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The Interaction Effects of Storage Condition, Storage Time and Initial Seed Moisture Content on Seedling Growth Performances of Coffee *(Coffea arabica L.)*

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Abstract
Arabica Coffee is one of the most important agricultural commodities in Ethiopia. Despite considerable effort at vegetative propagation of coffee plants, they still are propagated by seedlings produced from seeds. Coffee seeds have been considered intermediate storage behavior with varying results. It is highly desirable that seeds are stored safely to optimize coffee seedling production at the appropriate time and season with ideal climatic conditions for planting in the field. The objective of this study was to evaluate the effect of storage temperature, time of storage and initial seed moisture content on germination and seedling performances of coffee seeds and to determine the appropriate seed handling method. In this experiment, the effects of storage temperature (ST) with two levels (15ºC & ambient), time of storage with six levels (sowing after 1,2,3,4,5,&6 months) and initial seed moisture content with four levels (12, 17, 22 & 27%) on coffee seedling growth were studied in a split-split-plot factorial design. The data collected were subjected to Analysis of Variance (ANOVA) using statistical analysis system version 9.2 software (SAS, 2009). Treatment means were separated using LSD at 0.05 probability level. The present findings of storage environment with cold temperature (15ºC) maintained early seedling growth parameters much better performances than did ambient temperature condition. All tested seedling growth parameters were highest at initial time of storage. After third month seed quality drastically reduced especially under ambient storage condition. Seeds dried to 12% moisture content showed inferior performance throughout the trial period. Seeds with 27% initial moisture content showed higher performances at initial storage time but when aged drastically declined. Storage temperature, time of storage and initial seed moisture contents showed highly significant main and interaction effects and seeds dried to intermediate moisture level (17 & 22%), stored under cold temperature and sown at early times resulted in enhanced seedling growth. Hence, it is advisable drying coffee seeds to about 17% to 22% moisture contents and keep under storage with relatively lower temperatures at about 15ºC for not more than six months of storage. As the present finding was limited to single cultivar and done under specific environmental condition further investigation is significant.
Keywords: Arabica coffee, Seedling, Growth

INTRODUCTION

Coffee has been used by Ethiopians for many years as a food, a beverage and a medicine and has enormous economic, social and environmental significance in the country. It is the major source of foreign currency for Ethiopia and contributes more than 35% of the total export earnings (FAO/WFP, 2008). Thus, it is a cornerstone in the export economy of the country and it supports directly or indirectly the livelihood of over 25% of the populations (CSA, 2001). Coffee the defining feature of the national culture and identity, with 44% of the production consumed domestically (Mayne *et al*., 2002).

In fact, Ethiopia is endowed with environment suitable for producing different varieties and flavor of coffee beans. But despite its enormous genetic variability, favorable ecology for production and its importance in the national economy of the country, productivity of the crop remained much lower than released varieties yielding potential. The national average of coffee yield is about 748 kg per hectare and is much below the research results of 1500 – 2000 kg per ha and to that of some other countries like Brazil and Kenya (Alemayehu *et al*., 2008). This lower productivity is mainly because of poor and traditional management practices, disease and pests, use of inappropriate varieties, poor seeds, poor nursery management, and use of poor seedlings, which result in poor field establishment. Most importantly, the use of poor quality seeds and seedlings, along with poor nursery management practices and thus, poor seed germination and seedling growth are among the major factors contributing to low productivity of the crop in the country. Due to the damage that seeds have during the storage and limited information in our country about the storability of the seeds justified necessity of doing the experiment with the aim of giving practical information about storing of coffee seeds

Objectives

To evaluate the effect of storage temperature, time of storage and initial seed moisture content on seedling growth performances of coffee seeds and to determine the appropriate seed handling method

MATERIALS AND METHODS

Description of the Study Site

The experiment was executed in a nursery site at Jimma Agricultural Research Center (JARC), of the Ethiopian Institute of Agricultural Research. It is the National Coffee Research Coordinating Center in the country and is located 365 km away from Addis Ababa, 12 km from the Jimma town in the south west direction. The center is found within tepid to cool humid highland agro-ecological zone of the country at an altitude of 1750 meters above sea level, 7^0 46” N, latitude, and $36^0$47” E longitude in the sub humid tropical belt of south western Ethiopia. Average annual rain fall of the area is 1594 mm with 67% mean relative humidity. The mean minimum and maximum temperatures are about 11.6^0C and 26.3^0C respectively. The soil of the center has a characteristic of reddish to reddish brown clay nature, where erutic nitosols and chronic cambisols are dominant types with pH range of 5 to 6.

Experimental Materials

Following the conventional procedures widely applied in coffee seed preparation (Van der Vossen, 1979; Goodman, 1980; Rothofs, 1980), fully ripe red cherries were harvested from selected mother trees in the seed orchard of cultivar 74110 (which was selected as it is widely adapted, highly demanded and much produced) at, JARC, on 21st November 2011 growing season. This cultivar was selected for the present study, because it is high-yielding CBD resistant, widely adaptable, highly demanded and produced much,. The cherries were sorted out and pulped in a hand pulp separator. After pulping the selected cherries, the wet parchment beans were again sorted out, thoroughly washed, and taken to drying room, hut made of grass roof.

Then the wet parchment coffee was laid on wire mesh for drying under shade and when its skin dried dressed with fine wood ash following the JARC conventional practice and kept till it attained the desired four levels of moisture contents (27, 22, 17 and 12% [fresh weight base]). One kg of parchment coffee seeds was taken on 5th January 2012 till 2nd July 2012 from each of the four batches and kept separately in each of the two storage conditions. The storage conditions used in this study were cold store with 15^0C (SC1) and a room at ambient temperature (SC2). All the seed lots with four levels of MCs were kept under both storage conditions.

Representative samples of seeds were taken every month from each treatment combinations and were subjected to a series of tests in the laboratory and nursery trials to evaluate the potential viability (germination) and early seedling growth potential status of each seed lot.

Treatments and Experimental Design

A split-split plot factorial design was used with three replications.

Factors :-

A. Storage condition (cold 15°C & ambient temperature)
B. Time of storage (sowing after 1, 2, 3, 4, 5 & 6 months of storage)
C. Initial seed moisture content (12%, 17%, 22% & 27%)

As presented in Table1, in this experiment, storage conditions (SC) was assigned to main plot, time of storage (ST) was assigned to sub-plots while seed initial moisture level was assigned to sub-sub-plots. Total number of treatment combinations were 48 (2*6*4) replicated three times and the total number of experimental plots were 144. The treatments were randomly and independently assigned to main plots, sub plots and the sub-sub plots. Every routine nursery activity was practiced uniformly to all experimental units as per the recommendation of the JARC (Institute of Agricultural Research, 1996).

The model

Three factor analysis of variance model was used with General Linear Model (GLM) Procedures of SAS Version 9.2.

The linear statistical model for the split-split-plot design would be:

Yijk = μ +αi + βj + γk + (αxβ)ij + (αxγ)ik + (βxγ)jk + (αxβxγ)ijk + £ μijk

Where: - Yijk = the response measurement for the ijkth observation
μ = is the overall mean effect.
αi = is the effect of the ith level of sub-sub-plot
βj = is the effect of the jth of main plot
γk = is the effect of the kth of sub-plot
(αxβ)ij = is the effect of the interaction b/n actor A&B
(αxγ)ik = is the effect of the interaction b/n factor A&C
(βxγ)jk = is the effect of the interaction b/n factor C&B

(αxβxγ)ijk = the effect of interaction b/n the three factors
£μijk = is a random error component for all factors

Sampling and Data Collection
The observations were recorded on seed germination percent, shoot length, seedling root length, girth diameter, leaf area, seedling dry weight and seedling vigor Index and they were explained below.

Seedling growth measurements
Six months after sowing, ten plants were randomly selected from each plot for some preliminary linear growth measurements, including girth diameter, leaf area and lengths of shoot and taproot.
Shoot length = plant height was measured from the base to the tip of the seedling using a ruler.

Taproot length = the length between the collar region and the tip of the primary root was measured and the mean value was recorded in cm.

Stem diameter was measured at the base near the medium surface using a caliper (cm).

Leaf area (cm^2) leaf length from petiole to the tip and leaf width at broadest part was measured. Then leaf area per leaf was calculated using the procedure adapted by Yakob *et al*., (1998) as follows:

$$Y = K \times L \times B$$

Where: Y = estimated leaf area
K = constant specific to cultivars and canopy classes (0.67)
L = leaf length (cm) and
B = maximum leaf breadth (cm).

To facilitate measurement of the underground plant part and to minimize loss of fine roots during uprooting, the polythene tubes were sufficiently watered before the seedlings were pulled out and then immersed in a bucket of water to wash the soil off of the roots. Each seedling sampled was brought to the laboratory for measurement destructive parameters. Seedlings were cut with a scissor at collar point to separate the shoot from the root. The shoot, then, was separated to leaves and stems and fresh weight of each weighed using sensitive balance. Finally, the entire seedling parts were oven dried at 70°C until a constant weight following procedures outlined by Walsh and Beaton (1973). Then the seedlings were removed and allowed to cool in desiccators for 30 minutes before weighing in an electronic balance. The average was calculated and expressed as seedling dry weight in grams as described by Adjet-Twum and Solomon (1982).

Using the measurements of girth diameter and shoot length, and the total percentage of field emergence (%E), an attempt was made to establish some vigor indices for the seedlings at an early stage of growth following the techniques suggested by Abdul-Baki and Andeson (1973), and was expressed as pure number.
The formulae used to establish a seedling vigor index (SVI) of the young coffee plants in this study was;

$$SVI = \%E \times (GD + SH)$$

Where; SVI= seedling vigor index
%E = percentage field emergence.
GD = girth diameter (cm)
SH = stem height (cm)

Statistical Analysis
The seedling growth data collected were subjected to Analysis of variance (ANOVA) for split-plot design and treatment mean separation was carried out using least significant difference (LSD) at 0.01 and 0.05 probability levels using General Linear Model (GLM) procedure of SAS statistical version 9.2 software (SAS, 2009).

Result and Discussion
Shoot Length (SL in cm)
The main and interaction effects of storage condition, time of storage and initial seed moisture content was highly significant ($P< 0.01$) for shoot length (Table1). Shoot length progressively declined with time of storage irrespective of moisture content, storage environment and their interaction. Accordingly, seeds dried to 27% moisture content, stored in cold condition and sown at first month maintained significantly higher shoot length (17.99 cm) and the least shoot length was recorded for the treatment combination of seeds dried to 12% and 27% moisture content, stored in ambient condition and sown at sixth month of storage (11.22 & 11.25 cm, respectively). The result of this experiment revealed that seeds dried to 22% initial seed moisture content and stored in cold condition resulted in better maintained shoot growth than did the other treatment combinations (Table2).

This result also synchronized with the germination, emergence performance of seedlings and indicated that seed lots producing the taller seedlings are considered more vigorous than the seed lots producing shorter seedlings (Perry, 1984).

Table1: Analysis of Variance for shoot length (SL), taproot length (TRL), girth diameter (SD), leaf area (LA), seedling dry weight (TDW) and seedling vigor index (VI)

Source of Variation	DF	SL	TRL	MSG	LA	TDW	SVI
Rep	2	1.12**	0.86**	0.01**	0.03**	0.02**	68.21 ns
SC	1	76.83**	44.57**	0.01**	6.61**	0.29**	123065.90**
Error (a)	2	0.19**	0.42**	0.01**	0.56**	0.01**	163.20 ns
ST	6	44.27**	39.76**	0.03**	36.84**	0.94**	177370.79**
SC*ST	6	4.34**	3.45**	0.01**	0.18**	0.01**	215.54 ns
IMC	3	12.70**	30.02**	0.01**	29.50**	0.28**	32300.90**
SC*IMC	3	0.71**	2.30**	0.01**	0.14**	0.01**	5067.90**
ST *IMC	18	1.13**	0.55**	0.01**	1.29**	0.02**	3566.34**
SC*ST*IMC	18	0.04*	0.04*	0.01 ns	0.05**	0.00**	789.66**
Error (b)	12	0.06**	0.05**	0.01ns	0.02 ns	0.01*	260.34**
CV%		0.97	0.83	4.41	0.91	2.33	4.06

*, ** = Indicate significant differences at the 5% and 1% probability levels, respectively. ns = non-significant at 5% probability levels.

Table2: The interaction effects of storage condition (SC), storage time (ST) and initial seed moisture content (IMC) on shoot length (cm)

SC	IMC	Storage Time (in month)					
		1	2	3	4	5	6
Cold (15^{O}C)	12%	15.27^{e-h}	14.95^{hij}	14.65^{jkl}	14.42^{lmn}	13.98^{op}	13.72^{pq}
	17%	16.40^{c}	15.70^{d}	15.42^{def}	15.05^{f-i}	14.83^{ijk}	14.47^{k-n}
	22%	17.28^{b}	16.47^{c}	15.67^{d}	15.35^{d-g}	15.03^{ghi}	14.73^{i-l}
	27%	17.99^{a}	17.32^{b}	16.40^{c}	15.23^{e-h}	14.52^{klm}	14.13^{no}
Ambient	12%	14.95^{hij}	14.23^{mno}	13.38^{q}	12.82^{r}	11.68^{t}	11.22^{u}
	17%	16.35^{c}	15.53^{de}	14.75^{i-l}	13.87^{op}	12.75^{r}	12.18^{s}
	22%	16.62^{c}	15.33^{d-g}	14.55^{klm}	13.70^{pq}	12.70^{r}	11.97st
	27%	17.37^{b}	16.35^{c}	14.72^{i-l}	13.38^{q}	12.27^{s}	11.25^{u}
CV%		1.55					
LSD (5%)		0.3679					

Means followed by the same letter(s) are not significantly different at 5% level of probability

Taproot Length (TRL in cm)

The interaction effects of storage condition, time of storage and initial seed moisture content on taproot length was highly significant (P< 0.01) (Table1). Taproot length progressively declined with time of storage irrespective of moisture content, storage environment and their interaction. Accordingly, seeds dried to 27% moisture content, stored in cold condition and sown at first month maintained significantly higher tap root length of (19.20 cm) and the least taproot length was recorded from the treatment combination of seeds dried to 12% & 27% moisture content, stored in ambient condition and sown at sixth month of storage (12.93 & 13.40 cm, respectively). The result of this experiment revealed that seeds dried to 27% and 22% initial seed moisture content and stored in cold condition resulted in better maintained taproot growth than did the other treatment combinations (Table3).

Chandrasenan (1996) observed decline in germination percent, root length, shoot length, seedling vigour index, and seedling dry weight as the storage period increased. This result also synchronized with the germination, emergence performance of seedlings and indicated that seed lots producing the taller seedlings are considered more vigorous than the seed lots producing shorter seedlings (Perry, 1984).

Table3: The interaction effects of storage condition (SC), storage time (ST) and initial seed moisture content (IMC) on tap root length (cm)

SC	IMC	Storage Time (in month)					
		1	2	3	4	5	6
Cold (15^{O}C)	12%	16.03^{qr}	15.58^{stu}	15.25^{uv}	15.07^{vw}	14.70^{xy}	14.37^{yz}
	17%	18.47^{cd}	17.97^{ef}	17.52^{ghi}	17.13^{jk}	16.72^{lm}	16.35^{n-q}
	22%	19.09^{ab}	18.25^{de}	17.82^{fg}	17.27^{ij}	16.67^{lmn}	16.23^{opq}
	27%	19.20^{a}	18.63^{c}	17.72^{fgh}	17.17^{ijk}	16.40^{m-p}	16.13^{pq}
Ambient	12%	16.60^{lmn}	15.77^{rs}	15.33^{tuv}	14.50^{yz}	13.67^{z23}	12.93^{z4}
	17%	17.97^{ef}	17.43^{hij}	16.40^{m-p}	15.63st	14.87^{wx}	14.17^{z1}
	22%	18.70^{c}	17.73^{fgh}	16.50^{l-o}	15.70^{rs}	14.87^{wx}	13.95^{z12}
	27%	18.73^{bc}	17.73^{fgh}	16.83^{kl}	15.27^{uv}	14.33^{z}	13.40^{z3}
CV%		1.35					
LSD (5%)		0.357					

Means followed by the same letter(s) are not significantly different at 5% level of probability

Main Stem Girth (MSG in cm)

The interaction between storage condition, time of storage and initial seed moisture content was also highly significant (P< 0.01) for girth of the main stem (Table1). Girth of the main stem showed highly significant for seeds dried to 27% moisture content, stored in cold condition and sown at first month (0.31 cm) followed by seeds dried to 22% initial moisture, while the least stem diameter was recorded for the treatment combination of seeds dried to all the initial moisture levels, stored under ambient condition and sown after six months of storage (0.16 cm) The result of this experiment revealed that seeds dried to 22% initial seed moisture content and stored in cold condition resulted in better maintained stem diameter than did the other treatment combinations (Table4).

The early stages of plant development were slower when aged seeds were sown, and hence the rate of early seedling growth was indicated as the most consistent and sensitive measure of the level of deterioration, because these can adequately indicate the differences in vigor not revealed by the germination percentage (Woodstock and Grabe, 1967; Abdella and Roberts, 1969; Tekrony and Egli, 1977; and Steiner, 1990).

Table4: The interaction effects of storage condition (SC), storage time (ST) and initial seed moisture content (IMC) on stem diameter (cm)

SC	IMC	Storage Time (in month)					
		1	2	3	4	5	6
Cold (15^{O}C)	12%	0.25^{hij}	0.23^{jkl}	0.22^{lmn}	0.21^{m-p}	0.21^{n-q}	0.20^{pq}
	17%	0.27^{d-g}	0.26^{e-h}	0.25^{hij}	0.23^{jkl}	0.21^{m-p}	0.21^{n-q}
	22%	0.30^{abc}	0.28^{def}	0.26^{fgh}	0.24^{ijk}	0.23^{jkl}	0.22^{l-o}
	27%	0.31^{a}	0.28^{cde}	0.26^{e-h}	0.24^{ijk}	0.21^{m-p}	0.19^{qr}
Ambient	12%	0.26^{ghi}	0.24^{ijk}	0.22^{lmn}	0.21^{n-q}	0.19^{qr}	0.16^{s}
	17%	0.27^{efg}	0.26^{ghi}	0.23^{jkl}	0.21^{m-p}	0.20^{pq}	0.17^{s}
	22%	0.29^{bcd}	0.27^{efg}	0.24^{ijk}	0.21^{m-p}	0.19^{qr}	0.16^{s}
	27%	0.30^{ab}	0.28^{def}	0.23^{klm}	0.20^{opq}	0.17^{rs}	0.16^{s}
CV%		5.30					
LSD (5%)		0.0198					

Means followed by the same letter(s) are not significantly different at 5% level of probability

Mean Leaf Area per Leaf *(*LA in cm^2)

The interaction effects of storage condition, time of storage and initial seed moisture content was highly significant (P< 0.01) mean leaf area of coffee seedlings (Table1). With the advance of storage period, mean leaf area progressively declined. Accordingly, seeds dried to 27% moisture content, stored in cold condition and sown at first month resulted in significantly higher mean leaf area of (13.87 cm^2). These results could also be related to the positive impact of high seed moisture levels in retaining high seed viability (Perry, 1970; Van der Vossen, 1979; Osei-Bonsu, *et al*., 1989), which may result in rapid growth of seedlings during their earlier stages of development. The least mean leaf area was recorded for the treatment combination of seeds dried to 12% moisture content, stored in ambient condition and sown at sixth month of storage (8.10cm^2). The result of this experiment revealed that seeds dried to 17% followed by 22% initial seed moisture content and stored in cold condition better maintained mean leaf area higher than did the other treatment combinations (Table5). The early stages of plant development were slower when aged seeds were sown, and hence the rate of early seedling growth was indicated as the most consistent and sensitive measure of the level of (Woodstock and Grabe, 1967; Abdella and Roberts, 1969; Tekrony and Egli, 1977; and Steiner, 1990).

Table5: The interaction effects of storage condition (SC), storage time (ST) and initial seed moisture content (IMC) on leaf area (cm^2)

SC	IMC	Storage Time (in month)					
		1	2	3	4	5	6
Cold (15^{O}C)	12%	10.37^{lm}	10.15^{mno}	9.87^{pq}	9.28^{tuv}	8.86^{wx}	8.65^{xy}
	17%	12.36^{e}	12.10^{fg}	11.86^{gh}	11.15^{jk}	10.29^{lm}	9.67^{qr}
	22%	12.73^{d}	12.25^{ef}	11.81^{h}	10.98^{k}	10.29^{lm}	9.54^{rs}
	27%	13.87^{a}	13.08^{c}	12.45^{e}	11.12^{jk}	10.13^{mno}	9.37st
Ambient	12%	10.19^{mn}	10.03^{nop}	9.46^{rst}	9.09^{vw}	8.42^{y}	8.10^{z}
	17%	12.09^{fg}	11.85^{h}	11.23^{ij}	10.52^{l}	9.98^{nop}	9.27^{tuv}
	22%	12.45^{e}	12.09^{fg}	11.46^{i}	10.32^{lm}	9.87^{pq}	9.13^{uv}
	27%	13.46^{b}	12.89^{cd}	11.93^{gh}	9.93^{op}	9.34^{stu}	8.84^{x}
CV%		1.39					
LSD (5%)		0.2416					

Means followed by the same letter(s) are not significantly different at 5% level of probability

Total Dry Matter (TDW in gm)

The interaction effects of storage condition, time of storage and initial seed moisture content on total dry weight was highly significant (P< 0.01) (Table1). Total dry weight progressively declined with time of storage irrespective of moisture content, storage environment and their interaction. Accordingly, seeds dried to 27% moisture content, stored in cold condition and sown after a month maintained significantly higher total dry weight (1.37 gm). These results could also be related to the positive impact of high seed moisture levels in retaining high seed viability (Perry, 1970; Van der Vossen, 1979; Osei-Bonsu, *et al.*, 1989 and Wondyifraw, 1994), which may result in higher percentages of seedling emergence and subsequent rapid growth of seedlings during their earlier stages of development.

The least total dry weight was recorded for the treatment combination of seeds dried to 12% moisture content, stored in ambient condition and sown at sixth month of storage (0.51gm). The result of this experiment revealed that seeds dried to 22% followed by 17% initial seed moisture content and stored in cold condition better maintained total dry weight than did the other treatment combinations (Table6). Chandrasenan (1996) observed decline in germination percent, root length, shoot length, seedling vigour index, and seedling dry weight as the storage period increased.

Table6: The interaction effects of storage condition (SC), storage time (ST) and initial seed moisture content (IMC) on total dry weight

SC	IMC	Storage Time (in month)					
		1	2	3	4	5	6
Cold (15^{O}C)	12%	1.00^{ij}	0.93^{klm}	0.86^{opq}	0.81^{rstu}	0.71^{wx}	0.62^{y}
	17%	1.23^{d}	1.07^{gh}	0.97^{jk}	0.93^{klm}	0.87^{nop}	0.83^{p-s}
	22%	1.30^{bc}	1.15^{ef}	1.02^{i}	0.94^{klm}	0.90^{mno}	0.84^{pqr}
	27%	1.37^{a}	1.26^{cd}	1.09^{g}	0.87^{n-q}	0.79^{s-v}	0.67^{x}
Ambient	12%	1.00^{ij}	0.91^{lmn}	0.78^{tuv}	0.68^{x}	0.61^{y}	0.51^{z}
	17%	1.17^{e}	1.03^{hi}	0.93^{klm}	0.82^{q-t}	0.75^{vw}	0.70^{x}
	22%	1.26^{cd}	1.09^{g}	0.95^{jkl}	0.83^{p-s}	0.75^{vw}	0.68^{x}
	27%	1.33^{ab}	1.11^{fg}	0.90^{l-o}	0.76^{uvw}	0.68^{x}	0.59^{y}
CV%		3.33					
LSD (5%)		0.0493					

Means followed by the same letter(s) are not significantly different at 5% level of probability

Seedling Vigor Index (SVI)

The interaction effects of storage condition, time of storage and initial seed moisture content was highly significant (P< 0.01) for vigor index (Table1). Accordingly, seeds dried to 27% moisture content, stored in cold condition and sown at first month maintained significantly higher vigor index (464.32) and the least vigor index was recorded for the treatment combination of seeds dried to 12% & 27% moisture content, stored in ambient condition and sown at sixth month of storage (105.78 and 104.60, respectively). This could be attributed to the general decline in viability of seed lots as a result of prolonged storage. Vigorous seeds rapidly germinate, metabolize and establish in the field. Therefore, any method used to determine the rapidity of growth of the seedling will give an indication of seed vigour level (Perry, 1984).

Vigor index progressively declined with time of storage irrespective of moisture content, storage environment and their interaction. Chandrasenan (1996) observed decline in germination percent, root length, shoot length, seedling vigour index, seedling dry weight as the storage period increased. The seedling vigor test also was synchronized with the emergence performance of seedlings. Accordingly, seedlings from intermediate level of coffee seed moisture content and stored under cold condition showed better performance in emergence throughout the emergence period were also found to be more vigorous than seedlings from higher or lower initial seed moisture levels. These findings are in accordance with the results obtained from some other previous studies (Da Silva and Dias, 1985; Reddy, 1987; and Wondyifraw, 1994) was similar to those obtained for germination (Perry, 1984).

The result of this experiment revealed that seeds dried to 22% followed by 17% initial seed moisture content and stored in cold condition better maintained vigor index than did the other treatment combinations (Table7). The seed lot showing the higher seed vigour index is considered to be more vigorous (Abdul-Baki and Anderson, 1973).

Table7: The interaction effects of storage condition (SC), storage time (ST) and initial seed moisture content (IMC) on seedling vigor index

SC	IMC	Storage Time (in month)					
		1	2	3	4	5	6
Cold (15^{O}C)	12%	325.71^{f}	285.39^{hij}	271.23^{jkl}	236.09^{no}	143.65^{tuv}	129.81^{vwx}
	17%	392.75^{cd}	309.14^{fg}	281.99^{ijk}	264.22^{kl}	237.29^{mno}	206.81^{qr}
	22%	428.27^{b}	386.86^{d}	348.11^{e}	269.03^{jkl}	254.87^{lm}	228.16^{nop}
	27%	464.32^{a}	392.60^{cd}	310.56^{fg}	277.48^{jk}	190.22^{r}	161.32st
Ambient	12%	302.13^{gh}	265.63^{kl}	219.67^{opq}	151.76^{stu}	112.79^{xy}	105.78^{y}
	17%	325.76^{f}	266.85^{kl}	236.74^{mno}	214.25^{pq}	163.72^{s}	119.73^{xy}
	22%	345.25^{e}	275.73^{jk}	242.03^{mn}	215.19^{pq}	165.74^{s}	124.90^{wx}
	27%	410.05^{c}	361.35^{e}	299.88^{ghi}	222.96^{opq}	140.16^{uvw}	104.60^{y}
CV%		4.42					
LSD (5%)		18.183					

Means followed by the same letter(s) are not significantly different at 5% level of probability

CONCLUSION

The present study was carried out with the objective of determining the seedlings growth potentials of coffee produced from seeds stored for six months with 27%, 22%, 17% and 12% initial seed moisture contents under storage conditions at 15°C and ambient temperature at JARC using split-split-plot factorial Design.

According to the results obtained in this investigation, it was observed that the early seedling growth parameters tested resulted to be statistically influenced by the main and interaction effects of storage conditions, storage time and initial seed moisture contents. After four more months of storage all the factors resulted in highly significant ($P \leq 0.01$) difference for almost all the variables tested. The present findings of storage environment with cold condition (15ºC) maintained seedling growth parameters much better performances than did ambient condition. All tested seedling growth parameters were highest at initial time of storage and declined progressively with storage time. After third month seed quality drastically reduced especially under ambient storage condition. Seeds dried to 12% moisture content showed inferior performance throughout the trial period.

Seed stored under cold condition recorded minimum quantitative losses with better seed quality parameters throughout the storage period as compared to seeds stored under ambient condition. Seeds stored in cold condition maintained viability and vigor for longer period with minimum deterioration in seed quality.

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