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Influence of Drying Method and Fruit Position on the Mother Plant on Seed Quality of Spiderplant (*Cleome gynandra* L.) Morphotypes from western Kenya

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ABSTRACT

Spiderplant is among the most popular African indigenous vegetables in Kenya, particularly in the western and coastal regions of the country. The influences of natural drying methods and fruit position on the mother plant on seed quality have not been adequately studied for spiderplant. The original spiderplant seeds for the study were sourced from farmers in Kakamega District and from wildly growing plants within Chepkoilel Campus in Uasin Gishu District, both in western Kenya. Seed quality tests were done on the four spiderplant morphotypes to determine the influence of natural drying at ambient temperatures on seed germination and fruit position on the mother plant both seed weight and seed germination. The results showed that sun drying of spiderplant seeds caused improvement on seed quality indicated by increased seed germination and germination rate in a number of morphotypes, while bottom and middle fruits produced heavier seeds that also resulted in better germination than fruits at the top of the plant. The objectives of were to study the influences of natural drying at ambient temperatures and fruit position on the mother plant on seed quality.

Keywords: Fruit position, morphotypes, seed drying, spiderplant seed quality.

INTRODUCTION

Seed drying

Each crop and plant species undergoes characteristic changes leading to seed ripening, which must be known to establish the best time to harvest [1]. A seed reaches physiological maturity (PM) when it has attained maximum dry weight [2, 3]. At that stage it can be removed from the plant without impairing the seed's germination.

As soon as seeds mature on the mother plant, they begin to deteriorate. The rate at which deterioration takes place depends on the environmental conditions inside and around the seeds.

Seed deterioration eventually leads to loss of viability or death when the seed is not able to germinate [4].

Early seed harvest may be desirable for seeds of some crop species. Fruits that are dehiscent, such as those of spiderplant, must be picked as soon as they ripe but before the fruits dehisce to release the dry seeds that drop to the ground. Further to this, birds such as red-billed Quelea (*Quelea quelea*) among others have been observed to eat spiderplant seed at the yellow pod stage, causing great seed loss, particularly around areas of Eldoret in Kenya. Thus, a balance must be made between late and early harvest to obtain the maximum number of high-quality seed of spiderplant. The seed crop must therefore be harvested before they are dry on their own on the mother plant then be dried. Many seeds including those of spiderplant fall into the group that is referred to as orthodox, which can be dried to very low moisture contents and may be stored that way for years [5, 6].

Drying is a vital operation in the chain of seed handling, since the moisture content of seeds is the most important factor determining whether and to what extent they will be liable to deterioration during subsequent storage [7]. Drying also temporarily inhibits the germination of seeds, reduces the moisture content to a level that prevents growth of microorganisms, especially fungi and bacteria, apart from retarding attacks on seed by insects [8].

Seed drying is intended to reduce the seed moisture content to safe limits to maintain its viability and vigour during storage, which may otherwise deteriorate quickly due to mould growth, heating, and enhanced microbial activity. Seed drying also permits early harvesting, long-term storage of seeds, more efficient use of land and manpower, use of plant stalks as green fodder, and production of high quality seed [8].

Depending upon the climate and the method of harvesting adapted, the threshed seed may or may not be dry enough for safe storage. Under less favourable conditions, threshed seed almost always needs further drying [4].

Seed moisture content and drying temperature are important factors to consider in relation to seed storability and survival. The maximum temperature that seeds will tolerate depends on species and how dry the seed is. The air temperature that seeds can tolerate also depends on the rate of drying since evaporation cools the seed and, if energy input is kept constant, temperature of the seeds themselves will be lower than air temperature [4].

Sun and air are commonly used to dry seeds in developing countries. Farmers traditionally dry small quantities of seed, utilizing the sun and natural wind, by spreading the threshed seed in a thin layer on smooth earthen floor or on straw matting. Sun drying requires no additional expenditure or special requirements. The major limitations of sun drying, however, are delayed harvest, risks of weather damage, and the possibility of mechanical admixtures.

When seeds are dried under the sun, the sun normally raises the temperature, thus lowering the relative humidity in the air around the seed [7, 9]. It is necessary to ensure a continuous and adequate airflow to remove the evaporated moisture in the air around the surface of the seed. It is possible to have overheating when doing sun drying of seed, especially while the seed is still having high moisture content. High temperature and ultraviolet radiation through direct sunlight, together with high moisture content may accelerate respiration and impose stress to the seed, thereby bringing about ageing, thus adversely affecting the germinability, and may even kill the seed [7, 4]. Overheating may also cause seed breakage, bleaching, scorching, and discolouration, damage to seed coat and loss of nutritional quality [7]. Prolonged exposure of seed to direct sunlight should therefore be avoided.

Too rapid drying of seed crops with high moisture content may also damage seeds, causing bursting or 'case-hardening' in which the surface of the seed dries out rapidly, sealing moisture within the inner layers. Similarly, underdrying or slow-drying, which are common in humid regions, may result in seed deterioration due to fungi and bacteria, which in extreme cases lead to total loss [7].

The actual temperature reached during sun drying depends on many factors and varies from day to day and during the day. In the dry season, most sun-dried seed will reach moisture content of 7-10% depending on climate. Moisture content of below 8% is under many circumstances sufficiently low for short-term storage at ambient temperatures and also sufficient for medium-term storage at below 5^{O}C [4].

Seed drying in the shade on the other hand can be advantageous under certain circumstances, for instance where high temperatures in the sun are capable of damaging seeds with high moisture content, and also where seeds are not fully ripe and therefore require a slow drying process to after-ripen and be able to repair small mechanical damages once lower than 15-20% moisture content is reached [4].

In forestry tree species like mahogany, seeds are air dried under shade since exposure to direct sunlight has been observed to lower viability [10]. Drying under shade is reported to ensure the slow release of moisture from the seed [10].

Fruit position on the mother plant in relation to seed quality

Spiderplant is propagated using seeds, with flowering occurring early within 4-6 week of growth and lasting for at least 2 months. While the continued development of axillary branches and terminal flowers extends the flowering period to 6-12 months, fruit development and maturation may take 3-4 months, with seeds maturing over several weeks [11]. Thousand-seed weight (TSW) has variedly been given as 0.91± 0.01 g or 0.92± 0.00 g [12], or 0.8 g [13].

Seed quality is judged by attributes such as germination percentage and seed size or weight, among others [14]. Germination percentage which is most universally used indicates the potential stand expected from planting specific seed lot [14], while seed size and TSW are largely used in the gravimetric classification to qualify seed lots in different vegetable crops [15]. Further, seed size and weight are two among those characteristics that are frequently associated with seedling emergence and field performance of planted crops [2, 1]. Seed performance which is determined during seed development is also associated with seed position, which is determined by position of the ovules within the fruit and fruit positions on the mother plant [3, 1]. Size can be influenced by the conditions under which seeds develop [16]for instance, the genotype of a developing embryo can influence the size that the seed attains, and also the maternal plants can control the amount of resources invested per seed, thus influencing the performance of seedlings of a given species [17].

Despite the documented variability in seed weight among species, populations, cytotypes, individuals, and even within an inflorescence, it has been observed as one of the more stable morphological characteristics of many plant species [18]. There are counter arguments among some authors for the probable cause of seed weight variation within an inflorescence as being either due to environmental change during maturation, or genetical control, thus subject to evolutionary change [18]. In general, large seeds tend to have higher proportion of seed germinating and giving rise to more vigorous seedlings [19]. While some species show no relationship between seed size and seedling performance, small seeds of soybean, however have been shown to have better germination than larger ones [20, 2]. Probable reasons for contradictions may the species studied or the experimental conditions used [21]. In *Corchorus* spp., which is one of the AIVs, it has been observed that the seeds extracted from capsules at the top and middle of the stem tend to be bigger, germinating faster and producing larger seedlings than smaller ones that are extracted from the base of the stem [13]. Seed selection on the basis of some function of size can therefore be used as a means of improving seedling vigour and crop yield [22].

The fruit of spiderplant is a long-stalked, narrow and dry, dehiscent siliqua, which is spindle-shaped capsule [11, 13]. The fruits are green, turn yellow when ripe and easily release many small, rough, depressed-globular and grey-to-black seeds on dehiscence [23, 11].

The production of high-quality seed is of prime importance to farmers and seed companies. Although the cost of seed is usually minor in the production of any crop compared to other production costs, the importance of seed will count to any success of the farm operation.

The objectives of these studies were therefore to investigate the influences natural drying methods at ambient temperatures and fruit position on the mother plant on seed quality of the four spiderplant morphotypes from western Kenya.

MATERIALS AND METHODS

Plant Materials

The studies were partly carried out at Chepkoilel Campus, Moi University in Eldoret, Kenya, and partly at Plant Research International in Wageningen, The Netherlands.

Seeds used in these studies were derived from plants raised for morphological characterization of the selected types of spiderplant and to distinguish the morphotypes. The initial seed was obtained from a mixed stand of spiderplants that had previously been grown on a plot at the Chepkoilel Campus of Moi University, Eldoret, Kenya. These were ecotype collections originated from Kakamega and Uasin Gishu Districts of western Kenya. The mother plants for these studies were raised in a plastic house, at the Department of Seed, Crop and Horticultural Sciences, Chepkoilel Campus of Moi University; with a view to control the growing conditions and also seed damage and loss caused by birds. For the natural drying study, the four spiderplant morphotypes were raised in the seed bulking plots that consisted of ten wooden boxes for each morphotype, measuring 47 cm x 29 cm and 6.5 cm, between April and July 2003. The boxes were distantly placed to form four blocks in order to minimize chances of cross-pollination. The fruits in each block were harvested when they had matured and turned yellow, and bulked separately. The seeds were extracted by hand threshing and divided into two portions for each morphotype. One portion was air dried under shade away from direct sunlight for 7 days and the other one in the sun for 4 days, but both at ambient temperatures. In the case of the fruit position study, the four spiderplant morphotypes were raised in a similar manner as for seed bulking above, but in an RCBD experiment with four replicates per morphotype, between July and November 2003. After 50% flowering, 2 plants were tagged in each replicate. On the tagged mother plants, sample fruits that had matured and turned yellow were randomly harvested from the bottom, middle and top positions of the inflorescence and separately bulked for each morphotype and pod position. The seeds were extracted by hand threshing and air dried under shade at ambient temperature. The dried seeds in each case were then placed in heat-sealed aluminium foil packets with minimum air and stored in a dry place at room temperature ($20^{O}C$) until the time to execute the seed germination tests, which were done between January and April 2004.

Investigation on the Influence of Natural Drying at Ambient Temperatures on Seed Germination

Using top of paper (TP) method, four replicates each of 50 seeds, for the four spiderplant morphotypes, were germinated on top of one layer of round filter paper of diameter 80mm, placed on thick filter paper size 14.3cm x 20.2cm, and put into transparent germination boxes. The substrate was moistened with 50 ml tap water, before imbibing the seeds. The boxes were stacked with the last box having an empty box fitted over it as a lid. The boxes were placed in a germination cabinet with temperature set at $30^{O}C$. The incubation was done under continuous darkness. A completely randomized design was used. Radicle protrusion was monitored regularly between 9 and 120 hours, from the start of incubation. The time taken to reach 50% maximum germination (T_{50}), mean germination time (MGT) and percent maximum germination (Gmax) were calculated using the software package SeedCalculator 3.0 (Plant Research International, The Netherlands). Comparisons of data means were performed with Student's t-Test. Significance was assumed at the level of $P \leq 0.05$.

Investigation of the Influence of Fruit Position on Thousand Seed Weight (TSW)

For TSW determination, 3 replicates of 1000 seeds were randomly sampled from the 3 fruit positions of each morphotype. The seeds were weighed on an analytical balance (Mettler AE 163; Mettler Instrumen B.V.; Tiel, Switzerland). The data on seed weight were analysed using a statistical programme SPSS (SPSS Inc., Chicago) and subjected to ANOVA, with mean separation performed with Duncan Multiple Range Test.

Table 1 Influence of natural drying method on days to reach 50% germination (T_{50}) with four spiderplant morphotypes from western Kenya.

Morphotype	Natural drying method	T_{50} (mean ± S.E.)
GG	Shade	0.58±0.01a
	Sun	0.57±0.00a
GP	Shade	0.64±0.04a
	Sun	0.62±0.04a
PG	Shade	0.90±0.03a
	Sun	0.86±0.06a
PP	Shade	0.78±0.02a
	Sun	0.67±0.03b

Figures followed by different letters for each morphotype along the columns are significantly ($P \leq 0.05$) different, according to Student's t-Test. Data are means of four replicates of 50 seeds for the four spiderplant morphotypes.

Investigation of the Influence of Fruit Position on Seed Germination

Seed germination test involved the incubation done as previously described above for the influence of natural drying at ambient temperatures on seed germination. Radicle protrusion was monitored regularly between 9 and 120 hours, from the start of incubation. Germination rate (time taken to reach 50% germination, T_{50}) and percent maximum germination (Gmax) data were calculated using the software package SeedCalculator 3.0, with means compared according to Student's t-Test.

RESULTS

Influence of Natural Drying at Ambient Temperatures on Seed Germination

There were no significant ($P \leq 0.05$) differences in germination rate (T_{50}) in the method of drying, with all the spiderplant morphotypes, except for morphotype PP where sun drying showed a significantly ($P \leq 0.05$) lower rate than shade drying (Table 1). Morphotype GG had significantly higher rate with shade drying than the rest, while PG showed a significantly ($P \leq 0.05$) lower rate (Table 1). Where sun drying was applied, morphotype GG had significantly ($P \leq 0.05$) higher germination rate than the rest, and significantly ($P \leq 0.05$) lower rate was observed for PG (Table 1).

There were no significant differences in mean germination time (MGT) in the method of drying, with all the spiderplant morphotypes, except for morphotype PP where sun drying showed a significantly ($P \leq 0.05$) lower MGT than shade drying (Table 2). With shade drying, morphotypes GG and GP were not different but showed significantly ($P \leq 0.05$) lower MGT than the other; PG had significantly ($P \leq 0.05$) higher MGT than the rest (Table 2). Morphotype GG achieved significantly ($P \leq 0.05$) lower MGT than others with sun dry, with morphotype PG indicating significantly ($P \leq 0.05$) higher mean germination time was (Table 2).

Table 2 Influence of natural drying method on mean number of days to reach maximum germination (MGT) with four spiderplant morphotypes from western Kenya.

Morphotype	Natural drying method	MGT (mean ± S.E.)
GG	Shade	0.66±0.02a
	Sun	0.64±0.02a
GP	Shade	0.73±0.05a
	Sun	0.78±0.03a
PG	Shade	1.04±0.04a
	Sun	1.15±0.03a
PP	Shade	0.85±0.02a
	Sun	0.77±0.01b

Figures followed by different letters for each morphotype along the columns are significantly ($P \leq 0.05$) different, according to Student's t-Test. Data are means of four replicates of 50 seeds for the four spiderplant morphotypes.

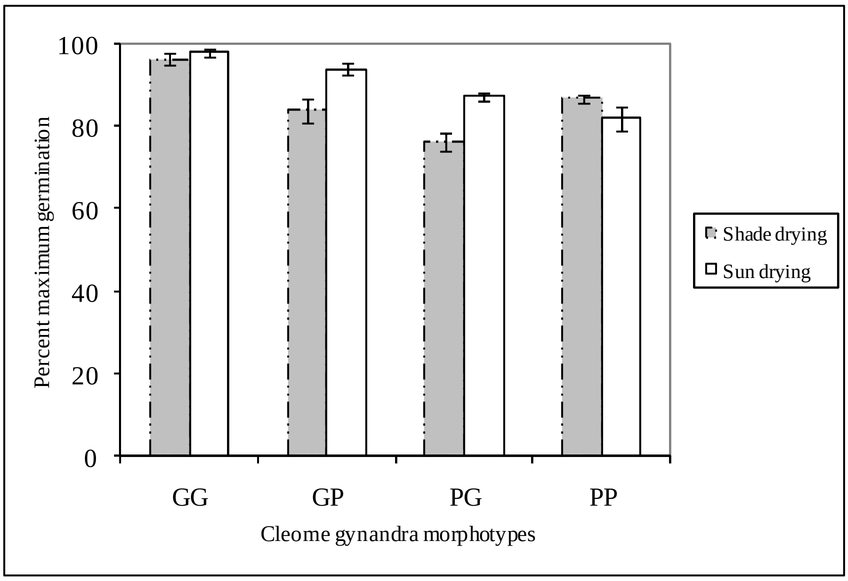

Figure 1 Influence of natural seed drying method on percent maximum germination (Gmax) with four spiderplant morphotypes from western Kenya:

The vertical lines indicate S.E. for comparisons of significant differences between natural drying methods.

Sun drying achieved a significantly (P≤0.05) higher percentage germination (Gmax) than shade drying with morphotypes GP, PG and PP (Figure 1). The morphotypes showed significant (*P*≤0.05) differences in Gmax with both natural drying methods, except for morphotypes GP and PP which were not different where shade drying was applied (Figure 1). Significantly (*P*≤0.05) higher germination occurred in morphotype GG with sun drying, while PG recorded significantly (*P*≤0.05) lower germination than the rest (Figure 1). With shade drying significantly (*P*≤0.05) higher germination was achieved by morphotype GG, and in PP a significantly (*P*≤0.05) lower germination than the rest was shown (Figure 1).

Influence of Fruit Position on a Thousand Seed Weight

Bottom fruits in GP and PP produced highly significantly (P≤0.001) heavier seeds than middle and top fruits, while middle fruits of all the four morphotypes produced highly significantly (P≤0.001) heavier seeds than top fruits (Table 3). Mean total TSW for capsule positions and morphotypes were also highly significantly (P≤0.001) different (Table 3). The overall mean TSW of 1.5750 ± 0.1071 g (dry air basis) was calculated from the results of Table 3.

Table 3 Influence of fruit position on a thousand-seed weight of four spiderplant morphotypes from western Kenya.

	Mean Thousand-seed Weight (g) ± S.E.			
Morphotype	Bottom fruits	Middle fruits	Top fruits	Morphotype totals
GG	1.565±0.007a	1.535±0.007ab	1.454±0.013bc	1.518±0.050f
GP	1.534±0.008a	1.461±0.013bd	1.381±0.007ce	1.459±0.067gj
PG	1.800±0.013a	1.708±0.014ac	1.605±0.018bd	1.674±0.054hkm
PP	1.726±0.015a	1.638±0.014bd	1.573±0.017ce	1.646±0.068iln
Fruit position totals	1.634±0.090a	1.585±0.095bd	1.503±0.095ce	

Figures followed by different letters a, b, c, d, and e along the rows, and letters f, g, h, i, j, k, l, m and n along the column for morphotype totals, respectively indicate high significant (P≤0.001) differences, according to Duncan's multiple range test. Data are means of three replicates of 1000 seeds for the four spiderplant morphotypes.

Influence of Fruit Position on Seed Germination

Bottom fruits in PP, middle fruits in GP and top fruits in PG produced seeds that showed significantly (P≤0.05) faster germination rate (T_{50}) compared to other fruit positions, while bottom fruits in GP and PP, and middle fruits in GP, PG and PP, were significantly (P≤0.05) faster in germination rate than top fruits (Table 4).

Table 4 Influence of fruit position on seed germination rate (T_{50}) with four spiderplant morphotypes from western Kenya.

Morphotype	**Germination Rate ± S.E. (T_{50})**		
	Bottom fruits	Middle fruits	Top fruits
GG	0.61±0.04a	0.62±0.03ab	0.72±0.06ac
GP	0.62±0.01a	0.53±0.02bd	0.92±0.05ce
PG	0.75±0.02a	0.74±0.01ac	0.59±0.02bd
PP	0.62±0.03a	0.78±0.03bd	0.87±0.03ce

Figures followed by different letters along the rows, for T_{50} are significantly (P≤0.05) different, according to Student's t-test. Data are means of four replicates of 50 seeds for the four spiderplant morphotypes.

Significantly (P≤0.05) higher germination was observed for the bottom fruits in GP than for top fruits (Table 5). No significant (P≤0.05) differences in germination were, however observed between bottom and middle fruits in all the four morphotypes; same when bottom fruits in GG, PG and PP, and middle fruits in GG and PG were compared with top fruits (Table 5).

Table 5 Influence of fruit position on seed maximum percentage germination (Gmax) with four spiderplant morphotypes from Western Kenya.

Morphotype	**Maximum Percentage Germination ± S.E. (Gmax)**		
	Bottom fruits	Middle fruits	Top fruits
GG	98.0±0.82a	96.0±1.41ab	95.0±2.38ab
GP	93.5±2.06a	92.5±2.75ac	77.0±2.38bd
PG	85.5±1.26a	88.0±1.63ab	79.5±5.12ab
PP	92.5±3.10a	96.0±1.15ab	84.0±1.83ac

Figures followed by different letters along the rows, for Gmax are significantly ($P \leq 0.05$) different, according to Student's t-test. Data are means of four replicates of 50 seeds for the four spiderplant morphotypes.

DISCUSSION

The observation generally indicates that where differences existed, sun drying had an improved effect on seed quality of spiderplant compared to shade drying. This observation contradicts that made by other investigators [10], where exposure of seeds of a forestry tree species like mahogany to direct sunlight resulted in lowered viability. The contradiction between the results of the two plant species could be extended to reflect upon the different behaviour as observed with seeds of some spiderplant morphotypes. Seed drying in the shade can be advantageous under some circumstances, such as where high temperatures in the sun are capable of damaging seeds with high moisture content, and also where seeds are not fully ripe, thus requiring a slow drying process to after-ripen and be able to repair small mechanical damages once lower than 15-20% moisture content is reached [4]. It is possible that the seed lots that were used in this investigation, and whose fruits were harvested at the yellow pod stage, did not have very high moisture content and also they were mature, thus not requiring the benefits of the slow process of drying under shade.

Further observations also show that morphotypes differed in germination performance. Morphotype GG outperformed all the other morphotypes in germination performance, while morphotype PG generally performed the least. It can be postulated in part that the best performance indicated by morphotype GG compared to PG could be due to the fact that the seeds of this morphotype reached the mature stage in good uniform time such that any seed samples taken from this lot for seed germination test could perform equally well. It has also been observed that that each crop and plant species undergoes characteristic changes that lead to seed ripening [3]. Seed is therefore mature when it can be removed from the plant without impairing the seed's germination, the so-called physiological maturity. The general least performance in germination by morphotype PG could also be attributed to the inherent nature of such seed species, for instance prone to faster deterioration or possessing some hard seed coat dormancy. And this could be attributed to the inherent nature of such seed species, for instance prone to faster deterioration or possessing some hard seed coat dormancy. It has been explained by other researchers that the rate at which deterioration takes place depends on the environmental conditions inside and around the seeds [4].

Pod position had effects on TSW, germination rate (time to reach 50% germination, T_{50}) and percentage germination. As regards TSW, while bottom fruits in GP and PP produced heavier seeds than middle and top fruits; for GP, PG and PP, the middle fruits produced heavier seeds than top fruits (Tables 3, 4 and 5). The direct relationship between fruit position and seed weight suggests higher reserves in larger, heavier seeds through assimilate partitioning. Although seed weight has been observed to be one of the most stable morphological characteristics of many plant species, variability in seed weight has been documented [18]. The variation observed in seed weight due to fruit position in the spiderplant morphotypes used could to an extent be accounted for by factors related to their genotypes as well as the seed production environment. This is because the genotype of an organism tends to be influenced by the environment to produce the phenotypic differences. Other authors [24] have also reported that as soon as accumulation of storage compounds has begun in seeds at a given morphological position, the mean final seed weight only depends on the duration of seed filling. This depends on the different source-sink ratios, hence variation in individual seed weight among different environmental situations are mainly due to variations in seed growth rate, even if the duration of filling varies. From this study, bottom and middle fruits that produced seeds with higher TSW than top ones reflected higher quality. Quality and productivity of onion seeds have also been correlated with seed size and TSW [15].

From the data available (Tables 3, 4 and 5), seeds from bottom and middle fruits in GP and PP germinated faster than those from top fruits. Bottom fruits in GP and middle fruits in GP and PP respectively, produced seeds that showed higher germination than those from top fruits. This agrees with the results of the studies with invasive plant species *Heracleum mantegazzianum*, where larger seed showed faster germination [25]; also with pepper, where seeds extracted from fruits in the first and second layers on the mother plant had generally higher germination percentages than in the third layer [26]. However, the reasons for the effects of seed size on germination need further investigation. The better performance of larger/heavier seeds may simply be a reflection of the greater amount of nutrients available to the developing embryo. The extent of assimilate partitioning to various positions of the fruit, hence the seed on the mother plant could partly explain the observed differences in germination rate and germination. Generally, fruit position (and therefore seed weight) was observed to correlate with germination rate and germination. Therefore, seed weight can be used as good predictor of seedling vigour.

Differences were shown in a few of the four morphotypes in their germination performances (Table 4 and 5). For instance, morphotype PP showed the lowest germination rate compared to the rest of the morphotypes. In terms of percentage Morphotype GG differed from GP, PG and PP, recording the highest percentage. The genotype of the individual morphotype could account for such differences as well as the growth environment, for instance GG appears to be more uniform in maturity. It has been stated that the size that the seeds attain, apart from being influenced by the conditions under which seeds develop, can also be influenced by the genotype of a developing embryo; the maternal plants is also capable of exerting control on the amount of resources invested per seed thus eventually influencing the performance of the seedlings and the adult plants [16, 17].

CONCLUSION

This study has shown that generally when fruits of spiderplant are harvested at the yellow pod stage and the seed threshed, drying the seed under the sun tends to improve the germination performance, compared to drying under the shade. The results also indicate that often bottom and medium fruits produce heavier seeds compared to top fruits; also that heavier seeds germinate faster and result into higher germination percentage. Different spiderplant morphotypes are also likely to produce seeds of different quality performance, a factor that could be inherent to each morphotype but influenced by the environment under which seed production is undertaken and post-harvest handling.

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REFERENCES

[1] Muasya RM, PhD Thesis, Wageningen University, (Wageningen, The Netherlands, **2001**).
[2] Tekrony, DM and D.B. Egli DB, In: R.H. Ellis, M. Black, A.J. Murdoch and T.D. Hong (Eds.), Basic and Applied Aspects of Seed Biology *(*Kluwer Academic Publishers, Dordrecht), **1997**.
[3] Jing HC, Bergervoet JHW, Jalink, Klooster M, Du SL, Bino RJ, Hilhorst HWM and Groot SPC, *Seed Science Research*, **2000**, 10, 435-445.
[4] Thomsen K and Stubsgaard F, Lecture Note C-5A, Danida Forest Seed Centre, Humlebaek, Denmark, **1998**.
[5] Kyereh B, Swaine MD and Thompson J, *Journal of Eco*logy, **1999**, 87, 772-783.
[6] Khurana E and Singh JS, *Current Science*, **2001**, 80(6), 748-757.
[7] Desai BB, Kotecha PM and Salunkhe DK, Seeds Handbook: Biology, Production, Processing and Storage, Marcel Dekker Inc., New York, **1997**.
[8] Hanson J, Procedures for Handling Seeds in Genebanks- Practical Manual for Genebanks, No. 1. IBPGR, Rome, **1985**.
[9] Agrawal, RL, Seed Technology, Oxford & IBH Publsihing Co. Pvt., New Delhi, **1980**.
[10] Naitinelia V, Singh K and Lal S, *Pacific Islands Forests & Trees Newsletter*, **1997**, No. 4, 97.
[11] Chweya JA and Mnzava NA, Promoting the Conservation and Use of Underutilized and Neglected Crops. 11, Gatersleben/Institute of Plant Genetic and Crop Resources Institute, Rome, Italy, **1997**.
[12] Hay FR, PhD Thesis, King's College, (London, UK, **1997**).
[13] Schippers RR, African Indigenous Vegetables: An Overview of the Cultivated Species, Natural Resources Institute/ACP-EU Technical Centre for Agricultural Rural Cooperation, Chatham, UK, **2002**.
[14] Spilde LA, *Journal of Production Agriculture***, 1989**, 2(2), 169-172.
[15] Gabriel, EL, Makuch MA Piccolo RJ, *Acta Horticularae (ISHS)* **1997**, 433, 573-584.
[16] Fenner M, *Horticultural Review*, **1993,** pp 183-213.
[17] Silvertown JW and Lovett-Doust J, Introduction to Plant Population Biology. Blackwell Science Ltd, Oxford, UK, **1993**.
[18] Chmielewski JG and Ruit S, **2002**, *Bartonia* 61, 15-26.
[19] Baskin, C.C. and J.M. Baskin, Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination, Academic Press, New York, **1998**.
[20] Chen KF., Lai SH, Cheng ST and Shanmugasundaram S, In: S. Shanmugasundaram (Ed.), Proceedings of a Workshop Held at Kenting, Taiwan, 29 April - 2 May 1991, **1991**.
[21] Castro J, *New Phytology*, **1999**, 144, 153-161.
[22] Gamiely S, Smittle DA, Mills HA and Banna GI, *HortScience*, **1990**, 25, 522-523.
[23] Siemonsma JS and Piluek K, Plant Resources of South-East Asia (PROSEA) No. 8. Bogor, Indonesia, **1994**.
[24] Munier-Jolain NG, Ney B and Duthion C, *European Journal of Agronomy*, **1996**, 5, 219-225.
[25] Moravcová L, Perglová I, Pyšek P, Jarošik and Pergil J, , *Acta Oecologica*, **2005**, 28, 1-10.
[26] Alan O and Eser B, *Pakistan Journal of Biological Sciences*, **2007**, 10 (23), 4251-4255.