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S2012-19: Bacteriological Quality of Water From Selected Water Sources in Samburu South – Kenya

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S2012-20: Effects of Seed Maturity Level, Desiccation, Packaging and Storage Temperature on Seed Quality of Spiderplant (Cleome gynandra L.)

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Abstract

Two experiments were conducted to determine the critical moisture content and the best storage conditions for spiderplant seeds with a view to addressing the poor seed quality and promote conservation of this plant genetic resource. In experiment one, seeds harvested at three pod maturity stages; yellow, yellow-green and green were dried above silica gel to percentage moisture contents of 20, 10, 5 and 2. For each maturity stage, viability and vigour tests were conducted. Percent germination and vigour increased with seed maturity. Prior to storage, initial germination for green, yellow-green and yellow pod maturity stages was 0.75%, 12% and 14.5% respectively. Green pod maturity stage had the least vigour as indicated by the mean germination time and electrical conductivity values of 4.18days and 420.77$\mu Scm^{-1}g^{-1}$ respectively. Yellow pod maturity stage had the highest vigour of 2.00 days mean germination time and electrical conductivity of 20.51$\mu Scm^{-1}g^{-1}$. Yellow-green pod maturity stage was intermediate with 2.02days mean germination time and 22.61$\mu Scm^{-1}g^{-1}$ of electrical conductivity. Germination of seeds from yellow and yellow-green pods increased with reduction in moisture content while that of green pods decreased. Based on this study, the critical moisture content for spiderplant seeds could be between 5% and 3%. Mature seeds that had been dried to the four moisture levels in experiment one were sealed in aluminum foil and polythene packets and stored at ambient temperatures (10^oC - 26^oC),

5°C and -20°C for six months. After six months storage period, viability and vigour tests were conducted. Seed stored for six months at 5% moisture content and minus 20°C recorded the highest seed quality. There were no significant differences (P>0.05) between seeds packaged in aluminium foil and polythene packets. In conclusion, spiderplant seed should be harvested at yellow pod maturity stage, dried to 5% moisture content, and stored at minus 20°C.
Key words: *Cleome gynandra* L., desiccation, storage conditions, viability, vigour

INTRODUCTION

Indigenous crop genetic diversity is of vital importance to future efforts of providing sustainable increases in agricultural production, especially through genetic manipulations. Great efforts should, therefore, be geared towards conservation of these germplasm, for present and future utilization. Many crops of regional or local importance have been relatively ignored by most scientific studies. Ironically, though, this goes on against a rich background of information on the vital role that these indigenous crops have played in feeding the majority of rural populations throughout Africa.

Among the wild edible plants, indigenous leafy vegetables feature prominently in the diet of African communities. The indigenous vegetables commonly grown in Kenya include cowpea (kunde), slenderleaf (mitoo, miroo), spiderplant (dek, tsaka, saget), Jews mallow (murere, apoth), African nightshades (managu, sugi, osuga) and leaf amaranths (dodo, terere). These species were considered as weeds and were not cultivated (Ivens, 1967), although harvested as vegetables from the world (Chweya, 1997; Bukenya-Zaraba, 1997). Slowly these species are being recognized as vegetables that need to be cultivated in small sections of the farm, kitchen and home gardens and along rows of staple crops (Chweya, 1997). However, these African indigenous vegetables have received little attention from scientists and policymakers in terms of plant breeding and seed production (Chweya, 1997; Schippers, 1997). There is need therefore of carrying out studies on how seed quality attributes of these vegetables are affected by seed production, handling and storage practices.

This study focuses on spiderplant (*Cleome gynandra* L.). Synonyms of *Cleome gynandra* (L.) are *Gynandropsis gynandra* (L.) Briq.; *Cleome pentaphylla* (L.); *Pedicellaria pentphylla* (L.); *Gynandropsis pentphylla* (L.); *Gynandropsis denticulate*; *Cleome acuta* (Hammer, 1986). *C. gynandra* belongs to the botanical family Capparaceae (Capparidaceae) and sub family cleomoideae. The family contains about 700 to 800 species divided into 45 genera (Kuhn, 1998; Kokwaro, 1994). The genus *Cleome* is a near relative of the cruciferae (Brassicaceae) family (Bremer and Wannorp, 1978). It has over 200 species (Iltis, 1967; Bruinsma, 1985) consisting of herbaceous plants.

Though not actually threatened with extinction, the spiderplant is facing the danger of genetic erosion. Little domestication has been done. With increasing pressure on agricultural land, its ecological niches are fast disappearing. Genetic erosion, hence, is bound to be rapid. In general, little is known about the cultivation techniques, the extent and structure of genetic variation, and the seed physiology of spiderplant. Very few systematic studies on characterisation and evaluation have been conducted on this species and little, if any, systematic germplasm collecting has been done (Martin, 1984). This is primarily because of the low priority and status accorded to this crop nationally and internationally. This is regrettable considering the significant contribution this local vegetable has played in the nutritional well being of many rural populations, especially in Africa. Furthermore, beyond Africa this vegetable has a significant role to play in widening the world's currently narrow food base. Grubben and Almekinders (1997) recommended that plant breeding and seed production by farmers and private sector should be stimulated. This they noted could reduce the risk of genetic erosion of this species. Chweya (1997) observed that there should be formal research to support domestication of spiderplant through activities like evaluation, characterization and seed production.

It is important, therefore, that germplasm of spiderplant be systematically collected, conserved, characterised and documented for present and future use. It is however, unfortunate, that little is known of spiderplant seed production, handling and seed storage physiology. Such studies are, therefore, important for effective management of spiderplant seeds under short and long-term storage. This would minimise genetic erosion of germplasm arising as a result of long-term storage ageing processes.

In Kenya, spiderplant has gained popularity among farmers due to its nutritional and medicinal values. In the local markets, bundles of leafy shoots as well as uprooted young plants are offered at exorbitant prices in many parts of Kenya (Western, Nyanza, Coast, Nairobi, Central and Rift Valley), (National Research Council, 1984; Maundu, *et al*., 1993). The vegetable can therefore provide a source of income for rural areas, especially for the poor rural women and the unemployed youth.

It is popular in cultural diets and existing evidence suggest that spiderplant is endowed with higher level of nutrients than its exotic counterparts (Chweya and Mnzava, 1997). The leaves contain over and above the normal recommended adult daily allowance of vitamins A and C, calcium and iron (Arnold *et al*., 1985). The amino-acid composition of spiderplant leaf-protein has a high chemical score, comparable to that of exotic vegetables such as spinach. High levels of

nutritionally critical amino acids, like lysine, arginine, aspartic acid, glutamic acid, tyrosine and histidine have been reported (Mnzava, 1990*).*

The leaves and seeds of spiderplant are used in indigenous medicine in many countries (Baruah and Sarma, 1984; Kumar and Sadique, 1987; Opole *et al*., 1995). Indigenous knowledge possessed by rural women in Kenya indicates that spiderplant has several medicinal uses (Opole *et al*., 1995). Its leaves are crushed to make a concoction that treats scurvy and marasmus. Sap from young leaves treats epilepsy and recurrent malaria. Seeds and roots are ingested for the expulsion of roundworms and bruised leaves are applied on boils to prevent formation of pus. Spiderplant has insecticidal, anti-feedant and repellent characteristics (Verma and Pandey, 1987; Chandel *et al*., 1987; Akhtar, 1990; Pipithsangchan, 1993). Leaves have anti-tick properties (Chandel *et al*., 1987). The ethanol extract is toxic to insect pests, such as painted bug (*Bagrada cruciferarum Krik*) and the Diamond Back Moth of cabbage (*Plutella xylostella* L.), (Pipithsangchan, 1993). The extract from the mature seeds is toxic to brinjal aphid *(Aphis gossypii* Glov.) and the larvae of *Heliothis armigera* (bollworm), (Verma and Pandey, 1987). The seeds contain phenolic compounds, which are natural products (Jain and Gupta, 1985). Lipids from seeds could be used in soap manufacture (Gupta and Chakravarty, 1987).

It has been reported that one of the major problems in the cultivation of spiderplant is the availability of high quality seeds (Chweya and Ezyaguirre, 1999). Farmers harvest leaves as vegetables for a number of times before allowing plants to go into seed production or nip off the first flower heads to encourage branching for more seed production. A survey carried by Maundu *et al*. (1993) found that the majority of growers use tins and polythene paper because they are readily available. Traditionally seeds are kept in guards and pots. Major problem faced by farmers is the production of seed that possesses low viability and viguor. The production practices, harvesting, processing, packaging and storage of spider plant could be contributing to poor quality of seed planted by farmers. The purpose of this research was to study how the seed quality of spider plant is affected by different maturity stages, packaging and storage conditions, with a view to finding out the optimal method of production, handling and storing of these seeds.

Fig.1: Photograph of spiderplant (*Cleome gynandra* L.) taken from one of the experimental plots.

MATERIALS AND METHODS

Maturity stage experiment

To ensure that seeds were harvested at different maturity stages even on a single plant, individual flowers with anthers exposed at a time when pollination is expected were tagged using strings of different colours for each date of tagging, which corresponded to the date of fertilization. The first tagging of flowers was done on 19/6/2002 on five plants from each of the six experimental plots, the second on 29/6/2002 while a final tagging was done on 29/7/2002. Thereafter, seeds were harvested at once on 14/8/2002 in three-pod maturity classes characterized by distinct visual colours. Yellow pods were at 55 days after fertilization (DAF); intermediate yellow-green pods were at 45 DAF and a final stage of green pods was harvested after seeds had been maturing on plant for 15 DAF.

Seeds enclosed in fruits at different maturity classes described above were manually removed from the plants on 14/8/2002 and placed in khaki envelopes (A 3), packed loosely in a carton (48 cmx36 cmx30cm) and transported to the laboratory at National Museums of Kenya (NMK), Nairobi, where they were kept under room temperatures. In the following morning six pods were shelled manually to obtain seeds for initial moisture content determination so that further

investigations on initial viability, vigour and desiccation could be started at known seed moisture content.

Desiccation experiment

Dry seeds of *Cleome gynandra* L. (accession number, GBK-032229-Uasin-Gishu), sealed in an aluminium foil packet (6cmx6cm) were obtained from the Gene bank of Kenya, Muguga. The seeds were transported to Chepkoilel campus of Moi University. Prior to sowing and in order to avoid imbibition injury, the sealed packets were opened and allowed to stand at room temperature over night. The seeds were planted in the field using Randomized Complete Block Design (RCBD) at Chepkoilel farm, Moi University Eldoret which is situated at latitude $0^0 30^0$ N, longitude $35^0 15^0$ E and altitude 2180 meters above sea level. The area is within the Uasin Gishu plateau, which is in the Lower Highlands (LH3) agro ecological zone (Jaetzold and Schmidt, 1982). The site has a temperature range of 10^0C- 26^0C and relative humidity of 45%- 55%. Spiderplant seeds were harvested at three developmental stages: yellow pods - 55 days after flower opening (DAFO); yellow-green pods - 45 DAFO and green pods -15 DAFO. Prior to desiccation, initial seed moisture on fresh weight basis was determined gravimetrically in five replicates each of 50 seeds in a well ventilated oven at 103^oC±1^oC for 17 hours. Seeds were removed in the oven and allowed to cool for about 30- 45 minutes inside a desiccator. Seed moisture content was expressed on a fresh weight basis as:

$$\% \text{ seed moisture content} = \frac{\text{Initial seed weight (g)} - \text{seed weight after drying (g)} \times 100}{\text{Initial seed weight (g)}}$$

The protocol developed by IPGRI and DFSC (1999) was followed with certain modifications to determine the seed desiccation tolerance at each of the three-development stages. Seeds were dried in silica gel in a ratio of 1:5 and enclosed in 6 cm x 8 cm perforated nets to allow the easy separation of the small seeds from the silica during re-weighing. For each maturity stage, randomly selected seed samples were dried to four target moisture levels of 20%, 10%, 5%, and 2% that gave a range above and below 12-14% which is the commonly recommended level for many crops. Seeds were dried using the method described in the DFSC/IPGRI protocol (1999):

$$\text{Weight of seed (g) at TMC} = \frac{\text{(100-IMC)}}{\text{(100-TMC)}} \times \text{initial seed weight (g)}$$

Where, TMC is the target moisture content and

IMC is the initial moisture content.

Periodically, seeds were removed from silica gel for re-weighing to monitor water loss and time taken to attain the various target moisture contents noted. To ensure consistent rapid drying of seeds, hydrated silica gel was replaced every five hours in all the containers at the same time and periodic thorough mixing of seeds particularly during re-weighing and changing of silica gel. After achieving the four-desiccation levels (20%, 10%, 5%, and 2% moisture content), germination, electrical conductivity and actual moisture content tests were carried out according to ISTA (2005).

Storage experiment

Storage experiments were set using seeds from yellow pod maturity stage dried using silica gel to four target moisture levels of 20%, 10%, 5% and 2% (from the desiccation experiment above). Dried seeds were sealed in aluminum foil and 30µm-thick polythene packets and stored at three storage temperatures: ambient, 5^{o}C and minus 20^{o}C for six months. Aluminium foil containers are commonly used for seed storage at the Gene bank of Kenya while polythene is more readily available to farmers. For each treatment, 400 seeds were used for germination, 200 seeds for moisture content determination and 100 seeds for electrical conductivity test. After six months storage period, seeds were removed from the storage conditions and percent germination, mean germination time and electrical conductivity tests carried out according to ISTA (1995).

RESULTS

Maturity stage of Cleome seeds

The results shown in Table 1 indicate that there were significant ($P \leq 0.05$) effects of maturity stages on percent germination, mean germination time and electrical conductivity of Cleome seeds (Table 1). Seeds from green pods had the lowest germination and vigour. Seeds from Yellow-green pods were intermediate and those from yellow pods had the highest germination percentage and vigour (Table 1). In general, germination was poor probably due to primary dormancy.

Table 1. Effect of maturity stage on percent germination, mean germination time and electrical conductivity of spiderplant seeds.

Maturity stage	Germination (%)	Mean germination time (days)	Electrical conductivity ($\mu Scm^{-1}g^{-1)}$

Green pods	(-)	(-)	(-)
Y/green pods	12.25 (±0.500)	2.06 (±0.005)	27.10 (±0.005)
Yellow pods	14.50 (±0.580)	2.04 (±0.008)	25.94 (±0.006)
Significance	*	*	*
$LSD_{0.05}$	1.45	0.01	0.93

In brackets are standard deviation values, *significant at $P \leq 0.05$ according to LSD test.

(-) no germination recorded

Experiment on Desiccation Tolerance

The percentage germination improved with decrease in moisture content, for seeds from yellow-green and yellow pod maturity stages (Table 2). Green pods maturity stage recorded zero germination at 5% and 2% moisture contents (Table 2). This implies that seeds at green pod maturity stage were immature and could not tolerate desiccation. Desiccation had no significant effects on mean germination time and electrical conductivity on seeds from yellow pod maturity stage (Table 2). Yellow pod maturity stage took the least time to dry to various target moisture contents (Table 2). This was due to the fact that the initial moisture content was low, at 27.1% (Table 2).

Table 2. Effect of desiccation on percent germination, mean germination time and electrical conductivity of spiderplant seeds harvested at different maturity stages.

Maturity stage	Initial moisture content	Target moisture content	Actual moisture content	Desiccation time (hrs)	Germination (%)	Mean germination time	Electrical conductivity
Green	70.2				1.50	4.18	420.77
		20	12.80	10.00	1.25	4.32	536.65
		10	10.00	10.75	0.75	4.33	543.21
		5	4.70	30.25	0.00	0.00	629.05
		2	2.30	33.42	0.00	0.00	658.48
Mean					0.70 (±0.58)	2.57 (±1.03)	557.63 (±68.91)
Significance					*	*	*
$LSD_{0.05}$					0.120	0.001	4.31
Y/green	41.3				5.00	2.02	22.61
		20	12.13	2.08	6.75	2.04	24.61
		10	10.80	2.75	9.00	2.05	25.75
		5	4.40	26.42	12.00	2.06	27.18
		2	2.10	29.42	11.75	2.14	32.18
Mean					8.90 (±2.42)	2.062 (±0.03)	26.261 (±2.51)
Significance					*	*	*
$LSD_{0.05}$					1.25	0.002	0.83
Yellow	27.1				6.75	2.00	20.51
		20	11.60	1.25	9.25	2.01	20.89
		10	9.80	2.33	11.50	2.01	21.17
		5	4.30	25.58	14.50	2.02	22.94
		2	2.40	28.75	14.00	2.04	24.47
Mean					11.20 (±2.08)	2.016 (±2.01)	21.99 (±1.37)
Significance					*	Ns	Ns
$LSD_{0.05}$					0.35	0.05	4.12

In brackets are standard deviation values. * Significant at $P \leq 0.05$, ns = not significant at $P > 0.05$ according to LSD test.

Storage of Cleome seeds

The three temperature regimes used in this study were significantly different ($P \leq 0.05$) in their effects on percent germination, mean germination time and electrical conductivity of spiderplant seeds stored for six months (Table 3). Seeds stored at minus 20^{o}C recorded the highest viability and vigour, while seeds stored at room temperature had the least seed quality (Table 3). Seeds stored at 5^{o}C were intermediate in quality.

Table 3. Effect of storage temperature on percent germination, mean germination time and electrical conductivity of spiderplant seeds stored for 6 months at 5% moisture content.

Storage temperature	Germination (%)	Mean germination time (days)	Electrical conductivity ($\mu Scm^{-1}g^{-1}$)
Room (25-30^{o}C)	85.0 ($\pm$0.58)	2.33 ($\pm$0.005)	36.24 ($\pm$0.006)
5	89.0 ($\pm$0.50)	2.27 ($\pm$0.005)	31.65 ($\pm$0.005)
-20	95.0 ($\pm$0.58)	2.21 ($\pm$0.006)	29.27 ($\pm$0.006)
Significance	*	*	*
LSD $_{0.05}$	3.5	0.03	1.43

In brackets are standard deviation values. *Significant at $P \leq 0.05$ according to LSD test.

Reduction in moisture content had a significant ($P \leq 0.05$) effect on percent germination, mean germination time and electrical conductivity (Table 4). Results of Table 4 show a general trend of seed quality improvement with moisture content reduction up to 5%. However, further drying to 2% moisture content resulted into a decline in seed quality (Table 4). Lowest germination of 55.5% was recorded at 2% moisture content and at 5% moisture content germination was highest at 94.5% (Table 4). Vigour as indicated by mean germination time and electrical conductivity was also lowest at 2% moisture content and highest at 5% moisture content (Table 4).

Table 4. Effect of moisture content on percent germination, mean germination time and electrical conductivity of spiderplant seeds stored for six months at minus 20oC.

Moisture content	Germination (%)	Mean germination time (days)	Electrical conductivity ($\mu Scm^{-1}g^{-1}$)
20	76.5 (±0.58)	2.26 (±0.006)	33.41 (±0.006)
10	78.8 (±0.50)	2.23 (±0.005)	31.99 (±0.005)
5	94.5 (±0.58)	2.21 (±0.006)	29.27 (±0.010)
2	55.5 (±0.58)	2.38 (±0.005)	35.67 (±0.005)
Significance	*	*	*
$LSD_{0.05}$	11.7	0.01	1.33

In brackets are standard deviation values. *Significant at $P \leq 0.05$ according to LSD test.

In this study, foil and polythene did not differ significantly ($P > 0.05$) in their effects on percent germination, mean germination time and electrical conductivity of Cleome seeds stored for six months (Table 5). Results of Table 5 indicate that foil gave higher seed quality than polythene.

Table 5. Effect of container on percent germination, mean germination time and electrical conductivity of spiderplant seeds stored for six months at minus 20oC and 5% moisture content.

Storage container	Germination (%)	Mean germination time (days)	Electrical conductivity ($\mu Scm^{-1}g^{-1}$)
Foil	94.5 (±0.58)	2.21 (±0.005)	29.27 (±0.006)
Polythene	93.5 (±0.58)	2.22 (±0.005)	29.28 (±0.006)
Significance	ns	ns	ns

$LSD_{0.05}$	2.8	0.03	1.15

In brackets are standard deviation values, ns = not significant at $P>0.05$ according to LSD test.

Effects of moisture and temperature after six months storage were significant ($P \leq 0.05$) for percent germination, mean germination time and electrical conductivity (Figure 1, 2, 3)). Seed stored at 5% moisture content and minus 20^{o}C gave better seed quality than seed stored at 2% moisture content while seeds stored at room temperature had the least quality (Figures 1,2,3). Highest germination of 95% was realized at minus 20^{o}C and 5% moisture content, while the lowest germination of 52% was recorded at room temperatures and 2% moisture content (Figure 1). The least mean germination time and electrical conductivity of 2.11 days and 26.36 $\mu Scm^{-1}g^{-1}$ respectively were recorded for seeds stored at minus 20^{o}C and 5% moisture content, while the longest mean germination time of 2.35 days and highest electrical conductivity of 35.13 $\mu Scm^{-1}g^{-1}$ were recorded for seeds stored at room temperatures and 2% moisture content (Figure 2,3).

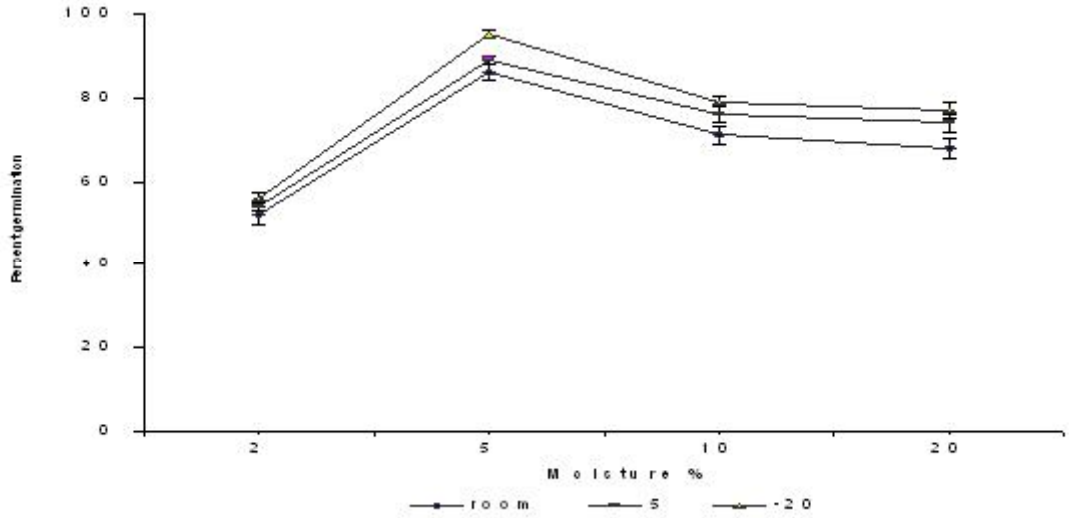

Fig.1. Effect of moisture and temperature on percent germination of spiderplant seeds stored for six months. Each point is an average of 4 determinations ± standard error of the difference (SED). Standard error bars are used to compare points within a temperature regime.

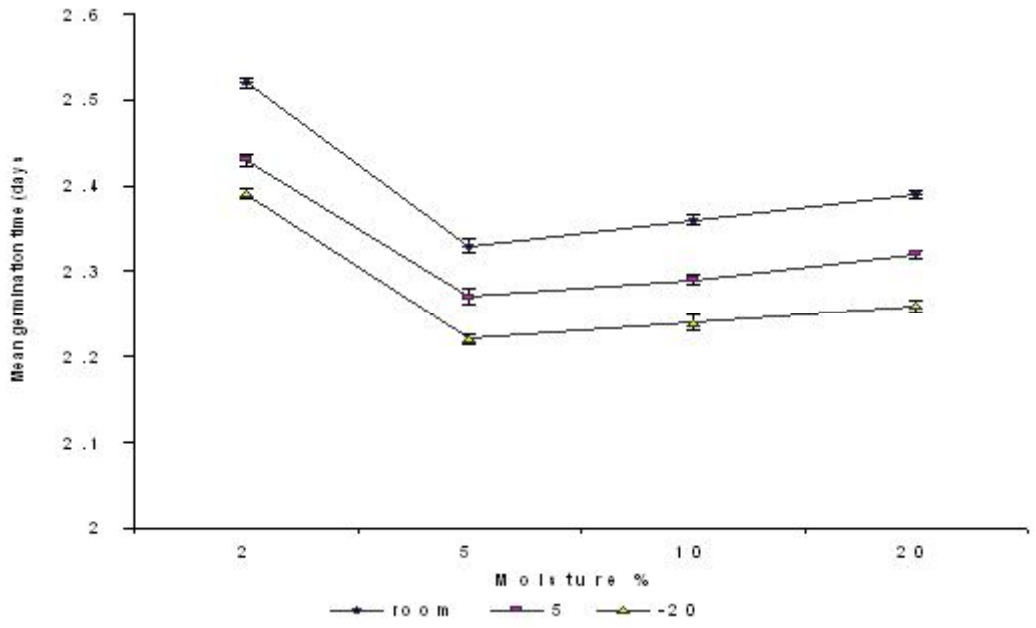

Fig.2. Effect of moisture and temperature on mean germination time of spiderplant seeds stored for six months. Each point is an average of 4 determinations ± standard error of the difference (SED). Standard error bars are used to compare points within a temperature regime.

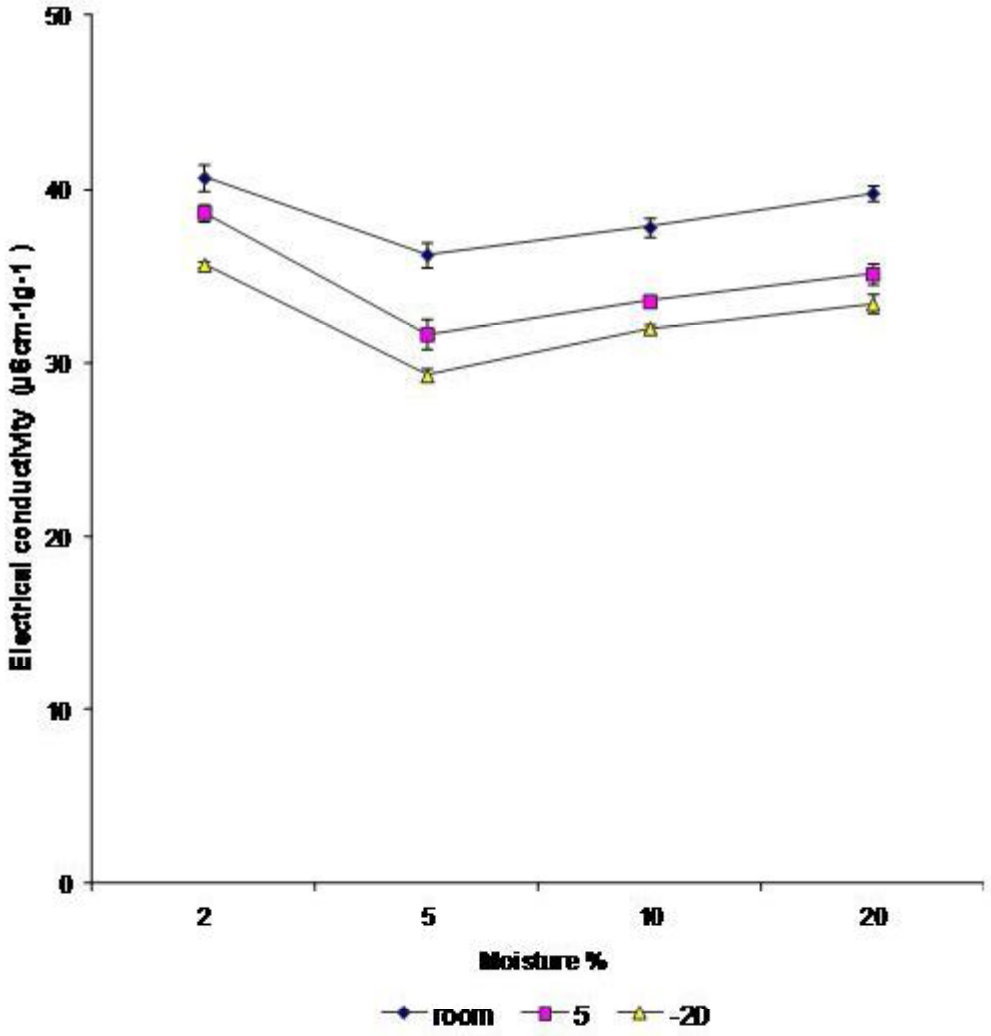

Fig.3. Effect of moisture and temperature on electrical conductivity of spiderplant seeds stored for six months. Each point is an average of 4 determinations ± standard error of the difference (SED). Standard error bars are used to compare points within a temperature regime.

DISCUSSION

Maturity Stage of Cleome seeds

The results of this study showed that there was an increase in germination percentage as well as in vigour as seeds developed to full maturity. Seeds from green pods had the least germination percentage, while seeds from yellow pods had the highest germination percentage and seeds from yellow-green pods were intermediate. According to Harrington (1972), Tekrony and Egli (1997), Muasya *et al*. (2002), highest seed quality is attained at physiological maturity, which in this study could be the yellow pod maturity stage. Xu and Bewley, (1991); Leprince *et al*., (1993); Bewley and Black, (1994); Kermode, (1995), pointed out that following fertilization, there is the histo-differentiation phase, followed by cell expansion phase and finally physiological maturity. From the findings of this study the green maturity stage was probably at the histo-differentiation stage, the yellow-green stage at cell expansion phase, while the yellow pod maturity stage was close to physiological maturity of spiderplant seeds and hence gave higher seed quality than green and yellow-green pod maturity stages.

Desiccation experiment

In this study the initial germination results obtained were very low and could be attributed to primary dormancy factors. Yepes (1978) observed that freshly harvested seeds of spiderplant exhibit dormancy. Thus, given that spiderplant seeds used in this study were freshly harvested and immediately processed for storage, there was a high possibility of primary dormancy being expressed, at least in the initial germination tests.

Orthodox seeds do not tolerate desiccation at all stages of their development (Kermode *et al*., 1986). According to Hong and Ellis, (1996), the development ability of seed to tolerate desiccation to very low moisture contents may occur at different developmental stages in different species. Dasgupta *et al*., (1982) demonstrated that, when immature desiccation-intolerant embryos of bean (*Phaseolus vulgaris* L.) were desiccated, there was a general collapse of the membranes, which was not apparent when more mature, desiccation-tolerant embryos were dried under the same conditions. In this study, no germination was observed when the seeds from green pods were dried to 5% and 2% moisture contents, indicating desiccation tolerance had not been attained or young Cleome could not survive rapid drying. This was in contrast to mustard seeds, which germinated prior to the attainment of desiccation tolerance (Fischer *et al*., 1988). Tolerance of rapid desiccation usually seems to be delayed until most of the reserve materials have been laid down, close to maximum dry weight or physiological maturity (Ellis *et al*., 1987). The present study is in

agreement with the above observation as seeds from yellow-green and yellow pods were tolerant to desiccation and viability increased with reduction in moisture content but seed from green pods was intolerant to desiccation and recorded zero germination.

Generally in this study, percentage germination increased with moisture reduction up to 5% but reduced at 2% moisture content. Reduction in vigour status was noticed especially for seed from green and yellow-green pods as indicated by increased mean germination time and electrical conductivity. This could be attributed to the rate at which drying was carried out (1:5; seed: silica gel). Kermode and Bewley (1994) demonstrated that while gradual rates of water loss result in the germination of castor bean seeds as young as 25 days after pollination (DAP), rapid drying over silica gel is fatal to seeds younger than 55 DAP. According to Ellis *et al*., (1985a), imbibition injury can occur in seeds that have been over dried. This study agrees with this observation especially for spiderplant seed dried to 2% moisture content where low percent germination was recorded across all the maturity stages.

Storage experiment

Viability increased in storage possibly due to loss of dormancy. After-ripening dormancy loss in stored seed has been observed in *Amaranthus retroflexus* (Omami *et al*., 1992) and *Festuca idahoensis* (Goodwin *et al*., 1995). Storage temperatures of -20^{o}C gave seeds of highest quality, implying that Cleome seeds are cold tolerant and probably chilling has a dormancy breaking effect.

Removing every last bit of water from seeds is detrimental (Ellis *et al*., 1985). Reports using numerous species (Chai *et al*., 1998) have demonstrated that detrimental effects were not initially evident, but became more apparent with time. In other words, the seeds aged more rapidly under extremely dry conditions. Hence it can be concluded that drying to extremely low water contents may shorten seed longevity and for many seeds there is an optimum moisture level for storage at which longevity is maximized and below which seeds are damaged. This is the critical water content (Ellis *et al*., 1985). In the present study, germination percent tended to increase with moisture reduction up to 5% but the trend declined at 2% moisture content (Table 4). Therefore the findings of this study are in agreement with the aforementioned observation by Ellis *et al*., (1985) that drying seeds to extremely low water contents could be detrimental and the damage is even more pronounced in storage.

Although germinability increased in storage, there was gradual seed deterioration as indicated by mean germination time and electrical conductivity (Table 4). Seeds stored at room

temperatures and 20% moisture content recorded the lowest vigour while seed stored at minus 20^{o}C and 5% moisture content recorded the highest vigour. This confirms the physiological influence of temperature and moisture content during storage that deterioration of orthodox seeds increases with increase in seed moisture and temperature (Perry, 1981). It has generally long been known that, the greater the moisture content and storage temperature of orthodox seeds, either singly or in combination, the shorter is the period of seed survival (Roberts, 1973a). Therefore, the high percent germination and high vigour (low mean germination time and low electrical conductivity) exhibited by *C. gynandr*a seeds stored at 5% moisture content and minus 20^{o}C is in agreement with the above observation. Roberts (1984), has pointed out that, a viability test is limited in detecting quality differences among high germinating seed lots. Tekrony and Egli, (1997) further observed that the results of seed storage are unlikely to adequately reflect the degree of seed deterioration that has taken place. This has been reflected in this study by the high germination of 95%, yet *C. gynandra* seeds had deteriorated in storage as indicated by the electrical conductivity measurements (Table 8). Deteriorated seed lots have high electrolyte leakage and are classified as low vigour, while those with low leakage are considered as of high vigour (ISTA, 1995).

CONCLUSIONS

The experiments carried out in this study depicted spider plant seed as orthodox (can tolerate desiccation to low moisture content without losing viability) in nature since viability increased with decrease in moisture content. On the basis of this study, spiderplant seeds should be harvested at yellow pod maturity stage. The drastic decrease in percent germination from 5% moisture content to 2% moisture content indicated that the critical moisture content (optimum moisture level for storage at which viability is maximized and below which seeds are damaged) for spiderplant seeds could be between 5% and 3%.

This study has confirmed the beneficial effect of drying seeds to low moisture contents and storing at low temperatures. Based on the results of this study**,** it may be concluded that, to achieve high seed quality**,** *C. gynandra* seed should be dried to 5% moisture content and stored at sub zero temperatures (preferably minus 20^{o}C) since a percent germination of 95% was obtained when the seeds were stored at these conditions. However, these conditions can only be available in such places as the gene banks and other institutes that conserve seed for long-term storage. In this study, a germination of 85% was recorded for seed stored at room temperatures (10^{o}C-26^{o}C). The study showed that foil and polythene are similarly good as packaging materials for *C. gynandra* seed (at least

for short-term storage). Therefore farmers can harvest spiderplant seed at yellow pod maturity stage, dry it to about 5% moisture content, package in polythene (since readily available) and store at room temperatures for six months.

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