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Germination and seedling vigour of hydroprimed stored seeds of African eggplant (*Solanum macrocarpon* L.) produced under different nitrogen fertilizer rates.

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Abstract.

The study was conducted in the laboratory and screen house of School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Niger state, Nigeria. Effects of two factors- nitrogen fertilizer application to the mother plant at 0, 20, 40, 60, 80, 100 kg ha^{-1} and hydropriming (hydro-primed and non-hydroprimed) on Solanum marcrocarpon (cv. FUTMSm-2) seed quality were tested during a storage period of 16 weeks. The laboratory study used a 6 x 2 factorial experiment which was subjected to a completely randomized design. Data were collected on 100-seed weight, changes in moisture content during storage, germination percentage, seedling length, seedling shoot and root length. Data collected on all parameters were subjected to analysis of variance using statistical analysis system (SAS) and means were separated using Duncan's multiple range test (DMRT) where significant differences occurred among treatments. Seeds produced with 60 kg N ha^{-1} were the heaviest while seeds produced without N application was the lightest. Moisture content increased with storage period. Germination percentages were low (about 1 to 10%) at 0 to 2 weeks after storage (WAS) at all N fertilizer rates. Impressive increase in values from about 57% (at 0 kg N ha^{-1}) to 87% (at 80 kg N ha^{-1}) were recorded between 4 and 10 WAS. The highest germination percentage of about 89 was obtained at 80 kg N ha^{-1} while the poorest was recorded at 0 kg N ha^{-1}. Viability was best maintained in seeds produced with 80 kg N ha-^{1} as germination percentage of 79% was still recorded at 12 WAS as against a range of 31-56% for other N treatments. Hydropriming resulted in enhanced seed germination. Seedlings from seeds produced with application of 80 or 100 kg N ha^{-1} were generally significantly longer than those produced with 0 kg N ha^{-1}. Root length values were significantly greater in seeds produced with 100 kg N ha^{-1} compared with the values recorded with 0 kg N ha^{-1}. No consistent trends were established in respect of shoot length. Hydropriming only resulted in significant increase in seedling length at 8 and 16 WAS and in root length at 0, 8 and 16 WAS. Hydropriming did not significantly influence shoot length. It is concluded that application of nitrogen fertilizer at 80 kg ha^{-1} resulted in the production of best quality seed and that hydropriming enhanced seed germination and seedling growth.

Key words: *Solanum macrocarpon*, seed moisture content, seed quality, hydropriming, seedling vigour, seed dormancy.
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Introduction

Solanum macrocarpon (African eggplant) is a tropical perennial plant that is closely related to eggplant. Its cutivars are mainly grown for their fruit in West Africa (humid coastal and high-rainfall zones) and southern Africa, while the leafy types are commonly grown throughout West and Central Africa. Fruit and leafy part are used in the preparation of delicacy such as African salad, yam and stew and so on. Oboh *et al.* (2005) reported that the unprocessed eggplant leaves had 4.3% protein, 0.6% fat, 1.4% crude fibre, 1.3% ash and 89.7% moisture content. Cyanide (2.0 mg/kg), phytate (40.4 mg/100 g), Ca (32.6 mg/kg) and Zn (8.2 mg/kg) were low. The leaves are used in cooking vegetable soups, while the fruits are eaten when cooked with rice in Indonesia. The juice from the vegetables is used in the treatment of gout, rheumatism, angina, inflammatory tumors, cancerous tissues, Parkinson's disease and it is also used as childbirth anaesthesia (Oboh *et. al.*, 2005).

Adequate fertility plays an important role in plant growth, development, yield and eventually the quality of seeds in many crops. Nitrogen fertilizer application was reported by Knowles *et. al.*, (1999) to result in the production of wheat seeds with higher germination percentage and reduced germination time. Wheat seeds produced with fertilizer application of 120 kg ha^{-1} N was reported to have greater vigour than seeds produced with 0, 60, 180 kg ha^{-1} N in an electrical conductivity test (Warraich *et al.*, 2002). Luzuriaga *et al.* (2006) reported that in *Sinapis arvensis*, addition of nitrogen to maternal environment reduced germination rate of seeds. Michaloic (1997) stated that highest seed yield and best seed quality (determined as vitamin C, sucrose, macro and micro elements contents) were recorded by application of 40 kg N and 150 kg K_2Oha^{-1}. Ali *et. al.* (2001) reported that the application of varying nitrogen fertilizer levels did not show significant effect on the seed germination percentage of pea. Gul *et. al.* (2006) also reported that different nitrogen level did not result in enhancement of germination percentage. A study done on rapseed by Oskouie (2012) howed that the application of different levels of nitrogen fertilizer did not significantly affect the standard germination of seed but result in reduced germination time.

Dormancy and low germination rates are problems and have been described in different species of *Solanum*. Ibrahim *et. al.* (2001) reported slow germination and germination range of between 15 and 50% in *S. incanum, S. torvum, S. integrifolium, S. surattense, S. khasianum, S. sanitwongsei* and hybrids of *S. melongena and S. ingrifolium*. Variations have also been recorded in *Solanum melongena* L. by Demir *et. al.* (2005). Gisbert *et. al.* (2011) recorded poor germination in seeds of *S. melongena, S. macrocarpon, S. aethiopicum* and *S. incamun* incubated in humid filter paper. Marked increases were however recorded in nutrient medium alone and in nutrient medium plus gibberellic acid (GA_3). They concluded that germination in seeds of *Solanum* species is limited by abscisic acid which is an inhibitor. Other treatment that have been employed to overcome dormancy include scarification, hot water, dry heat, fire, charate, acid and other chemical, mulch, water, cold and warm stratification, and light (Emery, 1987). According to Adebola and Afolayan (2006) the best condition for germination is one day presoaking in water followed by illumination under day/night temperature of 18-25 °C. Germination was less than 12% in complete darkness at 18-25 °C.

Seed priming is soaking of seeds in a solution of any priming agent without radical emergence (McDonald, 2000). Acording to Ashraf and Foolad (2005) the practice allows imbibition and activation of the initial metabolic events associated with seed germination, but prevents radicle emergence and growth. Improved germination and field performance of lentil was recorded in primed compared with unprimed treatment, but the effect of different priming was also significant, where invigoration of seeds by hydro-priming resulted in higher seedling emergence in the field, compared to control and seed priming with PEG. Abdulrahmani *et. al.* (2007) and Ghassemi-Golezai *et. al.* (2008) reported that whereas the final seedling emergence percentage of primed and unprimed seeds was equal, seedling from primed seeds emerged more quickly than those of unprimed. Seedling emergence from unprimed watermelon seeds was reported to be four days later compared to those from primed seeds (Demir and Mavi, 2004). Studies on pepper (Amjad *et. al.*, 2007) and sugarcane (Patade *et. al.*, 2009) have also revealed that halo priming improved seed germination, seedling emergence and growth under saline and drought conditions. Harris *et al.* (1999) demonstrated that on-farm seed priming (soaking seeds overnight in water) markedly improved establishment and early vigor of upland rice, maize and chickpea, resulting in faster development, earlier flowering and maturity and higher yields. The value of hydropriming has been demonstrated in other crops, such as wheat (Harris *et. al.*, 2001) chickpea (Musa *et. al.*, 2001), maize (Ashraf and Rauf, 2001), sunflower (Kaya *et. al.*, 2006) and Barley (Abdulrahmani *et. al.*, 2007).

To successfully raise a good crop of any plant species, it is required that its seeds be of high quality, germinating highly and rapidly. Information seem to be lacking in respect of the effect of mother plant soil nutrient level on the quality of *Solanum macrocarpon* seeds. The effect of hydropriming on seed germination on the crop may not also have been documented. Hence, this study was conducted to determine the effect of mother plant nutrition and hydropriming on the seed quality of *Solanum macrocarpon*

Materials and methods.

The experiment was carried out in the laboratory and screen house of the Department of Crop Production, School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Niger State, Nigeria. The seeds used for the study were extracted from completely yellow fruit harvested from *Solanum macrocarpon* (cv. FUTMSm-2) plants to which nitrogen fertilizer was applied at the rates of 0 (control), 20, 40, 60, 80 and 100 kg per hectare. Extracted seeds were thoroughly washed in water and shade dried in ambient condition (about 30°C and 40% relative humidity) for two weeks and then sealed in glass bottles until needed for the experiment.

Four replicates of hundred seeds were counted for each N treatment and weighed on a Mettler balance to determine the 100-seed weight. Seeds of the different N treatments were placed in open plastic plates and stored at 35 °C and relative humidity of about 85% for 16 weeks. Seed moisture content was determined at the onset of storage and at two weeks interval thereafter till the end of the storage period using the constant high temperature oven drying method at 130 °C for 1 hour (ISTA, 2005). On each test day, 3.30 g seeds of each of the different fertilizer treatments were soaked in 50 ml of water for 24 hours followed by air-drying in ambient condition to determine the effect of hydropriming on seed germination. Seeds that were not hydroprimed served as the control. Germination was tested on four replicates of 50 seeds from each treatment combination of nitrogen fertilizer (six levels) and hydropriming (two levels) placed on water-moistened layers of absorbent paper put in plastic Petri dishes and incubated at 30 °C for sixteen days on each test day. A seed is considered to have germinated when radicles emerge. Germinated seeds were recorded every-other-day and the final germination percentage was calculated.

For the seedling vigour test, four replicates of 10 seeds each for each treatment combination were planted in plastic containers filled with 2 kg of river sand and the resultant seedlings were monitored in the screen house for 16 days. Seedling length, shoot and root length were subsequently determined. Data collected on all parameters were subjected to analysis of variance using statistical analysis system (SAS) and means were separated using the Duncan's Multiple Range Test (DMRT) where differences between treatments were obtained.

Results

The effect of nitrogen application rates on 100 seeds weight of *Solanum macrocarpon* are presented in Table 1.

Table 1. Effect of nitrogen application rates on 100-seeds weight of *Solanum macrocarpon*.

N application (kg/ha)	100-seed weight(g)
0	0.370e
20	0.425b
40	0.398d
60	0.438a
80	0.433ab
100	0.408c
SE±	0.004

•Values in the same column with different letters are significantly different from each other ($p<0.05$). •SE±= standard error ($p < 0.05$).

Seeds produced with 60 kg N ha^{-1} were the heaviest (0.438g), while seeds produced without N application were the lightest (0.370g). The difference between the seed weight obtained at 60 and 80 kg N ha^{-1} was however insignificant. Application of 100 kg N ha^{-1} resulted in a significant decrease in seed weight compared to values recorded for 60 and 80 kg N ha^{-1}. The effect of storage period on the moisture content of seeds produced under different nitrogen fertilizer levels (0 to 100 kg ha^{-1}) are presented in Figure 1. Seeds of all treatments gained moisture over the period of storage from about 6-7.8 % at 0 week after storage (WAS) to 11.7 – 13.9 at 12 WAS with some decrease in moisture content (MC) at 14 and 16 WAS. Figure 2 shows that at 0 week of storage, the highest germination percentage (24%) was obtained at 60 kg N ha^{-1} followed by 80 kg N ha^{-1}. Germination values were at par at 0, 20 and 40 kg Nha^{-1} application but were significantly lower than the values obtained at 80 kg N ha^{-1}. Germination percentage remained low (about 1 to 10%) at 2 WAS in all the N treatments but increased in all N treatments at 4 WAS. Impressive increases in values of up to about 57% (at 0 kg N ha^{-1}) to 89% (at 80 kg h^{-1}) were recorded between 4 and 10 WAS. Viability was best maintained in seeds produced at 80 kg N ha^{-1} as germination percentage of 79% was still recorded at 12 WAS as against a range of about 31- 56% for other N treatments. Figure 3 shows that hydroprimed seeds generally germinated significantly higher than non-hydroprimed ones except at 6, 12 and 16 WAS.

Significant nitrogen x hydro-priming interaction effect was recorded at 0, 4, 6, and 12 WAS (Figures 4 and 5). It is evident from Figure 4a that at 0 WAS, hydro-priming of seeds produced with the application of 60 and 80 kg N ha^{-1} resulted in a significantly higher germination percentage compared to those from non-primed seeds. Priming had no significant effect on the seeds produced at N fertilizer rates of 0, 20, 40 and 100 kg ha^{-1}. Under non-hydroprimed treatment seeds produced at 60 and 80 kg N ha^{-1} germinated equally well and were both significantly better than seeds produced at 0, 20, 40 and 100 kg N ha^{-1}. When seeds were primed, germination was significantly higher at 60 kg N ha^{-1} (37 %)) than at 80 kg N ha^{-1} (19 %) which was in turn significantly better than at 0, 20, 40 and 100 kg N ha^{-1}.

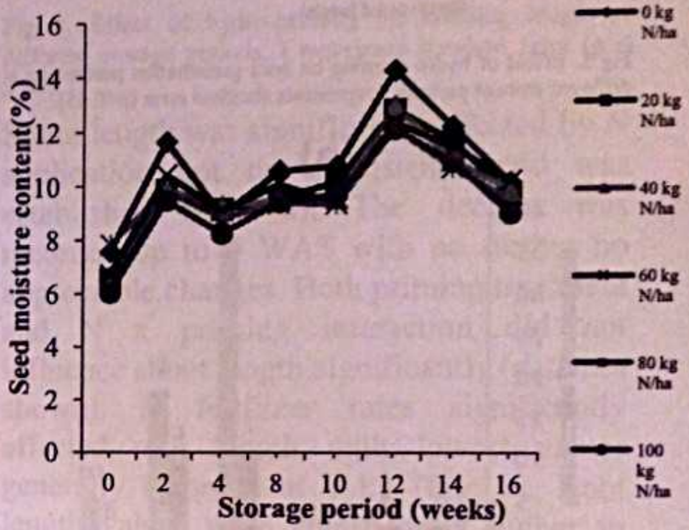

Fig. 1. Effect of storage period on the moisture content of seeds produced under different nitrogen fertilizer levels of 0 to 100 kg ha^{-1}.

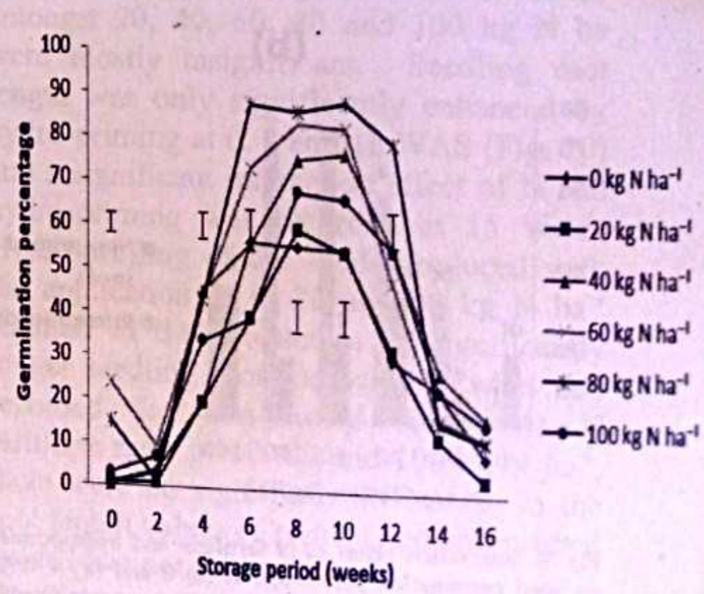

Fig 2. Effect of nitrogen rates on seed germination percentage at different storage periods. I represents standard error ($P < 0.05$).

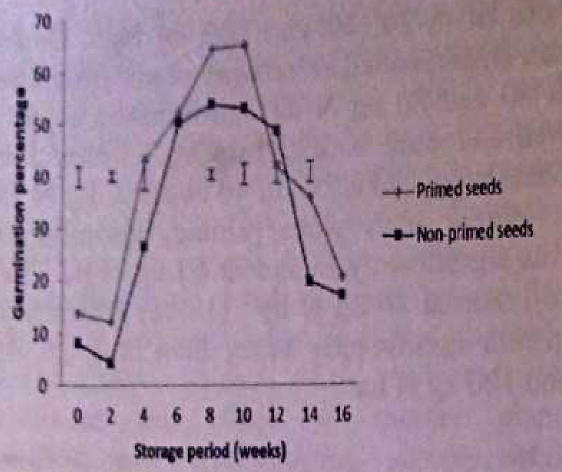

Fig 3. Effect of hydro-priming on seed germination percentage at different storage periods. I represents standard error (p<0.05).

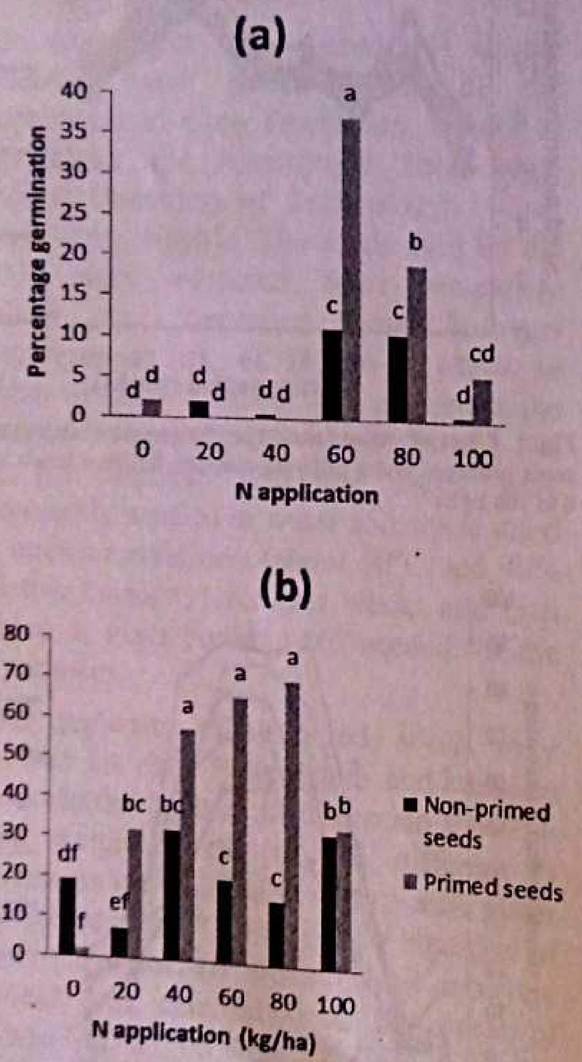

Fig. 4. Interaction effect of N fertilizer and hydropriming on seed germination percentage at (a) 0 and (b) 4 WAS respectively. Bars carrying different letters are significantly different from each other (p<0.05).

At 4 WAS, hydro-priming of seeds produced with application of 20, 40, 60 and 80 kg N ha^{-1} resulted in significantly higher germination percentages compared to those from non-primed seeds (Figure 4b). At N fertilizer rates of 0 kg ha^{-1}, non-primed seeds germinated better than primed seeds, while at 100 kg N ha^{-1} application rate there was no significant difference between primed and unprimed seeds. At 6 weeks of storage, seeds produced with the application of 0 and 20 kg N ha^{-1}, had similar germination percentage irrespective of the priming treatment while seeds produced with N application of 40 kg ha^{-1} germinated significantly higher when unprimed than when primed (Figure 5a). Seeds produced at 60, 80 and 100 kg N ha^{-1} germinated significantly higher when primed (90.5 %, 92.5 %, and 40.5 % respectively) than when unprimed (56 %, 83 %, and 25.5 % respectively). At 12 WAS seed produced at N fertilizer rates of 0, 20 and 100 kg ha^{-1} germinated significantly higher when unprimed (45.5 %, 46.0 %, and 70.0 % respectively) than when primed (15.0 %, 19.0 % and 40.0 % respectively) while it was reverse in seed produced at 80 kg N ha^{-1}. Seed produced at 40 and 60 kg N ha^{-1} had similar germination percentage irrespective of priming treatment.

Seedling length was significantly affected by N values and was generally lowest in seeds harvested from the control plots (0 kg N ha^{-1}). Application of N at 80 or 100 kg N ha^{-1} resulted in significantly greater seedling length when compared to 0 kg N ha^{-1} except at 0, 6 and 14 WAS (Fig. 6). Hydropriming of seeds only resulted in significant increase in seedling length compared to the non-primed treatment at 8 and 16 WAS (Fig 7). Seedling length generally increased from about 7-8 cm at 0 WAS to about 9-10 cm at 6 WAS and then declined with further ageing to about 6-7 cm at 16 WAS.

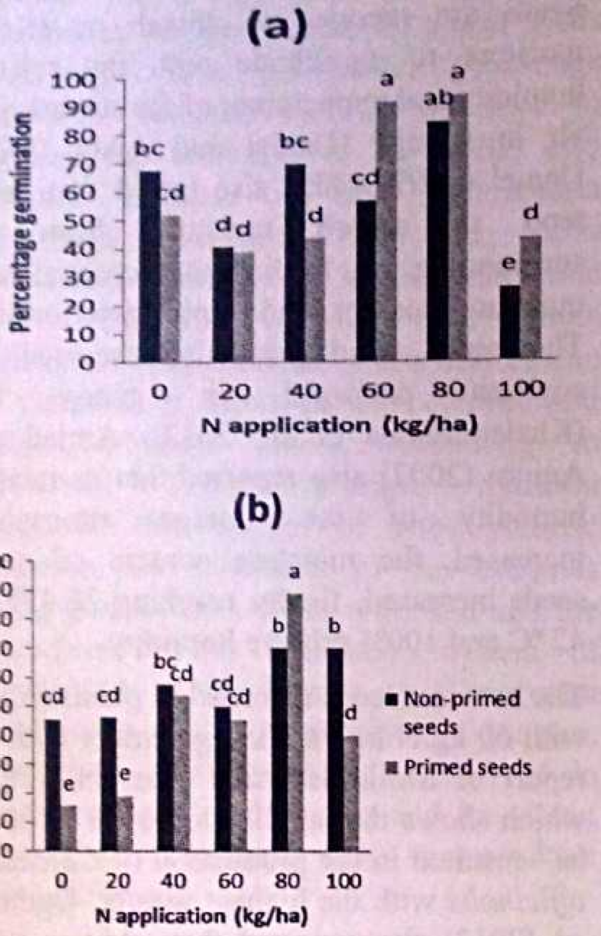

Fig 5. Interaction effect of N fertilizer and hydropriming on seed germination percentage at (a) 6 and (b) 12 WAS respectively. Bars carrying different letters are significantly different from each other (p<0.05).

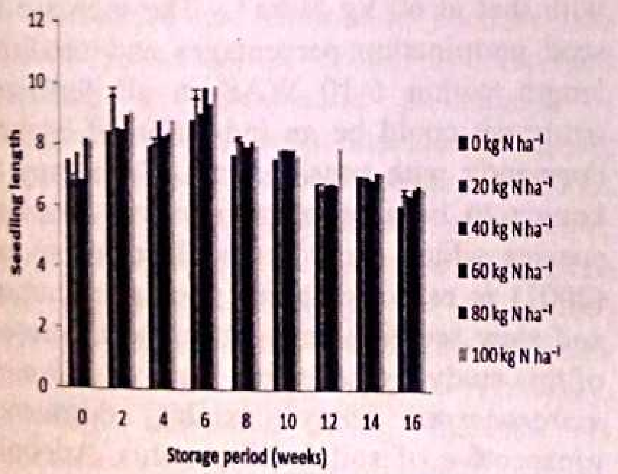

Fig 6. Effect of nitrogen rates on the seedling length at different storage periods. I represents standard error ($p < 0.05$).

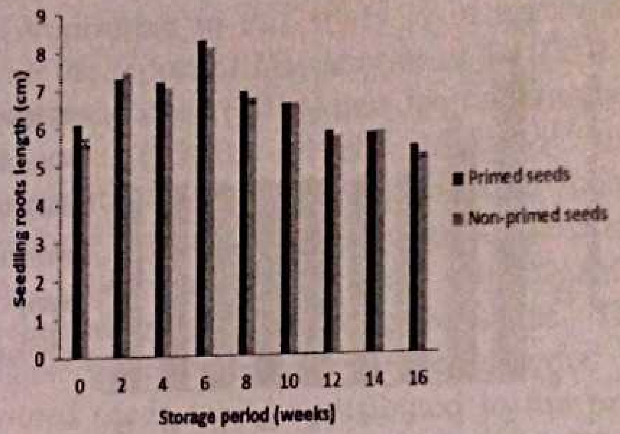

Fig 7. Effect of hydro-priming on seedling length at different storage periods. I represents standard error ($p < 0.05$).

Shoot length was significantly affected by N application but no consistent trend was established (Fig. 8). The decline was recorded up to 4 WAS with no further no appreciable changes. Both priming treatment and N x priming interaction did not influence shoot length significantly (data not shown). N fertilizer rates significantly affected root length with lowest values generally recorded at 0 kg (Fig. 9). Root length values were significantly higher in seed produced with 100 kg N ha^{-1} compared with the valued recorded with 0 kg N ha^{-1}. The differences among the values recorded amongst 20, 40, 60, 80 and 100 kg N ha were mostly insignificant. Seedling root length was only significantly enhanced by hydro-priming at 0, 8 and 16 WAS (Fig. 10) and a significant interaction effect of N and hydro-priming was recorded at 16 WAS. Hydro-priming of the seeds produced with the application of 0, 20 and 40 kg N ha^{-1} resulted in the production of significantly longer seedling root compared to what was recorded for non-primed seeds. At N fertilizer rates of 60, 80 and 100 kg N ha^{-1}, there were no significant differences in the root length values of primed and non-primed seeds (data not shown).

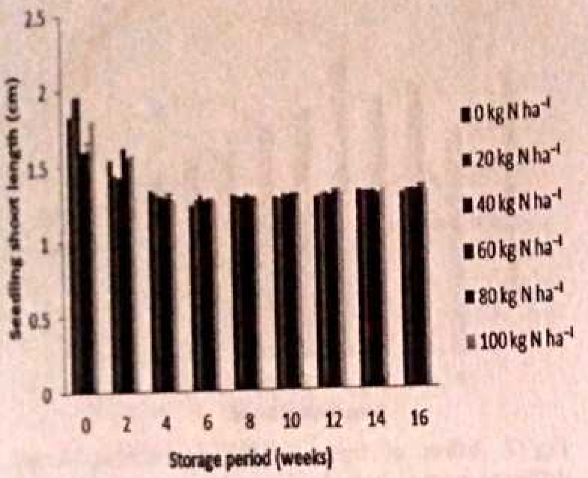

Fig 8. Effect of nitrogen on seedling shoots length at different storage periods I represents standard error ($p < 0.05$).

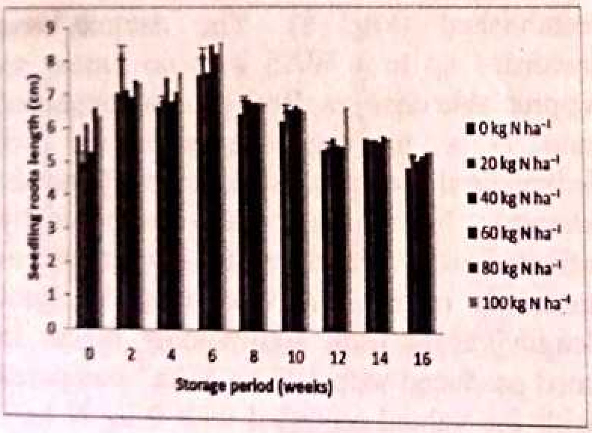

Fig. 9. Effect of nitrogen on seedling roots length at different storage periods. I represents standard error ($p < 0.05$).

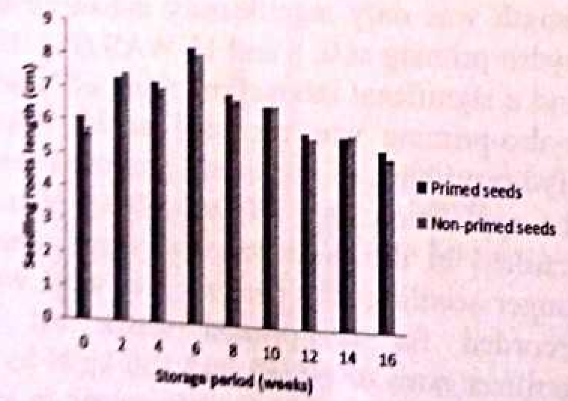

Fig 10. Effect of hydro-priming on seedling roots length at different storage periods I represents standard error ($p < 0.05$).

Discussion

Increase in moisture content of stored seeds with increase in storage period is in agreement with report of other researchers. Seeds are reported to absorb or release moisture to equilibrate with the relative humidity and temperature of the surrounding air in storage (Daniel and Ajala, 2006). Daniel (2007, 2009) also stated that seeds tend to absorb moisture from the surrounding air, leading to increased seed moisture content and rapid deterioration. The same trend was also reported for soybean packaged in gunny bag (Khalequzzama *et al.*, 2012). Amjad and Anjum (2002) also reported that as relative humidity of the storage atmosphere increased, the moisture content of onion seeds increased, finally reaching 26.42% at 42 °C and 100% relative humidity.

The heaviest seeds recorded in plants treated with 60 kg N ha^{-1} are in agreement with the report of Mollafilabi and Hosseini (2012) which shows that application of N at 60 kg ha^{-1} resulted in the production of *Calendula officinalis* with the highest weight. Ogutu *et al.* (2012) also reported that addition of N fertilizer increased 1000 seed weight by 4.5% in bean. In rape seed, the highest seed weight was produced at 120 kg N ha^{-1} but the value obtained was statistically similar with that at 60 kg N ha^{-1}. The increase in seed germination percentages and seedling length within 6-10 WAS in all fertilizer treatment could be an indication of broken dormancy with passing time. Dormancy is known to be a problem in many *Solanum* species which according to Ibrahim *et. al.* (2001) is responsible for poor germination and slow seedling emergence and the result of this study indicates that seeds of *Solanum marcrocarpon* may exhibit dormancy irrespective of soil fertility status. Adebola and Afolayan (2006) also reported seed dormancy in *Solanum aculeastrum*.

Application of N fertilizer influenced germination percentage as well as seedlings length in this study. This agrees with the report of others. Knowles *et. al.* (1991)

reported that nitrogen fertilizer application resulted in the production of wheat seeds with higher final germination percentage and with reduced number of days to germination. Warraich *et. al.* (2002) also recorded increase in final germination percentage, reduced time to 50% germination and mean germination time with N application in wheat. The authors opined that N application effects may be due to increase in grain protein content and weight amongst others. According to Chaturvedi (2005) nitrogen nutrition influences the content of photosynthetic pigments, the synthesis of the enzymes taking part in the carbon reduction and the formation of the membrane system of chloroplasts. N being an important constituents of nucleotides, proteins, chlorophyll and enzymes, is involved in various metabolic processes and has direct impact on vegetative and reproductive phases of plants.

Decline in germination percentage and seedling growth parameters as seeds aged in the current study agrees with the report of Maity *et. al.* (2000) which shows that during ageing, mung bean seeds lose vigour, ability to germinate and ultimately become less viable. Hussein *et. al.* (2001) also reported decrease in germination percentage of sunflower seeds with increasing ageing period. The author further reported reductions in seedling length, germination speed index, seed vigor index, seedling fresh and dry weight. Siddiqui *et. al.* (2008) reported that when wheat seeds were incubated under high relative humidity, viability decreased with increase in incubation period. Shashibhaskar (2009) recorded maximum decrease in quality traits such as germination percentage, seedling length, seedling vigour index, seedling dry weight, germination speed, dehydrogenase activity with higher moisture content in tomato seeds after 10 months storage. The enhancement of seed germination by hydropriming in this study is in agreement with the report of Dastanpoor *et. al.* (2013), Ahammad *et al.* (2014) and Janmohammadil *et. al.* (2008) which revealed that germination percentage, germination index, seedling vigour index and length of seedling and other parameters were significantly increased by hydropriming of seeds. The higher germination percentage recorded in primed seeds may be attributed to the pre-germination steps such as DNA and RNA synthesis accomplished in the seed during the priming state, consequently the seeds are physiologically close to germination and have fewer steps to complete than unprimed seeds (McDonald, 2000).

It is concluded from this study that nitrogen fertilizer application significantly affected seed weight, germination percentage and seedling growth of *Solanum macrocarpon*. Application of 80 kg N ha^{-1} resulted in best germination percentage. Seed hydropriming improved germination throughout the storage period but only improved seedling length prior to storage. Seed germination percentage and seedling growth generally declined as seed aged beyond 10 and 6 WAS respectively. Based on the result of this study, application of 80 kg N ha^{-1} to the mother plant is recommended to obtain high quality seed of *Solanum macrocarpon*. Seed should also be hydroprimed to obtain higher germination percentage.

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