperiod but long photoperiods delay or even prevent fruit set in some cultivars (Linnemann and Azam- Ali, 1993). Flowering is considered day neutral, but continuous light was shown to delay flowering by 6 to 11 days in some genotypes

(Nishitani et al., 1988). Maturity period ranges from 90 days for early maturing varieties to 150 days for late maturing types (Linnemann and Azm- Ali, 1992).

2.2 Bambara groundnut yield and yield parameters

2.2.1. Bambara groundnut yield.

Variability in Bambara groundnut yield has been reported by many researchers, a range of 270 to 2054 kg/ha was realised in variety trials. Yields as low as 56kg/ha have been reported in Zambia (Begemann, 1988; Pristly and Greening, 1956). In a variety trial in Swaziland, involving six different coloured seedlots (brown speckled, cream speckled, red speckled, black, red and cream) sown for 3 successive seasons, showed no significant yield differences between colour types. Average unshelled weight was 643 kg/ha (Swaziland Government Annual Report, 1979). Average yields at peasant level with no inputs, ranges from 300 to 800 kg/ha (Duke et al., 1977; Begemann, 1988). But with sound cultural practices such as optimum plant density, soil fertilization, yields could probably be higher in accessions carefully selected for specific environments.

Some cultural practices normally used in the traditional farming sector depress the yields of Bambara groundnut. In Malawi, it was found that earthing up especially during the time of flowering, significantly depresses the yield of Bambara groundnuts (Annual Report of the Agricultural Research Council of Malawi,1973). This is because earthing up causes fungal damage to the fruiting points. In humid environments, Bambara groundnuts should be harvested at 108 to 115 days after planting. However, waiting until 143 days after planting will probably result in maximum yields if pod rotting can be prevented (Goli and Ng, 1987).

Karikari (1972) observed that the yield of Bambara groundnut is positively correlated to morphological characteristics of the plant. He reported a high range of yield variation of 808 to 1100 kg/ha from the bunch cultivars than from semi- bunch types whose yield range was 714 to 767 kg/ha. The relationship of yield to yield components has been reported by some researchers. For example, Mbewe and Lungu, (1990) worked with 26 accessions and observed that the yield was positively correlated with number of branches per plant, number of pods per plant, number of nodes per plant, harvest index and 100- seed weight. Nkumba (1993) in his breeding work also reported the highest estimate of heritability (h^2 =0.22-0.25) was for 100-seed weight which signified the relationship the parameter had with seed yield.

2.2.2 100 seed weight and number of pods.

Most pods contain only one seed but a few genotypes have two, three or even four seeded pods. The length of the pod is generally proportional to the number of seeds per pod. However, the number of pods per plant tends to decrease as the number of seeds increase (Goli et al., 1991). In a preliminary evaluation and utilization trial of fourteen cultivars of Bambara groundnut, Karikari and Lavoe (1977) reported that yield was very highly correlated with 100 seed weight, number of seeds per pod and number of pods per plant. The coefficients in all 14 cultivars being greater than r=0.8. These results confirm the earlier correlation studies of 27 local varieties of Bambara groundnut. Karikari (1972) observed that yield was significantly and positively correlated with number of pods per plant, number of seeds per pod and 100 seed weight. The high correlation coefficient (r=0.8) means that these parameters can be used as indicators of the grain yield. Begemann (1988) working with a number of landraces of Bambara groundnut over rainy and dry seasons also reported that 100

seed weight was an indicator for higher yields. Goli et al. (1991) reported strong yield correlation with the number of leaves per plant and 100 seed weight.

2.2.3 Number of nodes and number of branches

Flowers of Bambara groundnut are borne on the auxiliary racemes arising from the above ground stem nodes (Tindall,1988). Two or three flowers normally arise from each node (Doku and Karikari 1969). Therefore, it is evident that the number of flowers initiated is dependent upon the number of the nodes. Similar results were reported by Karikari and Lavoe (1977) who showed that yield was positively correlated (r=0.52) with the number of nodes. The same researchers also reported that the number of branches per plant was positively correlated (r=0.8) to grain yield.

Doku and Karikari (1969) reported that Bambara groundnut is capable of producing up to 20 branches comprising of 12 internodes each. The flower buds and leaves are borne alternately at each node. The more the branches the more the nodes where flowers are initiated and thus more pod yield (Tindall,1988).

2.3 Environmental factors affecting germination and emergence

2.3.1 Temperature.

Germination and emergence phases of seedling development are very critical for the achievement of a successful agricultural crop. They indirectly determine the density of the crop stand and consequently its yield (Hadas et al., 1974).

Temperature is the main environmental factor governing the germination of seeds in a moist soil. Heydecker (1977) reported that the prevailing soil temperature determines

both the fraction of seeds in a sample which germinate and the rate at which they germinate. Ong and Monteith (1986) have demonstrated that for tropical species, germination and growth will occur in a temperature range from about 10°C to 45°C. These are temperature limits at which metabolic processes responsible for organized growth function. Experiments with Bambara groundnuts have shown that the rate of germination in response to temperature regimes between 10°C to 50°C is delayed as compared to groundnuts. Groundnuts gave consistently and significantly higher final germination fractions at each temperature regime than Bambara groundnuts (Zulu, 1989). The low response of the rate of germination in Bambara to temperature is due to the interaction between temperature and moisture. Bambara groundnut exhibited high germination percentage at water potential of zero and this declined as the water potential was reduced.

2.3.2 Moisture.

When a crop is sown, the time which elapses before germination and emergence of the seedling is strongly dependent on temperature as well as moisture in the seedbed. Under field conditions, emergence of Bambara groundnut could be as low as 45% of the seeds planted, and to assess emergence, a longer period of more than 14 days is required (Zengeni and Mupamba, 1995). The poor emergence of Bambara groundnut in the field is attributed to the planting of the crop on marginal lands with less rainfall and very high soil temperature. According to observations by Man et al. (1969), water shortage has been identified as one of the most important causes of the failure of seed germination and plant growth in arid and semi-arid zones that have little or no irrigation facilities. As stated by Rao and Gupta (1976) seeds require an optimum

range of moisture below or above which they will either not germinate or if germination takes place, it will be poor or slow.

A limited supply of soil moisture is probably the most common stress encountered by seeds in the field. An excess of soil water also incorporates a stress due to the restriction of oxygen supply to the germinating seedling (Heslehurst, 1990).

Elia and Mwandemele (1986) observed that decreased water availability reduced the number of flowers per plant, the percentage of fertile pollen, plant dry weight, plant height and number of branches per plant. This shows that although Bambara groundnuts grow well in areas of marginal rainfall, yields can be higher if there is sufficient water to improve seed setting. Kutch and Schuh (1983) also reported that Bambara groundnuts require at least 75 days of sufficient water supply in to give maximum yields. Although, the yield and yield attributes of Bambara groundnuts are reduced by severe water stress, Brough and Azam- Ali (1992) observed that the grain proximate composition is not affected by water stress as is the case with other legume crops.

2.4 Priming effects on germination.

Priming is the exposure of quiescent seeds to a solution or matricum of low water potential that permits seed hydration without seed germination (Bradford, 1986). This seed treatment can improve seed germination and seedling emergence particularly under adverse seed- bed conditions such as low temperature (Pill and Finch- Savage, 1988); reduced water availability (Frett and Pill, 1989); or salinity (Wiebe and Muhyadin, 1987).

Priming has been widely used to improve germination and emergence of crops such as vegetables, maize, sunflower and pastures. Little work has been attempted on the brassica crop because of the wide range of temperature over which brassica seed germinate limiting opportunity for priming to improve the performance (Heydecker, W. and Coolbear, 1977).

Poor emergence has also been observed to commonly occur in sh-2 (Shrunken-2) endosperm maize hybrids. Sung and Chang (1992), reported that priming maize seed improved emergence from 39% at 10° C to 92% at 25° C. It also reduced Mean Emergence Time (MET) to 3.5 days and Emergence coefficient (EC) to 25% per day. In the maize which was not primed, MET increased by 15 days and EC was 1.8% indicating poor uniformity of cool temperature emergence. Many studies (Khan et al., 1978; Dell'Aquila and Taranto, 1986; Fu et al., 1988; Dell' Aquila and Bewley, 1989; Smith and Cobb, 1991) have related the enhanced germinability to the repair of the membranes and build-up of germination metabolites. Lowering temperature from 25° C to 10° C, induced concomitant decline of amylase activity. Alpha –amylase is a key enzyme in starch degradation and its activity relates to seed vigour in barley (*Hordeum vulgare* L.) and therefore, enhanced emergence (Ching et al., 1977). The priming effect also results from reduction in the time lag phase of imbibition, if the seeds are not re-dried after priming (Brocklehurst and Dearman, 1983).

Studies with sunflower (*Helianthus annuus* L.) have shown that priming improves the rate and uniformity of seed germination and seedling emergence. It reduces reciprocal time to 50% germination by 2.4 hours. The germination synchrony was improved

significantly by reducing the time between 10% and 90% germination by 62.4 hours (Hamsimbi, 1998; Unpublished data).

Klein and Hebbe (1994) reported that priming of tomato seeds (*Lycopersicon esculentus* Mill., cv Ben Shefer) at high temperature improved germination to more than 85% and seedling from seeds sown immediately after treatment were significantly taller than controls. But in the seeds that were stored for 3 months after priming the height advantage was no longer evident when compared to the control. Annon (1979) reported that the germination of leek seed (*Allium porrum* L.) was notoriously slow and erratic leading to poor and variable stands. Priming in PEG solution significantly improved the rate and uniformity of seed germination and emergence. Frett et al. (1991) reported increased germination from 85% in untreated seeds to 90% in treated seeds of asparagus. It also reduced time to 50% germination from 7.5days in untreated seeds to 3.0 days in treated seeds.

Yaklich and Orzolek (1977) reported early germination of primed seeds in PEG than in untreated seeds of pepper (*Capsicum annuum* L.). They observed reduced germination time and more uniform germination in primed seeds as compared to unprimed seeds. The final germination percentage was 85% in treated seeds as compared to 81% controls. But these results were not significantly different. In greenhouse observations, the treated seeds emerged faster than the controls. This advantage was not demonstrated in the field conditions.

Pill and Korengel (1997) reported that the germination of common kentucky bluegrass (*Poa pratensis* L.) was faster generally, by 5.1 days than the untreated seeds when the

treated seeds were not re-dried before planting. In the glasshouse, the emergence of the treated seeds (5.5days) was enhanced as compared to untreated seeds (6.5days). The plants had higher dry weights (17mg/20shoots) than the untreated plants (13mg/20shoots) associated with earlier germination and emergence.

Frett and Pill (1995) worked on four Fescue species: SR5100 Chewing fescue (*Festuca rubra* L. spp Commutata Gaud); SR3100 hard fescue (*Festuca longifolia* (Thuill.); Pennlawn creeping fescue (*Festuca rubra* L. spp rubra); and SR8300 tall fescue (*Festuca arudinacea* Schreb.). They found out that priming increased germination from 88% in unprimed seeds to 91% in treated seeds of all species. It also increased germination synchrony at 35°C and increased germination percentage from 68% in untreated seeds to 82% in treated seeds under stressful conditions of high temperature and reduced water availability. More rapid seedling emergence from the primed seeds (4.3 days) compared to non-primed seeds (5.7days) led to greater seedling shoot dry weights (132mg/25shoots) in treated seeds compared to 126 mg/25shoots in untreated seeds.

However, priming might produce positive or negative effects on the seeds because of the characteristics of the agent used and varying varietal and even between seed-lots of the same cultivar response to a given priming treatment (Brocklehurst and Dearman, 1983a; Brocklehurst, et al., 1984).

2.4.1. Effects of different priming agents on germination and emergence of seeds

The optimal priming treatment for a seed-lot is determined by trial and error (Bradford, 1986). Response to a given priming treatment can vary between seeds due

to the nature of priming agent (Frett and Pill 1989); the duration of seed exposure to the priming agent (Evans et al., 1989) and the temperature of the water potential of the priming (Frett and Pill, 1989; Haigh and Barlow, 1987). The commonly used priming agent is Polyethylene glycol (PEG) of 8000 molecular weight. Molecules of this size are colloidal hence the reduction in water potential is derived matrically. PEG is inert and nonphytotoxic but sufficiently viscous to hinder aeration (Mexal et al., 1975). The inorganic salts commonly used are KH_2PO_4, K_3PO_4, KNO_3, NaCl, $NaNO_3$, KCl and NH_4NO_3 (Haigh and Barlow, 1987). Dissociated ions from such salts do penetrate seed tissue, whereas PEG molecules do not. Variable uptake of different ions from priming salts does not only influence the amount of water absorbed by the seeds along the osmotic gradient but also exert disruptive specific ion effect on enzymes and membranes (Haigh and Barlow, 1987).

The priming of legume seeds has received little attention compared to other agricultural crops such as horticultural crops. Hence, literature cited in this text is related to findings of the horticultural crops.

In a comparison of 12 priming agents experiment for tomato (*Lycopersicon esculentus* mill.) and asparagus *(Asparagus officinalis* L.), Frett et al., (1991) reported that priming treatments had no effect on the Final Germination percentage (FGP) of tomato seeds, with all treatments averaging 92% germination. But it increased asparagus FGP from 85% in untreated seeds to 90% in primed seeds. The non response to priming on FGP in tomato seed has been reported before (Alvarado and Bradford, 1988; Haigh and Barlow, 1987). In contrast to the reported results, Evans and Pill (1989) found no effect of priming on FGP of aspragus. The priming treatment

decreased the time to 50% germination (G_{50}) of tomato and asparagus seeds. Salt solutions including sea water gave lower G_{50} values for tomato seeds than PEG while the G_{50} values for asparagus seeds ere similar for all priming treatments. Haigh and Barlow (1987) found that inorganic salts were superior to PEG for improving germination of tomato and carrot (*Daucus carota* L.) seeds. But the same researchers found the opposite results in case of onion (*Allium cepa* L.) and sorghum (*Sorghum bicolor* L.) seeds in which PEG performed much better than the salts. Alvarado and Bradford (1988) observed that there was more rapid germination following KNO_3 priming than PEG due to high seed moisture content and presumably a more advanced stage of development. Of all the salts, the effect of NO_3 salt in reducing the G_{50} of tomato and asparagus seeds and in reducing the germination synchrony G_{10}-G_{90} of tomato seeds was more significant (Frett et al., 1991). Haigh and Barlow (1987) found that tomato seeds primed in solutions that contained KNO_3 germinated more rapidly and synchronously than those primed in solutions without KNO_3. They assumed that the NO_3^- salt may be absorbed preferentially to lower the internal osmotic potential and thereby encourage water influx into the seed. Nutritional effects of nitrate uptake during priming in providing additional substrate for amino acid and protein synthesis are also possible.

In another comparison experiment of different chemicals for treatment of vegetable seeds involving 3 priming agents, Broklehurst and Dearman (1984) reported that all treatments reduced mean emergence time for leek (*Allium porrum* L.) while potassium dihydrogen phosphate (KH_2PO_4) lowered the emergence percentage. In celery (*Apium graviolens* L.) PEG and KH_2PO_4 improved germination and emergence while glycerol was less effective. In carrots (*Daucus carota* L.) the result was similar

as in celery. In onion (*Allium cepa* L.) all the treatments reduced mean time for germination and emergence.

Durrant et al. (1983) observed that the germination of beet (*Beta vulgaris* L.) was enhanced when primed in sodium chloride (NaCl) at osmotic potential –0.5 MPa for 6 days at 15^{O}C than priming in magnesium sulphate ($MgSO_4$) and a combination of KNO_3 and K_3PO_4. It also improved emergence at low soil moisture and increased seedling dry weight at low temperature. Khan et al. (1983) working with the same crop (beet) using PEG and $MgSO_4$, observed that these priming agents improved germination, field and greenhouse emergence and finally yield of beet.

Jett et al. (1996) compared osmotic priming in PEG and matric priming in calcium silicate to determine the most effective treatment for improving broccoli (*Brassica oleracea* L. var italica) seed germination. They observed that both treatments increased germination rate in the laboratory, greenhouse and field conditions. However, matric priming had a greater effect on germination and root rates from 15°C to 30°C. Both treatments decreased the mean thermal time for germination by >35%. The greater germination performance in calcium silicate was attributed to increased oxygen availability during priming, increased seed calcium content and improved membrane integrity.

Mauromicale and Cavallaro (1995) observed that priming tomato (*Lycopersicon esculentum* Mill. Cvs rio fuego and sunny) in PEG and $KNO_3 + K_3PO_4$ salts resulted in significantly reduced mean time of germination by 4 days as compared to that of the control which was 9.5 days except for PEG. The salts improved the final

germination percentage in both cultivars by 40% while PEG only improved the final germination percentage in rio fuego by 13% as compared to the controls.

Smith and Cobb (1991) compared emergence of pepper (Capsicum annuum L.) primed in different salts with molarity ranging from 10 –300 mM, distilled water and unprimed seeds. They observed that the emergence of seeds was enhanced in salts in the 10 – 100 mM salt range and inhibited in the 200 – 300 range by <5.0%. Seeds soaked in distilled water and then dried, germinated faster than controls but not as fast as seeds primed in salt solutions.

Alvarado et al. (1987) observed that priming of tomato (*Lycopersicon esculentum* miill.) in KNO_3 or PEG resulted in rapid germination than untreated seeds at $20^{O}C$ and $30^{O}C$ germination temperature. At $10^{O}C$ PEG was of little benefit while KNO3 reduced time to 50% germination by 60% compared to 80% for the control. Priming did not affect the final germination percentage. In the field experiment, primed seed emerged earlier and more uniformly than seedlings from non-primed seeds. Treated seedlings maintained greater mean plant dry weights, leaf area and ground cover percentage than non-primed seedlings throughout pre-flowering period. This advantage was due entirely to early emergence rather than increased growth rate. The early growth advantage from seed priming did not improve earliness of maturity, total yield, or soluble solid content of fruits.

Cantliffe et al. (1981) reported that priming seeds of lettuce (*Lactuca sativa* L.) in K_3PO_4 or PEG is more effective for increasing germination rate over non primed seeds at 30% than priming seeds in water. In the field experiment, about 70 – 80% of

primed lettuce seeds emerged more rapidly and uniformly than non- primed seeds which exhibited only 50% emergence. At harvest, plants from primed treatment, were at a more advanced and more uniform stage of maturity than plants from non primed seeds.

Haigh et al. (1986) reported that priming tomato (*Lycopersicon esculentum* Mill.), carrot (*Daucus carota* L.) and onion (*Allium cepa* L) in mixture of salts; K_3PO_4 + KNO_3 resulted in no effect on the emergence of tomato, increased emergence in carrot and decreased emergence in onions. Despite these species differences, all priming treatments reduced time spread and increased rate of emergence. While priming in a mixture of K_2HPO_4 + KNO_3 resulted in a slight increase in the final emergence percentage of tomato in the field. It also reduced the time spread of field emergence of primed seeds than for non -primed seeds. The mean time spread of primed seeds was 36% shorter than that of non- primed seeds. In carrots, there was no difference in the final emergence percentage between primed seeds and non -primed seeds. On the other hand in onions, the final emergence percentage of the primed seeds was reduced by half to that of the non -primed seeds. The final emergence percentage was 32% in primed seeds as compared to 60% non- primed seeds. The rate of emergence of the primed seeds was faster than that of the non -primed seeds.

Frett and Pill (1995) reported that priming fescue pasture grass (*Festuca* spp) in solid matrix vermiculite No 5 resulted in superior post priming seed germination than priming in PEG or sodium nitrate ($NaNO_3$) at higher water potentials, lower temperatures or for longer duration. At high water potentials, higher than –1.5 Mpa,

resulted in about 10% of primed seeds in PEG and $NaNO_3$ germinated during the period of priming at $20^{O}C$.

2.4.2 Priming and yield

Rabin and Berkowitz (1988) evaluated priming effects on stand establishment and yield for parsley (*Petroselinum crispum* mill.) seed sown on 3 dates in the field. Stand establishment occurred under progressively higher temperature for early, middle and late plantings. Priming enhanced early seeded stands by 78% at one site and 76% at a second site in comparison with untreated seed. This priming effect on seedling establishment for the earliest planting led to a 67% increase in early yield (96 days from seeding) and 28% yield increase over the untreated seed at a later harvest. Stands of primed seed sown at later dates were enhanced to a lesser extent and yields were not affected by osmotic priming. These results of yield increase agree with earlier findings by Ely and Heydecker (1981) and Pill (1986).

Khan and Taylor (1986) reported an improved emergence rate and final stand of beet seed pellets amended with 1.10 to 3.95 mg PEG per seed ball in the field. The number of seedlings per ball 17 days after planting ranged from 1.39 to 1.60 for PEG amended pellets compared to 0.71 plants for non -PEG pellets or dry seeds. The PEG amended seed pellets yielded 16 to 18 marketable roots per meter of row compared to 11 roots from non -PEG pellets. In tomato Alvarado et al., (1987) reported no yield increase after priming in PEG and KNO_3 as compared to the non- primed seeds.

2.4.3. Commercial application of priming

Commercially primed seeds have a place in the vegetable industry as they can be dried back and stored prior to planting them with conventional planting equipment. In the Salinas Valley of California, the use of primed lettuce seed is a large commercial enterprise which has overcome the problems of high temperature dormancy in lettuce. In Australia, the tomato industry is using commercially primed seeds to establish seedlings earlier in the spring and to achieve a more concentrated yield at harvest (Cantliffe et al., 1987). The commercial application for seed priming in the Australian vegetable seed industry is on farmer demand basis where the more innovative producers are looking for a leading edge in their production operation. Such growers require industry to supply high quality seed, primed with nutrient and / or growth regulators guaranteeing 98 –99% germination for sowing in their nursery or direct seeded field situation. Priority crops are tomato (*Lycopersicon esculentum* Mill.), pepper (*capsicum annuum* L.), carrot (*Daucus. carota* L.) and celery (*Apium graveolens* L.).

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Experimental site.

The evaluation of the response of Bambara groundnuts to priming was carried out in 1999, in two experiments at the University of Zambia, School of Agricultural Sciences.

Experiment 1 involved assessment of effects of priming agents on germination of seeds under laboratory conditions and Experiment 2 was to determine the priming effects on emergence and yield performance of Bambara landraces under glasshouse conditions.

3.2 Seed source

Three Bambara groundnut landraces, identified by seed colour, were used in the study. Two of the landraces (cream and red) were collected in Chongwe district and the other (brown) from Kalomo district. All these seeds were from the 1998/99 growing season.

3.3 Seed treatment .

Prior to priming all the seeds were weighed and then soaked in 1% sodium hypochloride (NaOCL) solution for one minute to sterilize them against fungal seed borne diseases on the seed coat. Then the seeds were washed in distilled water and air dried in the laboratory. After drying, they were divided into two equal sets. One set was primed while the other was kept to be used as a control in the experiments.

Three (3) priming agents [Polyethylene Glycol (PEG), Potassium nitrate (KNO_3), and Potassium dihydrogen phosphate (KH_2PO_4] were used. A total of 1200 seeds from each landrace of ungraded seed size were primed in each of the priming agents. Priming was at a water potential of –1.5 MPa under two different temperatures, 10° C and 15° C for 3 days. The solutions were prepared according to Michel and Kaufmann (1973). The seeds were soaked in 20 mls of the solutions on filter paper in petri dishes. Care was taken not to inudate the seeds with the solution to allow for respiration. The solutions were topped up as required during the priming. After priming, the seeds were washed in distilled water to remove the solutions on the seeds, then the washed seeds were dried back to their original weight over a period of 7 days in the laboratory. Each set of seeds from a treatment was then divided into two equal amounts; one half was used for the germination experiment in the laboratory; while the other half was used in the experiment on emergence and performance.

3.4 EXPERIMENT 1

3.4.1 Laboratory experiment

The purpose of the laboratory experiment was to evaluate the germination response of the 3 Bambara groundnut landraces to different priming agents. In this experiment there were 3 factors involved were:

- three landraces - Brown = A1, Red = A2 , Cream = A3. (3)
- two priming temperatures - 10°C = B1, 15°C = B2. (2)
- three priming agents and the control – KNO_3= C1, KH_2PO_4 = C2, PEG = C3, un primed seeds (control) = C4. (4)

The experiment had a total of 24 treatments as shown below.

Treatments, as combinations of factor levels, used in Experiment I and Experiment II.

A1B1C1 = Brown primed in KNO_3 at 10°C

A1B2C1 = Brown primed in KNO_3 at 15°C

A1B1C2 = Brown primed in KH_2PO_4 at 10°C

A1B2C2 = Brown primed in KH_2PO_4 at 15°C

A1B1C3 = Brown primed in PEG at 10°C

A1B2C3 = Brown primed in PEG at 15°C

A1B1C4 = Brown unprimed at 10°C

A1B2C4 = Brown unprimed at 15°C

A2B1C1 = Red primed in KNO_3 at 10°C

A2B2C1 = Red primed in KNO_3 at 15°C

A2B1C2 = Red primed in KH_2PO_4 at 10°C

A2B2C2 = Red primed in KH_2PO_4 at 15°C

A2B1C3 = Red primed in PEG at 10°C

A2B2C3 = Red primed in PEG at 15°C

A2B1C4 = Red unprimed at 10°C

A2B2C4 = Red unprimed at 15°C

A3B1C1 = Cream primed in KNO_3 at 10°C

A3B2C1 = Cream primed in KNO_3 at 15°C

A3B1C2 = Cream primed in KH_2PO_4 at 10°C

A3B2C2 = Cream primed in KH_2PO_4 at 15°C

A3B1C3 = Cream primed in PEG at 10°C

A3B2C3 = Cream primed in PEG at 15°C

A3B1C4 = Cream unprimed at 10°C

A3B2C4 = Cream unprimed at 15°C

3.4.2. Experimental design.

A split- split plot design with four replication was used. The experimental unit comprised of three priming agents at two priming temperatures and three landraces of bambara groundnuts. Fifty seeds were planted in a petri dish per replication.

3.4.3. Management of seeds.

Distilled water was added to each petri –dish when necessary to prevent seeds from drying out. To ensure adequate air supply to the seeds, all petri- dishes were from time to time opened.

To prevent fungal growth on the seeds, Chlorothalenil a fungicidal wettable powder was applied to the seeds at 3g/litre using a hand sprayer. Temperature readings were recorded daily as germination was done at room temperature (this was done to get the average germination temperature because room temperature fluctuates with the weather on a particular day).

3.4.4 Germination counts.

Germination counts involved the removal and counting of seeds that had germinated. In this case, the seed was considered germinated when the radicle had protruded through the testa by 10 mm, a criterion used by several workers (Covell et al., 1986; Garcia- Huidobro et al.,1982; Mwale et al., 1995; Mwale et al., 1999). The experiment was terminated when there was no further germination after three days. The remaining seeds at this stage were treated with tetrazolium 1% to verify their viability.

3.4.5. Data collection.

3.4.5.1. Cumulative germination.

The progressive germination of seeds in a treatment was presented by plotting the progress of germination percentage with time. The percent germination were angularly transformed because they were not normally distributed before being analysed.

3.4.5.2. Time to 50% percent germination (t50).

Time to 50% germination was derived from the cumulative germination curves by dropping a vertical line from the point representing 50% of the final germination of each graph to the x-axis. The t_{50} values so estimated were based on the total number of seeds that had germinated in each treatment and not the total number sown. This allowed for t_{50} to be estimated even in treatments (or replicates) where less than 50% of the seeds originally sown had germinated (Lanteri et al, 1993).

3.4.5.3 Rate of germination (Rg).

Rates of germination were calculated as reciprocals of the t_{50} values (Lanteri et al,1993).

3.4.5.4 Germination syncrony (G_{10-90})

This measures the time spread of germination. It is calculated as the time between 10% and 90% of the maximum germination of the total seeds in a replication. The values are extrapolated from the germination curves of each replicate (Lanteri et al, 1993).

3.5 EXPERIMENT 2

3.5.1.Emergence and growth development experiment in the glass house.

The experiment was done in order to assess the effect of priming agents on the emergence and performance of Bambara groundnut in the glasshouse. The experiment was planted in the glasshouse to simulate field conditions.

3.5.2 Emergence Experiment .

The other 50% of the primed seeds were planted in pots in the glass house. Fifty seeds from each treatment were divided into five lots of 10 seeds and each lot planted in a pot. Each treatment comprised of five pots to which 10 seeds were sown per replication. The pots were perforated at the bottom to allow for free drainage of water. To reduce contamination from the floor the pots were placed on small plates.

3.5.3 Experimental design

A split – split plot design with four replications was used with landraces being the main plots, priming temperature being the subplots and priming agents and control being the sub – sub plots.

3.5.4. Cultural practices

For the purpose of the experiment the loamy sand soil used was collected on virgin land in Chongwe's Kanakantapa ressettlement scheme. The soil structure was loose and friable, and this was sterilized at 100^{O}c for 24 hr. Planting was done in moist soil which was saturated the previous day and allowed to drain to field capacity. Irrigation was every two days to keep the soil moist for easy emergence of the seeds. The plants were then thinned to two plants per pot at 3 weeks and later to one plant per pot at 4

weeks. The thinning was staggered to help selection of a more health plant to grow to maturity. All necessary husbandry practices were applied for a health crop.

3.5.5. Emergence counts.

The emerging seedlings per pot were being counted on daily basis. The seeds were considered emerged when the coleoptile hook straightened to expose the first two leaves. The emerging seedlings were identified by placing a stick besides them as they emerged above the soil in order to avoid double counting of the emerged seedlings.

3.5.6. Data collection.

3.5.6.1 Cumulative emergence.

The progressive emergence of seeds in a treatment was presented by plotting the progress of emergence percentage with time. The percent emergence were angularly transformed because the percent germination were not normally distributed (Harris et al, 1987).

3.5.6.2. Time to 50% emergence t_{50}.

This is a measurable response from the cumulative germination curve. Time to 50% emergence was estimated from the cumulative emergence curves by dropping a vertical line from the point representing 50% of the final emergence of each graph to the x-axis. These values so estimated were based on total number of seeds that had emerged in each treatment and not total number sown (Harris et al, 1987).

3.5.6.3. Rate of emergence.

Rates of emergence were calculated as reciprocals of the time to 50% emergence values (Harris et al,1987).

3.5.6.4 Emergence syncrony (E_{10-90}).

It was calculated as time between 10% and 90% of the maximum emergence of the total seeds. The values were estimated from the cumulative emergence curve by dropping a vertical line from the point representing 10% and another from point representing 90% of the final emergence of each graph to the x- axis. Therefore, the time taken between the two values was the estimate of the germination spread (Harris et.al, 1987).

3.6. Grain yield and its components.

Data on yield and its component were taken after harvest (IBPGR,1987). The following parameters were measured.

- Number of branches per plant
- Number of nodes per plant
- Number of pods per plant
- Number of stems per plant
- Harvest index.
- 100 seed weight (sampled from the shelled harvested grain)
- Seed yield kg^{-1}

The data was collected from a sample of 5 plants from each replication giving rise to a total of 20 plants per treatment.

3.5.1. Statistical analysis

The final percent emergence (Ef), time to 50% emergence (E_{50}), emergence rate values, emergence syncrony values, yield and yield parameters were subjected to analysis of variance. The phenotypic correlation among yield components studied and seed yield were calculated.

Duncan Multiple Range Test was used to separate means.

CHAPTER 4 RESULTS

4.1 LABORATORY GERMINATION

4.1.1. Time to 50% germination

Priming significantly ($P \leq 0.01$) reduced the time to 50% germination in KNO_3 (6.4 days) and KH_2PO_4 (5.7 days) as compared to the control (7.1 days)(Table 3). Potassium dihydrogen phosphate reduced time to 50% germination by 1.4 days compared to the control. Similar reduction was observed in KNO_3 by 0.7 days while PEG was not different from the control.

Landraces responded differently to priming agents for time to 50% germination. The cream landrace had the least number of days taken to reach 50% germination followed by the brown landrace (6.7 days) and lastly the red landrace (7.6 days). The difference between the cream and the red landrace was significant. It took 2.1 days more to reach 50% germination in the brown landrace from the cream landrace.

Priming agent x landrace interaction was significant especially in the cream landrace. This was observed between the KH_2PO_4 and PEG. The cream landrace had the least number of days taken to reach 50% germination when primed with both KNO_3 and KH_2PO_4. The difference was more pronounced between KH_2PO_4 and PEG. It took 2.7 days more to reach 50% germination from KH_2PO_4 to PEG. While the differences was not significant for the red and brown landraces. The control values were comparable to those of PEG in all cases.

Priming temperature had no effect on the landrace response to the time to 50% germination. Similarly, there was no interaction between priming agents and priming temperature.

Table 1. Time to 50% germination for the three Bambara groundnut landraces primed in three different agents.

Landrace (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	7.5 a b	6.3 b	6.5 b	6.6 b	6.7 a b
Red	7.4 a b	7.0 a b	8.3 a	7.5 a b	7.6 a
Cream	4.4 c	3.8 c	6.5 b	7.2 a b	5.5 b
MEAN	6.4 a b	5.7 b	7.1a	7.1a	6.6

$C.V.\ (\%)_A = 17.8$ $C.V.\ (\%)_C = 11.9$

Means in the same row followed by the same letter are not significantly different according to Duncans' Multiple Range Test at $P \leq 0.01$.

4.1.2 Germination rate

Priming agents had no effect on the germination rate of the seeds. Similarly, landraces did not respond differently to priming agents. But there was an interaction between landraces and the priming agents. The germination rate in the cream landrace was higher by 0.06 seeds/day from KH_2PO_4 to PEG. There were no differences observed in the red and brown landraces. Generally, the germination rate was lower in the control across the landraces.

Table 2 Germination rate for the three Bambara groundnut landraces primed in three different agents.

Landraces (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	0.15 b c	0.17 b c	0.16 b c	0.16 b c	0.16 a
Red	0.14 c	0.15 b c	0.13 c	0.14 c	0.14 a
Cream	0.20 a b	0.22 a	0.16 b c	0.14 c	0.18 a
MEAN	0.16 a	0.18 a	0.15 a	0.15 a	0.16

$C.V.\ (\%)_A = 27.95$ $C.V.\ (\%)_C = 19.8$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

4.1.3 Final germination (Gf)

Priming agents were significantly ($P \geq 0.01$) different for final germination (Table 1). Potassium nitrate has the lowest final germination of 42% compared to the control (78.6%). Similar lower final germination was observed for KH_2PO_4 at 52.2% while PEG (74.6%) was not different from the control (78.6%) and represented the highest germination.

Table 3. Final germination of the three Bambara groundnut landraces primed in three different agents.

Landrace (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	44.7 d	63.7 b c	78.0a b	82.6 a	67.3 a
Red	61.7 c	68.3 b c	72.7 a b c	77.6 a b	70.1 a
Cream	21.4 e	24.5 e	73.1 a b c	75.7 a b c	48.7 b
MEAN	42.6 c	52.2 b	74.6 a	78.6 a	62.0

C.V. $(\%)_A$= 15.1 C.V. $(\%)_C$ =11.9

Mean in the same row followed by the same letter are not significantly different according to Duncans' Multiple Range Test at $P \leq 0.01$.

The final germination percentage was lower in the cream landrace (48.7%) followed by the brown landrace (67.3%) compared to the red landrace (70.1%) (Table2). In all cases the lowest final germination percentages were when primed in KNO_3 and the highest were when primed with PEG. The control, however, gave relatively the highest germination values. The final germination values for the brown landrace change by 43% from KNO_3 to KH_2PO_4. There was virtually no change with the red and cream landraces. The cream landrace on the other hand had a 198% change in the final germination values from KH_2PO_4 to PEG. The changes were not as large for the brown and red landraces, which had 23% and 6% respectively.

In general priming temperature had no effect on the final germination of Bambara groundnuts (Table 4). The priming agents were significantly ($P \leq 0.01$) different for final germination. Potassium nitrate had the lowest final germination percentage at both priming temperatures of 42% followed by KH2PO4 (52.2%) compared to the control (78.6%). But there were no significant differences between PEG and the control.

The priming temperature x priming agent interaction was significant for final germination (Table 4). This effect is manifested through the changes in final germination observed in KH_2PO_4 and PEG. The values for final germination changed by 46% from KH_2PO_4 to PEG at 10°C and 40% at 15°C priming temperature. Germination in the control was higher than in any of the agents but not significantly ($P \leq 0.01$) different from PEG.

Table 4. Final germination of Bambara groundnut landraces in three priming agents at two temperatures.

Temperature (B)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
10°C	42.0 c	49.9 b c	72.9 a	78.6 a	60.8a
15°C	43.1 b c	54.5 b	76.3 a	78.6 a	63.2a
MEAN	42.6c	52.2b	74.6a	78.6a	62.0

C.V. $(\%)_C = 14.0$ C.V. $(\%)_B = 11.9$

Means in the same row followed by the same letter are not significantly different according to Duncans' Multiple Range Test at $P<0.01$.

4.1.4. Germination synchrony (G_{10-90}).

Priming agents had no effect on the germination synchrony of landraces (Table5.) There were no significant ($P \leq 0.05$) differences in germination synchrony between the primed seeds and the control in all landraces. Similarly, the landrace did not respond differently to priming agents for germination synchrony.

The priming temperature x landrace interaction was not significant. Similar results were observed with the priming temperature x priming agent interaction. The interactions were not significant.

Table 5. Germination synchrony for the three Bambara groundnut landraces primed in three different agents

Landraces (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	6.8 a	5.6 a b	5.1 a b	5.7a b	5.8 a
Red	6.6 a	6.1 a b	6.5 a	6.4 a	6.4 a
Cream	5.2 a b	4.8 a b	4.3 b	6.5 a	6.4 a
MEAN	6.2 a	5.5 a	5.3 a	5.8 a	5.7

$C.V.\ (\%)_A = 29.5$ $C.V.\ (\%)_C = 16.6$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

4.2. SEEDLING EMERGENCE IN THE GLASS HOUSE

4.1.1 Time to 50% emergence

Priming agent effects were not significantly ($P \leq 0.01$) different for the time to 50% emergence. Similarly, there were no significant ($P \leq 0.01$) differences in the landrace response to priming agents for time to 50% emergence. The interaction between priming agent and priming temperature was not significant. Similarly, there was no interaction between priming temperature and the landraces.

4.1.2. Emergence rate

Priming agents had no effect on the rate of emergence of seedlings across all landraces. Therefore, priming agents effects were not significantly ($P \leq 0.01$) different for the rate of emergence of seedlings. Landraces did not respond differently to priming agents for emergence rate.

4.2.1 **Final emergence percentage.**

Priming agents had significant ($P \leq 0.01$) influence on the final emergence percentage of the Bambara groundnut landraces in the glasshouse (Table 6). The priming agents reduced final germination to 37.3%, 48.5% and 66.5% in KNO_3, KH_2PO_4 and PEG, respectively, compared to the control (77.6%).

Landraces responded differently to priming agents. The red landrace had the highest final emergence (68.7%) followed by the brown landrace (58.9%) and finally the cream landrace (44.9%). These results were significantly ($P \leq 0.01$) different from each other. The priming agent x landrace interaction was significantly ($P \leq 0.01$) different for final emergence. But the lowest final emergence was exhibited when primed using KNO_3 across landraces and the highest was when primed in PEG. Generally, the control exhibited the highest final emergence values across the landraces. The final emergence values for the cream landrace, changed by 62% from KNO_3 to KH_2PO_4 and 76% from KH_2PO_4 to PEG. A similar trend was observed in the brown landrace whose final emergence values changed by 31% from KNO_3 to KH_2PO_4 and 56% from KH_2PO_4 to PEG. The red landrace on the other hand changed least by 19% from KNO_3 to KH_2PO_4 and 6% from KH_2PO_4 to PEG.

Table 6. Final emergence for three Bambara groundnut landraces primed in three different agents in the glasshouse.

Landraces (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	36.1 e	47.3 d	74.5 a b	77.7 a b	58.9 b
Red	57.5 c	68.5b	72.8 a b	76.ab	68.7 a
Cream	18.4 f	29.78 e	52.3 c d	79.1 a	44.9 c
MEAN	37.3 d	48.5 c	66.5 b	77.6 a	57.5

$C.V.\ (\%)_A = 6.31$ $C.V.\ (\%)_C = 8.23$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

The priming agents were significantly ($P \leq 0.01$) different for the priming temperature Table 7. All priming agents exhibited lower emergence percentages across priming temperature of 37.3% in KNO_3, 48.5% in KH_2PO_4 and 66.5% in PEG as compared to the control (77.6%).

The priming temperature had no significant effect on the final emergence percentage.

The priming temperature x priming agent interaction was significant (Table 7). Priming with KNO_3 had the lowest emergence values at both temperatures, While PEG had the highest values for emergence. The change from KNO_3 to KH_2PO_4 was 34% and from KH_2PO_4 to PEG was 37% at 10°C. Similar changes were observed at 15°C priming temperature. The changes were 27% from KNO_3 to KH_2PO_4 and 36%

from KH_2PO_4 to PEG. The gap in emergence values was wider when seeds were primed at 15°C. The landrace x priming temperature interaction was not significant.

Table 7. Final emergence percentage of Bambara groundnut landraces in three priming agents at two temperatures in the glasshouse.

Temperature (B)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
10°C	35.5 d	47.6 c	65.5 b	77.6 a	56.6a
15°C	39.1 d	49.5 c	67.5 b	77.6 a	58.5a
MEAN	37.3 d	48.5 c	66.5 b	77.6 a	57.5

C.V. $(\%)_C = 10.9$ C.V. $(\%)_B = 8.2$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

4.1.3 Emergence synchrony (E_{10-90})

Priming agents were not significantly ($P<0.01$) different for emergence synchrony Table 8. Similarly, there were no differences in emergence synchrony among landraces.

The landrace x priming agent interaction was significant ($P<0.01$) for emergence synchrony. This was manifested by the changes in emergence synchrony of the brown landrace. The values changed by 90% from PEG to KH_2PO_4. But there was no significant ($P \leq 0.01$) difference in emergence synchrony due to the priming agent x landrace interaction in the other two landraces (red and cream).

Priming temperature x priming agent interaction was not significant. Similarly, priming temperature x landrace interaction was not significant.

Table 8. Emergence synchrony for Bambara groundnut landrace primed in three different agents in the glasshouse.

Landraces (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	8.0 a	7.4 a b	3.9 c d	4.1 c d	5.8 a
Red	4.3 c d	6.0 a b c	5.1 b c d	5.0 c d	5.1 a
Cream	3.5 d	4.7 c d	5.3 b c d	4.1 c d	4.4 a
MEAN	5.2 a b	6.0 a	4.8 a b	4.4 b	5.1

C.V. $(\%)_A = 29.0$ C.V. $(\%)_C = 22.5$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

4.3.0. PERFORMANCE OF SEED YIELD AND YIELD COMPONETS.

4.3.1 Number of stems per plant

Priming had an effect on the number of stems produced per plant (Table 9). KNO_3 produced significantly ($P \leq 0.05$) lower number of stems per plant (4) compared to the control (5.0). Priming seeds with KH_2PO_4 (5) and PEG (5) did not result in any significant effect on the number of stems produced by the resulting plants. Similarly, there were no differences among landraces in as far as the number of stems per plant was concerned.

Table 9. Number of stems per plant for three Bambara groundnut landraces primed in three different agents

Landraces (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	4.5 a b	5.0 a	4.6 a b	5.0 a	4.8 a
Red	4.3 b c	4.8 a b	5.1 a b	4.3 b c	4.6 a
Cream	3.6. c	4.8 a b	4.5 a b	4.8 a b	4.4 a
MEAN	4.1 b	4.8 a	4.8 a	4.7 a	4.6

$C.V.\ (\%)_A = 13.6$ $C.V.\ (\%)_C = 9.7$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.05$.

The landrace x priming agent interaction had an effect on the number of stems produced per plant. This was manifested in the changes in the number of stems between KNO_3 and KH_2PO_4 in the cream landrace. The number of stems changed by 33% from KNO_3 to KH_2PO_4. But there were no significant difference in the number of stems produced per plant between PEG, KH_2PO_4 and the control. There were also no significant differences among priming agents in the red and brown landraces.

The priming agent x priming temperature interaction was not significant. Similarly, the landrace x priming temperature interaction was not significant.

4.3.2. Number of branches per plant

The priming agents had a significant ($P \leq 0.05$) effect on the number of branches per plant (Table 10). Potassium nitrate produced plants with significantly ($P \leq 0.05$) lower number of branches (10) compared to the control (11). PEG (13) and KH_2PO_4 (12) were not different from the control (11). There were differences in the number of branches among landraces (Table 10). The brown landrace produced the highest number of branches (14), compared to the red landrace (11) and the cream landrace with 10.0 branches per plant. But there was no significant ($P \leq 0.05$) difference between the red and cream landraces on the number of branches per plant.

Table 10. Number of branches per plant of three Bambara groundnut landraces primed in three different agents in the glasshouse.

Landraces	Priming agent (C)				
(A)	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	12.9 a b	14.0 a	14.6 a	13.9 a	13.8 a
Red	8.3 d e	11.3 b c	13.1 a	9.8 c d	10.6 b
Cream	7.5 e	11.3 b c	10.8 c	10.4 c	10.4 b
MEAN	9.6 c	12.2 a b	12.8 a	11.4 b	11.5

$C.V.\ (\%)_A = 11.7$ $C.V.\ (\%)_C = 10.1$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

The priming agents x landrace interaction was significant. In the red landrace, the number of branches changed by 4% from KNO_3 to KH_2PO_4 and 17% from KH_2PO_4 to PEG. A much higher change of 51% was observed from KNO_3 to KH_2PO_4 in the cream landrace. There were no significant ($P \leq 0.05$) difference among priming agents

in the brown landrace. Generally, priming with KNO_3 produced lower number of branches per plant while priming with PEG produced plants with a higher number of branches.

Priming temperature x priming agent interaction had a significant ($P \leq 0.05$) influence on the effect of priming agents on the number of branches per plant (Table12). Priming at 10°C produced significantly ($P \leq 0.05$) lower number of branches per plant in KNO_3 (9.0) compared to KH_2PO_4 (13) and PEG (14). KH_2PO_4 (12.7) and PEG (13.8) were not significantly ($P \leq 0.05$) different from the control, although PEG had the highest number of branches. In contrast, there were no significant differences in the number of branches per plant between priming agents and the control at 15°C priming temperature.

Priming temperature x priming agent interaction had a significant ($P \leq 0.05$) influence on the effect of priming agents on the number of branches per plant (Table11). Priming at 10°C produced significantly ($P \leq 0.05$) lower number of branches per plant in KNO_3 (9.0) compared to KH_2PO_4 (13) and PEG (14). KH_2PO_4 (12.7) and PEG (13.8) were not significantly ($P \leq 0.05$) different from the control, although PEG had the highest number of branches. In contrast, there were no significant differences in the number of branches per plant between priming agents and the control at 15°C priming temperature.

Table 11. Number of branches per plant of Bambara groundnut landraces in three priming agents at two priming temperatures in the glasshouse.

Temperatures (B)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
10°C	9.0 d	12.7 a b	13.2 a	11.4 b c	11.6a
15°C	10.1 c d	11.6 b	12.5 a b	11.4 b c	11.4a
MEAN	9.6 c	12.2ab	12.8a	11.4b	11.5

C.V. $(\%)_c = 12.8$ C.V. $(\%)_B = 10.1$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

Priming temperature x landrace interaction was not significant.

4.3.3. Number of nodes per plant

Priming in different types of agents had an effect on the number of nodes produced per plant (Table 12). PEG produced significantly ($P \leq 0.01$) higher number of nodes per plant (86) compared to the control (70). KNO_3 (58) had the lowest number of nodes per plant compared to the control (70) while KH_2PO_4 produced 65 nodes per plant which was not different from the control (70).

Differences in the number of nodes per plant among landraces were observed. The brown landrace produced significantly ($P \leq 0.01$) higher number of nodes than the red and cream landraces. No significant differences were observed between the red and cream landraces with regard to the number of nodes produced per plant (Table 12).

Table 12. Number of nodes per plant for three Bambara groundnut landraces primed in three different agents.

Landraces (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	89.9 a	84.2 a	101.1 a	90.9 a	91.5 a
Red	47.2 b c	61.1 b	92.8 a	60.2 b	65.4 b
Cream	36.3 c	49.3 b c	64.2 b	59.2 b	52.3 b
MEAN	57.8 c	64.9 b c	86.1a	70.1b	69.7

$C.V.\ (\%)_A = 28.0$ $C.V.\ (\%)_C = 13.5$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

The priming agent x landrace interaction had an effect on the number of nodes produced per plant. PEG had a significantly ($P \leq 0.01$) higher number of nodes per plant in the red landrace (93) compared to KH_2PO_4 (61). The number of nodes per plant changed by 53% from KH_2PO_4 to PEG in the red landrace. There were no significant ($P \leq 0.01$) differences among priming agents in the brown and the cream landraces.

The priming agent x priming temperature interaction was significant for the number of nodes per plant (Table 13). Generally, PEG (86) produced significantly ($P \leq 0.01$) higher number of nodes per plant compared to the KNO_3 (58) and KH_2PO_4 (65). The change from KH_2PO_4 to PEG was 37% at 10°C. Similar result was observed at 15°C

but the change from KH_2PO_4 to PEG was only 28%. The control was not different from KNO_3 and KH_2PO_4 at both priming temperatures.

Table 13. Number of nodes per plant of Bambara groundnut landraces in three priming agents at two priming temperatures.

Temperature (B)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
10°C	57.4 c	65.2 c	89.3 a	70.a b c	70.5a
15°C	57.5 c	64.6 c	82.9 a b	70.9 b c	68.9a
MEAN	57.8 c	64.9 b c	86.1a	70.1b	69.7

$C.V.\ (\%)_C = 6.31$ $C.V.\ (\%)_B = 13.5$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

The priming temperature x landrace interaction was not significant.

4.3.4 Number of pods per plant

Priming agents had no effect on the number of pods per plant. There are no significant ($P \leq 0.05$) differences among priming agents as compared to the control (Table 9). On the other hand, differences in the number of pods per plant among landraces were observed. The brown landrace had the highest number of pods per plant (39) while the cream landrace produced the least number of pods per plant (27). But it was not significantly ($P \leq 0.05$) different from the red landrace with 32 pods per plant.

Table 14. Number of pods per plant for three Bambara groundnut landraces primed in three different agents in the glasshouse.

Landraces (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	41.7 a	41.4 a	36.2 a b	36.1 a b	38.8 a
Red	29.1 c	31.1. b c	36.5 a b	30.9 b c	31.9 a b
Cream	21. 6 d	26. 1 c d	32.6 b c	29.0 c	27.3 b
MEAN	30.7 a	32.8 a	35.1a	32.0 a	32.7

C.V. $(\%)_A = 22.5$ C.V. $(\%)_C = 13.4$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

The priming agent x landrace interaction was not significant for the number of pods per plant. Similarly, the priming temperature x priming agent interaction was not significant.

The priming temperature had an influence on the number of pods produced by a landrace (Table 15). There were significant ($P \leq 0.01$) differences in the number of pods per plant when primed at both 10°C and 15°C. The number of pods per plant was 33% more in the brown landrace than in the red landrace and 54% more than the cream landrace. The brown landrace (39) had significantly higher number of pods per plant as compared to the cream landrace (27 pods per plant), though not significantly

different from the red landrace. There were no significant differences in the number of pods per plant across priming temperatures.

The priming temperature x landrace interaction was significant. At 10°C the number of pods per plant was 19% more pods per plant in the red landrace than in the cream landrace. But there were no significant differences between the brown and the red landraces. A similar trend was observed at 15°C. The red landrace had 15% more pods per plant than in the cream landrace but there were no differences between the red and the brown landraces.

Table 15. Number of pods per plant for the three Bambara groundnut landraces primed at two temperatures in the glasshouse.

Temperature (B)	Landrace (A)			
	Brown	Red	Cream	MEAN
10°C	37.2 a b	33.8 b	28.6	33.2
15°C	40.5 a	30.0 c d	26.0	32.2
MEAN	38.8 a	31.9 a b	27.3 b	32.7

C.V. $(\%)_A = 22.5$ C.V. $(\%)_B = 13.6$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

4.3.5 Harvest index

Harvest index is the ratio of the yield (seeds) to total biomass (foliage + roots +pods). Priming in a number of priming agents had an influence on the harvest index of

Bambara groundnuts. KNO_3 (55.9) had a significantly ($P \leq 0.05$) higher harvest index compared to the control (50.6)(Table 17). On the other hand, PEG (43.6) had a significantly ($P \leq 0.05$) lower harvest index of the plants compared to the control (50.6). KH_2PO_4 (47.5) was not different form the control (50.6).

The harvest index was not significantly ($P \leq 0.05$) different among landraces as indicated by the results in Table 17. Priming temperature x priming agent interaction had no effect on the harvest index. Similarly, the priming agent x landrace interaction was not significant.

Table16. Harvest index for three Bambara groundnut landraces primed in three different agents.

Landraces (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	52.7 a b	47.6 b c	41.6 c	48.3 b c	47.6 a
Red	61.4 a	49.0 b c	41.8 c	53.7 a b	51.5 a
Cream	53.6 a b	45.9 b c	47.9 b c	49.4 b c	49.1a
MEAN	55.9 a	47.5 b c	43.6 c	50.6 b	49.4

$C.V.\ (\%)_A = 16.7$ $C.V.\ (\%)_C = 11.9$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.05$.

4.3.6 100 seed weight

Priming had an effect on the 100 seed weight of the plants. KNO_3 had significantly ($P \leq 0.05$) higher 100 seed weight (51.0g) compared to the control (46.4g) (Table16). On the other hand, PEG (41.6g) produced significantly ($P \leq 0.05$) lower 100 seed weight compared to the control (46.4g). KH_2PO_4 (44.9g) was not different from the control (46.4g).

The 100 seed weight was significantly ($P \leq 0.01$) different for the landraces. The brown landrace had the lowest 100 seed weight (39.1g) followed by the cream landrace (49.3g) and finally the red landrace with 49.5g. There were no differences between the cream and the red landraces.

The priming agent x landrace interaction was significant. The brown landrace primed in KNO_3 produced a higher 100 seed weight (44.7g) compared to KH_2PO_4 (36.9g) and PEG (36.2g). There were no differences between KH_2PO_4 (36.9g), PEG (36.2g) and the control (38.7g). On the other hand, there were no differences among priming agents in the red and cream landraces.

Table 17. 100 seed weight of Bambara groundnut landrace prime in three different agents.

Landraces (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	44.7 c d	36.9 e	36.2 e	38.7 e	39.1 b
Red	55.6 a	50.4 a b c	44.5 c d	47.4 b c d	49.5 a
Cream	52.7 a b	47.2 b c d	44. 2 d	53.0 a b	49.3 a
MEAN	51.0 a	44.9 b	41.6 c	46.4 b	46.0

$C.V.\ (\%)_A = 13.1$ $C.V.\ (\%)_C = 8.1$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.05$.

The priming agent x priming temperature interaction was not significant for 100 seed weight. Similarly, the priming temperature x landrace interaction was not significant for 100 seed weight.

4.3.7 Yield per plant.

Despite some significant variations in yield components as a result of priming, there were no significant differences ($P \leq 0.01$) in the final yield of the crop (Table18). The yield ranged from 10.46g/per plant to 12.81 g/plant but, as mentioned above, this variation was not found to be due to seed priming.

There were no yield differences among landraces. There were no significant ($P \leq 0.01$) differences in yield among landraces (Table18). The red landrace produced the highest yield (12.29g/plant) followed by the brown landrace (11.41g/plant) while the cream landrace produced the lowest yield (11.40g/plant).

The landrace x priming agent interaction was not significant. Priming temperature x priming agent interaction was also not significant. Similarly, the priming agent x landrace interaction was not significant.

Table 18. Yield per plant for three Bambara groundnut landraces primed in three different agents.

Landraces (A)	Priming agent (C)				
	KNO_3	KH_2PO_4	PEG	CONTROL	MEAN
Brown	14.18 a	11.77 a b c d	9.21 d	10.46 c d	11.41a
Red	12.86 a b c	12.96 a b c	11.46a b c d	11.88 a b c d	12.29 a
Cream	9.56 d	13.69 a b	10.70 b c d	11.66 a b c d	11.40a
MEAN	12.2 a	12.81 a	10.46b	11.33 a b	11.7

$C.V.\ (\%)_A = 5$ $C.V.\ (\%)_C = 15.7$

Means in the same row followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.01$.

CHAPTER 5

5.0 DISCUSSION

Priming of different Bambara groundnut landraces in different priming agents did not improve the germination and emergence of Bambara groundnut landraces. This is contrary to the findings of many scientists who have worked on different crops and found priming to be beneficial. In the case of many vegetables, such as carrot celery and onion (Broklehurst and Dearmen 1983), Leek (Broklehurst et al., 1984,. Corbineau et at., 1994) and lettuce (Tarquis and Bradferd, 1992) priming was found to be beneficial in improving the germination of the seeds. Priming also stimulated the germination of other crop species such as sweet corn (Sung and Chung, 1993), field corn (Bodsworth and Bewley, 1981) and sunflower (Hamusimbi coilard, 1998).

The non response of Bambara groundnut landraces to priming in the present study could have been due to the drying back of the seeds after hydration. It is possible that the seeds might have entered phase III of imbibition that is concurrent with radical elongation. If this was the case, then drying back could have caused desiccation of the growing embryo that accompanies phase III of imbibition. Rocha (1959) reported decreased germination percentage, emergence rate, emergence synchrony and time to 50% emergence in onions after drying the hydrated seeds. The adverse effect of drying back was also observed by Brocklehurst and Dearman (1983) who reported that priming benefits in germination are realised in the reduction of the time lag phase of imbibition if the seeds are not re-dried after priming.

Mukurumbila (2000) reported improved germination of Bambara groundnuts after priming and planting without drying back the seeds.

The other underlying factor that might have caused low germination of the primed seeds could have been as a result of over priming especially in the salt solutions. Uptake of ion from priming salts can lower the seed water potential thereby encouraging water influx into the seed that can result in "over priming" a term used to describe the greater water content of seeds primed in salt than in PEG (Khan, 1992, Alvarado and Bradford, 1988). This was evidenced by the softening of the endosperm especially in the cream landrace during germination.

There were differences in the final germination of Bambara groundnut landrace after priming. The germination percentage was much lower in the cream landrace as compared to the brown and red landraces. This confirms the report by Bradford (1986) that the optional priming treatment for a seed lot is determined by trial and error. The response to a given priming treatment can vary between varieties and seedlots of the same cultivar (Brockle hurst and Dearman, 1983). There are variable factors, which include the nature of the priming agent, the duration of seed exposure to the priming agent, and the temperature and water potential of the priming agent (Khan 1992; Parera and Cantiliffe, 1994; Pill, 1994). In this experiment, it was observed that priming Bambara groundnuts in PEG did not affect the final germination of all landraces statistically. But priming in KNO_3 and KH_2PO_4 drastically lowered the final germination percentage of all landraces.

Haigh and Barlow (1987) reported that dissociated ions from inorganic salts can penetrate seed tissue and the variable uptake of different ions from priming salts would not only influence the amount of water absorbed by the seeds along the osmotic gradient, but may also exert disruptive specific ion effects on enzymes and membranes where as PEG molecules being inert do not. Salt solutions were found to be toxic to sorghum seeds and thus not suitable for priming sorghum (Haigh and Barlaw, 1987). It may also be deduced that the salt solutions could have been toxic to the Bambara groundnut landraces when compared to the result obtained from PEG.

Priming at higher temperature of 15°C slightly improved germination of all landraces than priming at 10°C. But the difference was not significant may be because the progression was small. Pill and Korengel, (1997) reported improved germination of Kentucky Bluegrass when primed at 20°C as compared to 5°C.

Priming in this experiment significantly reduced germination time relative to the control in the salt solutions while there was no difference between PEG, and control. This is in line with results reported by Alvarado, et al. (1987) in tomato seeds. The germination rate was higher in seeds primed in KH_2PO_4 by 0.03 seeds/day as compared to the control while KNO_3 and PEG were not different. But priming had no effect on the germination spread of the seeds.

Priming agents had an effect on the growth of the plants. From observations, KNO_3 produced relatively smaller plants compared to the other priming agents and the control. Due to the small stature of the plants primed in KNO_3, it was found that the numbers of stems, nodes and branches were lower as compared to the results obtained

from other priming agent and control. Subsequently, this increased the harvest index of the KNO_3.

The landrace differences could be attributed to differences in growth habits of the plants. The brown landrace was semi bunch while the red and cream landraces were bunch types. This resulted in the plants having more branches and nodes on which more pods were formed especially aerial pods.

The 100 seed weight was significantly associated with grain yield in the red landrace. The implications are that the greater the weight of the 100 seeds, the greater will be the ultimate grain yield. This was true with the red landrace. Lavoe and Karikari (1978), and Mbewe and Lungu (1990) reported that 100 seed weight was significantly correlated with grain yield. The brown landrace produced lower 100 seed weight than the cream landrace but its ultimate yield was not different from the red and cream landraces. This was due to the brown landrace being more prolific although seed size was smaller. The bulk quantity contributed more to the ultimate yield in this case.

The grain yield of between 277 kg/ ha and 510 kg/ha have been reported in Zambia (Mbewe and Lungu, 1990; Nkumba, 1998). In this study the grain yield of landraces ranged between 11.40 g/plant to 12.29g/plant which when extrapolated to yield per hectare using the plant population and field spacing it ranges between 1085 kg/ha and 1269 kg/ha. This could be attributed to the environment under which the crop was grown. The environment in the glass house was controlled i.e., the temperature was uniform and light intensity on the plants was also semi controlled. Higher yields than those obtained in this study were recorded at Msekera research station in 1989. Yields

ranging from 864 kg/ha to 2054 were reported in variety trials (Annual report 1988/89). This could be attributed to selection of the varieties done through repeated experiments. While the seed used in this experiment was obtained from farmer grain crop.

The reduced light intensity inside the grass house stimulated vigorous growth of the plants. Reduction in light intensity affects photosynthetic rate of the leaves in Bambara groundnuts. Muraki et al. 1991 reported a reduced photosynthetic rate of Bambara groundnuts with reduced light intensity due to reduction in the thickness of the leaves as a result of a decrease in the thickness of the water storage cells. This could have attributed to the reduction in yield in this experiment.

Other cultural practices such as disease control and irrigation was easy in the glass house and it was applied uniformly. The sterilization of soils did not only control the soil borne diseases but also weeds, which resulted in no competition from the weeds. This glass house environment could have contributed to high yields of landraces as compared to when they are grown out in the field under rain fed conditions.

CHAPTER 6

CONCLUSION

The different priming agents and priming temperatures did not improve the germination rate of Bambara groundnuts. This suggests that other inherent factors in Bambara groundnut that affects germination may be at play. From observations of the germinating seeds, the seed coat impedes germination as the radical could be seen coiling under the seed coat. Similarly, different priming agents and priming temperature did not improve the emergence of Bambara groundnuts. The analysis of yield from the resultant plants primed in different priming agents and temperature were not significant. This shows that bambara groundnut was a stable crop but may be responsive to environmental changes.

There was a strong interaction between the priming agent and landrace for time to 50% germination and final germination percentage. The number of days taken to reach 50% germination was much lower when primed in the salt solution than in PEG which is inert. This could suggest that the seeds took up more salts that enhanced the uptake of water into the seeds resulting into much quicker germination. But the final germination percentage was lower in seeds primed in salt solution than in PEG and the control. This could suggest that there was over-priming (too much water taken up by the seeds) of the seeds that led to the dying of the fast growing embryo especially after seed drying back. From the above results one would suggest that priming Bambara groundnuts in salt solution result in negative effects on final germination and subsequent emergence of Bambara groundnuts.

A concrete conclusion cannot be made from this experiment. In future experiments on priming concentration should be on use of inert materials and water soaking to enhance germination. Other suggestions are being made that factors such as seed coat hardiness and embryonic maturity have to be considered seriously if tangible result to improve germination are to be achieved. It is therefore, recommended that the experiment should be repeated off season in a controlled environment and in the field to simulate farmer conditions.

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Appendix A. Soil Characteristics Of Soil From Kanakantapa Used In The Glass House.

Soil character	Unit	Results
pH CaCl2	-	4.98
0rganic matter	%	1.85
Total nitrogen	%	0.08
Extractable phosphorus	Mg/l	14.76
Exchangeable potassium	Meq/100g	0.68
Exchangeable sodium	Meq/100g	0.68
Exchangeable calcium	Meq/100g	0.20
Exchangeable magnesium	Meq/100g	1.75

Appendix B. Daily Mean Temperature Distribution (^{o}c) In The Glass House.

Day	November	December	January	February	March	April
1	30	31	-	36	34	-
2	36	30	-	28	32	-
3	32	32	-	34	22	26
4	-	-	28	29	-	18
5	37	-	28	-	-	27
6	-	28	36	-	28	26
7	-	31	26	-	23	24
8	35	27	-	35	27	-
9	39	18	-	23	28	-
10	23	31	24	34	32	25
11	-	-	30	32	-	21
12	22	-	34	-	-	23
13	-	32	26	-	-	26
14	-	18	26	24	30	25
15	31	27	18	22	27	-
16	33	28	-	30	32	-
17	34	30	-	20	32	23
18	35	-	36	30	-	22
19	35	-	27	-	-	-
20	-	34	22	-	24	-
21	-	35	25	33	26	-
22	29	36	-	31	26	-
23	33	36	-	27	23	-
24	32	29	31	27	29	-
25	37	35	28	29	-	-
26	33	-	31	29	-	-
27	-	-	24	33	28	-
28	-	36	32		29	-
29	32	33	-		27	-
30	31	33	-		30	-
31	-	37	-		26	-

Appendix C. Daily Maximum Temperature Distribution (^{O}c) In The Glasshouse.

Day	November	December	January	February	March	April
1	36	32	-	20	20	-
2	38	36	-	35	32	-
3	39	37	-	28	30	28
4	-	-	33	30	-	30
5	39	-	31	-	-	26
6	-	-	35	-	30	29
7	-	28	36	34	31	27
8	36	32	-	25	19	-
9	38	25	-	26	24	26
10	30	29	28	35	-	21
11	29	-	28	27	-	28
12	22	-	32	-	-	28
13	-	25	21	-	-	27
14	-	30	24	24	34	-
15	31	25	36	26	29	-
16	36	33	-	20	30	29
17	38	34	-	24	38	25
18	38	-	35	33	-	-
19	38	-	34	-	-	-
20	-	29	34	-	26	-
21	-	31	26	36	30	-
22	30	35	-	29	29	-
23	36	29	-	30	28	-
24	30	38	32	24	30	-
25	19	34	36	30	-	-
26	36	35	33	35	-	-
27	-	-	30	29	36	-
28	-	-	25		29	-
29	33	36	-		35	-
30	33	31	-		35	-
31	-	35	-		30	-

Appendix D. Daily Mean Light Intensity Reaching The Crop In The Glass House

Day	November	December	January	February	March	April
1	43960	48388	-	44606	46068	-
2	43943	51166	-	39844	40695	46018
3	46703	33711	-	33597	5034	53010
4	-	-	33588	23392	-	47281
5	40001	-	10778	-	-	69776
6	-	-	29722	-	27086	37843
7	-	58055	11550	-	4161	-
8	42933	38088	-	29988	17863	-
9	56766	3198	-	6584	24625	64516
10	24330	35544	18530	28064	19667	6640
11	-	-	34526	29790	-	17723
12	40133	-	39961	-	-	16498
13	-	6358	25025	-	-	50720
14	-	7132	11368	4110	20342	-
15	67583	29500	-	16800	19518	38260
16	69611	40267	-	5538	22840	22035
17	66650	66488	17881	26680	35767	-
18	42835	-	28537	-	-	-
19	55511	-	18570	-	-	-
20	-	41607	18551	40682	61581	-
21	-	44781	23256	21453	45365	-
22	38898	55344	-	20732	34323	-
23	33075	54991	-	27913	16356	-
24	63866	43213	41966	25676	57633	-
25	78233	-	19491	-	75251	-
26	40316	-	39481	-	62298	-
27	-	64888	16041	21946	160483	-
28	-	47822	29000	36247	48948	-
29	51516	61548	-	-	25583	-
30	72891	51880	-	-	-	-
31	-	37888	-		-	-

Appendix E. Daily Maximum Light Intensity Reaching The Crop In The Glass House

Day	November	December	January	February	March	April
1	23915	43013	-	2891	1474	-
2	53258	42861	-	14805	8154	-
3	77441	23418	-	7084	24271	4959
4	-	-	30311	40374	-	12561
5	69338	-	15474	-	-	28815
6	-	-	19984	-	21641	18448
7	-	4872	37297	3721	10281	8728
8	68650	40814	-	8805	2350	-
9	30013	19371	-	6503	5363	-
10	38688	7290	28243	14856	-	16887
11	19003	2431	24544	4692	-	8993
12	15571	3830	27395	-	-	24211
13	-	43700	5356	-	-	7050
14	-	25102	8377	9684	33211	38803
15	24853	52820	-	22152	28111	-
16	98216	-	-	10510	14005	8898
17	67533	-	35478	16505	35767	10740
18	75566	14870	27533	-	-	-
19	74616	28265	30788	-	-	-
20	-	47666	23520	30900	125140	-
21	-	39855	41588	24364	23215	-
22	25334	47898	-	12280	23788	-
23	39813	-	-	18150	29785	-
24	18991	-	35664	24898	48571	-
25	2281	52311	10763	-	24926	-
26	64015	41944	18718	-	14605	-
27	-	34223	21877	1958	87466	-
28	-	11952	12423	28162	51828	-
29	85983	60055	-	-	37523	-
30	58333	-	-		-	-
31	-	-	-	-	-	-

Appendix F. Daily Maximum Light Intensity Outside The Glass House

Day	November	December	January	February	March	April
1	109100	120800	-	108700	71600	-
2	104700	111300	-	63100	111900	-
3	105000	113400	-	99900	15520	41600
4	-	-	71300	59100	-	96000
5	106000	-	44600	-	-	95100
6	-	65500	91400	-	74100	95600
7	-	103400	24300	-	11190	26800
8	108700	109700	-	102000	40400	-
9	141600	41600	-	8780	52000	33800
10	33600	118300	20600	68400	12390	13800
11	-	-	125500	60500	-	118500
12	43000	-	90100	-	-	60100
13	-	11700	48400	-	-	59500
14	-	4700	12030	9880	37600	-
15	102400	58500	137300	40200	186600	-
16	110100	141200	-	40400	31300	111700
17	104400	122800	-	1462	108800	39700
18	100600	-	107900	35100	-	-
19	106800	-	37700	-	-	-
20	-	111600	38000	-	32100	-
21	-	101900	68000	98900	127500	-
22	33800	107000	-	128100	125900	-
23	60000	114600	-	47700	19000	-
24	130800	80000	110300	106000	120000	-
25	150700	99000	47500	62600	-	-
26	131100	-	96000	45200	-	-
27	-	-	28800	123400	137300	-
28	-	107700	80900	-	92400	-
29	108400	98700	-	-	26600	-
30	112200	107200	-	-	34500	-
31	-	116200	-	-	29100	-

Appendix G. Daily Mean Light Intensity Outside The Glasshouse

Day	November	December	January	February	March	April
1	96900	92100	-	52400	1591	-
2	97200	89400	-	37000	15800	-
3	88100	38200	-	14930	114900	11730
4	-	-	78400	131600	-	26200
5	79000	-	15060	-	-	111600
6	-	-	24600	-	65300	76600
7	-	9240	44400	11240	13030	15990
8	106100	48300	-	19020	4750	-
9	72900	20300	-	44500	12960	12060
10	66200	14530	111700	27900	-	-
11	18560	-	33700	7810	-	95800
12	17220	-	29800	-	-	92600
13	-	4630	8500	-	-	18420
14	-	1130	16130	14840	143000	105700
15	31600	114900	11800	29700	36000	-
16	99300	27600	-	100400	28300	-
17	95200	122500	-	23600	125400	16180
18	20200	-	57100	30300	-	13030
19	95600	-	114300	-	-	-
20	-	20100	70800	-	93000	-
21	-	107500	91700	106400	124300	-
22	27700	103200	-	72400	31900	-
23	35200	65500	-	23200	12110	-
24	23600	22600	102900	32700	31500	-
25	3000	80100	51400	48300	-	-
26	93400	-	37500	40900	-	-
27	-	-	44300	107400	32200	-
28	-	76800	27900	-	19000	-
29	85000	97700	-	-	91800	-
30	81600	34900	-	-	11900	-
31	-	116000	-	-	21600	-

Appendix H. Analysis Of Variance of Germination Percentage, Time To 50% Germination, Germination Rate and Germination Synchrony.

Source	DF	Mean Square			
		Germination percentage	Time to 50% germination	Germination rate	Germination Synchrony
Replication	3	221.02	3.01	0.00	7.57
Factor A	2	4315.54**	35.34**	0.01*	19.39*
Error	6	131.49	2.07	0.00	4.16
Factor B	1	127.65	1.68	0.00	3.26
AB	2	25.24	1.20	0.00	1.30
Error	9	76.13	0.48	0.00	2.29
Factor C	3	7278.60**	10.65**	0.00*	3.31
AC	6	1249.11**	7.63**	0.00	1.06
BC	3	26.95	0.51	0.00	0.65
ABC	6	110.90	0.66	0.00	2.05
Error	54	108.59	1.23	0.00	1.79

*, ** denote significant at $P \leq 0.05$ and $P \leq 0.01$ respectively

Appendix I. Analysis Of Variance of Emergence Percentage, Time To 50% Emergence, Emergence Rate And Emergence Synchrony.

Source	DF	Mean Square			
		Emergence percentage	Time to 50% emergence	Emergence rate	Emergence Synchrony
Replication	3	0.47	1.01	0.00	2.65
Factor A	2	45.61.92**	0.79	0.00	16.97*
Error	6	19.77	0.29	0.00	3.29
Factor B	1	86.64	0.15	0.00	2.54
AB	2	4.55	0.02	0.00	0.12
Error	9	39.12	0.63	0.00	1.64
Factor C	3	7783.16**	1.73 *	0.00**	12.25**
AC	6	913.08**	2.64**	0.00**	16.61*
BC	3	13.04	0.06	0.00	1.18
ABC	6	51.00	0.21	0.00	1.65
Error	54	44.79	0.55	0.00	2.64

*, ** denote significant at $P \leq 0.05$ and $P \leq 0.01$ respectively

Appendix J Analysis Of Variance of Yield and Yield Components.

Source	DF	Mean Square			
		Number of pods per plant	Number of branches per plant	Number of nodes per plant	Number of stems per plant
Replication	3	125.66	7.01	669.12	0.51
Factor A	2	1079.40**	133.96**	12795.65**	1.13
Error	6	81.03	2.70	573.19	0.54
Factor B	1	26.99	0.70	55.82	0.26
AB	2	117.35*	10.44*	1026.76*	0.04
Error	9	19.66	2.18	148.76	0.23
Factor C	3	79.46	48.26**	3460.94**	2.46**
AC	6	127.61**	6.46*	580.24**	0.90*
BC	3	31.73	6.04	65.95	0.37
ABC	6	264.45**	20.24**	1165.64**	1.07*
Error	54	38.55	2.70	175.70	0.40

*, ** denote significant at $P \leq 0.05$ and $P \leq 0.01$ respectively

Appendix K. Analysis Of Variance of Yield and Yield Components.

Source	DF	Mean Square			
		Harvest index	100 seed weight	Yield per plant	Yield in kg/ha
Replication	3	559.26	174.81	21.29	245974.46
Factor A	2	124.03	1123.17**	8.35	483073.47**
Error	6	102.39	54.43	12.08	4379.95
Factor B	1	0.39	50.74	36.98	242465.31
AB	2	2.53	1.09	9.53	117196.18
Error	9	36.65	29.59	6.95	75894.49
Factor C	3	647.57**	363.47**	25.29*	93008.75
AC	6	75.24	41.08*	19.81*	340751.53**
BC	3	0.20	50.55	10.25	50665.08
ABC	6	7.85	23.68	36.98**	362378.52**
Error	54	69.09	27.89	7.45	57299.17

*, ** denote significant at $P \leq 0.05$ and $P \leq 0.01$ respectively

Appendix L. Soil Texture Classification

Soil Composition	Percentage
Sand	87.7
Clay	0.6
Silt	11.7

Textural Class S/LS

Key:

S/LS = Between sand and loamy sand