academicresearchJournals

Vol. 8(6), pp. 537-551, August 2020
DOI: 10.14662/ARJASR2020.485

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Review

Factors Affecting Quality Coffee (*Coffea arabica* L.) Seed Production and Seed Supply System in Ethiopia: Review

Dawit Merga[1*] and Daba Etana[1]

[1]Ethiopian Institute of Agricultural Research Jimma Agricultural Research Center, P.O.Box 192, Jimma, Ethiopia, Fax. +251 47 111 1999 and Tel. + 251 47 111 0206
Corresponding Author, E-mail:- dawitmerga@gmail.com

Accepted 30 August 2020

***Coffea arabica* is angiosperm plant and propagates by seed like other coffea species. Limited quality coffee seed production and supplying system is currently challenging issue. Thus, the present review conducted with the intension of factors affecting quality coffee seed production and its supplying system in Ethiopia. The two principal factors that affect quality coffee seed production are pre-harvest and post-harvest factors. Pre-harvest factor include field management practice, insect pest and disease and stage of fruit maturity; while seed drying method, seed storage time, seed initial moisture content and types of container for seed storage are post harvest factors. Deep reddening and reddening stage fruit used for seed showed more than 88% germination; but at yellow and green stage germination was 70% and less. Seed drying under corrugated iron and glass tukul enhanced germination up to 80% and more; but under open sun it ceased to 70%. Seedling emergence percentage rapidly decreased after 3-5 months of storage time; hence, seed sowing to nursery as soon as harvesting without further storage increase seedling emergence and make earlier the attain first true leaf and mean day of germination. Seed with initial moisture content of 55.2% stored in glass jar recorded 97.5%, 89.1%, and 84.5% in seed viability; seedling emergence percentage and seedling attain first true leaf respectively after 5 months storage. Jimma Agricultural Research Center (JARC) has released 42 improved coffee varieties up date, and distributed 341.821 ton and 347,308 coffee seed and seedling respectively. However, seed demand and supply is not compatible as a result of seed supply system problems in Ethiopia. Formal coffee seed supply system mandate given to JARC, and well established informal coffee seed supply system is lacking in Ethiopia. Thus, for further technology disseminate and to response seed demand, formal and informal coffee seed supply need to be diversified with strong agricultural extension work in Ethiopia.**

Keywords: Coffea arabica L., post-harvest factor, pre-harvest factor, quality seed and seed supply

Cite this article as: Dawit M., Daba E (2020). Factors Affecting Quality Coffee (*Coffea arabica* L.) Seed Production and Seed Supply System in Ethiopia: Review. Acad. Res. J. Agri. Sci. Res. 8(6): 537-551

INTRODUCTION

Coffee belongs to the family *Rubiaceae* and the genus *Coffea* (Seyoum, 2004; Wintgens, 2009), in which there are at least 141 species (Couturon *et al*., 2016). However, Arabica coffee and Canephora coffee are the dominating species; contributing 60% and 40% in world coffee production respectively (Farah and dos Santos, 2015). Coffee is angiosperm plant and can be propagate by seed; also, by stem cutting and tissue culture. Ethiopia is the only home land and center of diversity for Arabica coffee (*C. arabica*) (Anthony *et al*., 2001). Hence, Ethiopian coffee is a momentous source of coffee genetic resources for the world coffee industry. Today, coffee can be cultivated in most parts of the tropics, accounting the forth next to cereals, pulses and oils crops in production in Ethiopia (CSA, 2019) and the second crop following oil crop in the world market.

Despite the existence of enormous genetic diversity and its importance in the country's economy, the national average productivity of the crop is very low (646 Kg ha-1 green coffee) (CSA, 2019) when compared with the released varieties yield potential which range from 1500Kg ha^{-1} to 2680Kg ha^{-1}. Low productivity of the crop comes from utilizing non improved and limited use of improved coffee varieties. Likewise, most coffee seed source for users (up to 41.8%) come from farmers own saved (which is not from improved varieties) and others source of seed are: agricultural office, farmer seed exchange, research center, NGO and farmers cooperatives respectively according to their attribution next to own saved in Ethiopia (2018 unpublished survey). Also, erroneous management of the coffee plant during the early stage of establishment in the field and the use of weak seedlings with undesirable shoot and root growth for field planting contribute for low productivity. This emanates mainly from poor seed preparation and handling, use of deteriorated seeds and growing media not suitable for germination and seedling growth, improper depth of seed sowing, and pre-germination practices (Wondyifraw, 1994; Tesfaye *et al*., 1998; Anteneh *et al*., 2008). Similar results reported by Taye *et al.* (2011) in Ethiopia; the authors noted that the poor seed preparation and handling cause average national coffee yield remains low. This implies that the predominant use of improved coffee varieties and modern husbandry practices play vital role in average national coffee yield increment in the country.

The genetics (genotype-species and varieties to plant), environment and its management are the three factors which greatly affect coffee yield and seed quality (http://www.fao.org/documents/). Also, according to Desse (2008) the seed quality production problems are mainly associated with poor agronomic practices like uncontrolled shade level, lack of stumping, pruning and weeding; poor harvesting practices, such as stripping and collecting dropped fruits from the ground; also, improper post harvest processing and handling practices, improper storage and transportation are the other factors.

Jimma Agricultural Research Center (JARC) has released a total of 42 coffee varieties along with improved agronomic and processing techniques. However, the inadequate supply of high quality coffee seeds still remains a major obstacle, mainly due to almost the absence of multiple formal coffee seed system in the country (Taye *et al*., 2011). Also, the main factor that causes low coffee seed production in Ethiopia is that, the limited in number of formal seed system responsible for the production and supply of improved coffee seeds from the released and adaptable coffee varieties. Thus, JARC and its implementing centers (sub-centers) are the only governmental institution that had taken the scheme of multiplying improved coffee seeds in Ethiopia (Negusie *et al*., 2008).

JARC cannot meet the rapidly growing demand for improved coffee varieties in Ethiopia as described by (Negussie *et al*., 2008). As a result of inadequate improved coffee seeds produced from the released pure-line and hybrid coffee varieties, and poor seed preparation and handling practice; production of coffee seed quality and supplying system are bottle neck in Ethiopia. Therefore; the general objective of this review is to comprehend factors affecting quality of coffee seed production and its supplying system and make out the existing gap for the next action plan to solve the problems in Ethiopia.

LITERATURE REVIEW

The Coffee Seed

Physiological parameters such as plant growth, flowering, and fruit set; fruit drop, fruit ripening, bean disorders, soil moisture stress, drought, and shade management play a critical role in maintaining a healthy in both Arabica coffee and Canephora coffee which is also key for coffee seed production (https://ecofriendlycoffee.org).

The coffee seed has different size and shape in nature. This means it is elliptical or egg-shaped, plane convex, possessing a longitudinal furrow on the plane surface (Dedecca, 1957). Practically from these different shapes, quality coffee seed should be plane convex possessing a longitudinal furrow on the plane surface and well grooved shape. The outer cover of the seed is formed by a hard pale brown endocarp that becomes the "parchment" after drying. The endocarp contains an enclosed seed, which has a thin, green testa known as the spermoderm or "silver skin" (figure 1), which is a remnant of the perisperm (Mendes, 1941).

In *C. canephora* seeds the spermoderm is adherent and brown (Fazuoli, 1986). Measurements made with a large number of seeds of *Coffea arabica* indicate that the seeds are 10 to 18 mm long and 6.5 to 9.5 mm wide (Dedecca, 1957); C. canephora seed 5.62 to 7.44 mm wide. Other species such as *C. racemosa* have smaller seeds (5-7 mm long and 3-3.5 mm wide (Guerreiro Filho, 1992) (figure 2).The endosperm, which is a living tissue, contains a hard external region and soft internal region, which surround the embryo (Krug and Carvalho, 1939; Mendes, 1941; Dedecca, 1957; De Castro and Marraccini, 2006). The part of the endosperm in front of the radicle tip is referred to as endosperm cap or micropylar endosperm and around the rest of the embryo is the lateral endosperm (Silva *et al*., 2004) (figure 1).

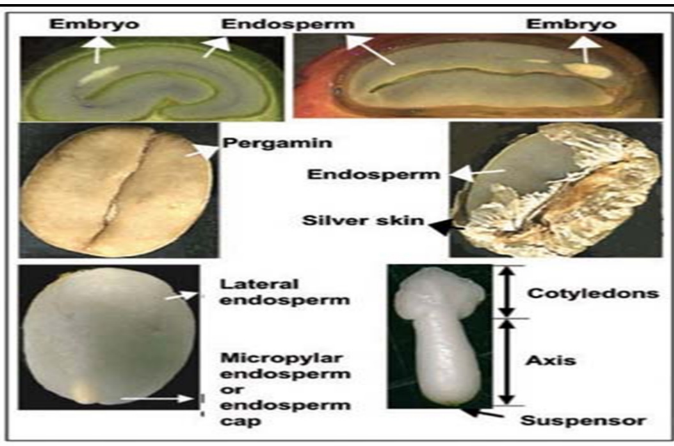

Figure 1. Cross section of a coffee seed showing the folding of the endosperm and embryo localization. Coffee seed with the pergamin. Imbibed coffee seed (*Coffea arabica* cv. Rubi) with endocarp removed, showing the endosperm cap and lateral endosperm. Observe the appearance of a protuberance in the endosperm cap and remnants of the spermoderm or "silver skin" on the surface at the basal end of the seed. Imbibed coffee embryo isolated after 7 days of imbibition in water, showing the cotyledons, the embryonic axis and remnants of the suspensor at the radicle tip.

Figure 2. *Coffea* seeds of different sizes. A- *C. racemosa*; B- *C. canephora*; C- *C. arabica*; D- *C. liberica*. The bar corresponds to 1cm.

Source:- Mirian *et al*.(2006)

The endosperm tissue has a high content of polysaccharides (Wolfrom *et al*., 1961). The cell walls are composed of cellulose and hemicelluloses, mainly insoluble mannans (Huxley, 1964; Wolfrom and Patin, 1964). The lateral endosperm is extremely hard because the mannan is deposited there as very thick cell walls; in the micropylar region, however, the walls are much thinner (Gong *et al*., 2004). Coffee mannans contain 2% of galactose, as a side chain to the mannan backbone (Bewley and Black, 1994); mobilization of the endosperm cell walls following germination likely provides for a source of carbohydrate for the growing seedling. Protein, lipids and minerals are present in the cytoplasm of the endosperm cells and are probably another source of reserves (Dentan, 1985). The embryo is very small, 3 to 4 mm long and is composed of an axis and two adherent cordiform cotyledons (figure 1); it is localized close to the convex surface of the seed (Dedecca, 1957; Huxley, 1964; Rena *et al*., 1986). The embryo contains few storage reserves, and depends upon the endosperm for nutrients until the seedling become autotrophic (Giorgini and Campos, 1992). Polyembryony and empty seeds have been observed in coffee at a frequency of 1.2 % (Mendes, 1941). Thus, using coffee seed having endosperm quality (healthy) and better seed size with enough endosperm play vital contribution for seedling growth up to it independently prepare its own food and in growing productive coffee plant.

Coffee Seed Development

In coffee, seed development is typically characterized by a synchronous flowering and fruit development. This concept is very important for hybrid coffee seed production. Anthesis in Arabica coffee can occur on a single day or during a few days (Wormer, 1964; Alvim, 1973). Each flowering period lasts only 2 or 3 days and is followed by intense vegetative development. Hence, enough hybrid seed production is very challenging.

Fruits may not commence growth immediately after flowering, but may stay up to 60 days after pollination or anthesis (DAA); *C. arabica* is characterized by cleistogamic self-pollination (Ramaiah and Vasudeva, 1969; De Castro *et al*., 2004). This latent state may continue until all flowering and favorable environmental conditions for growth are completed, *i.e.* a minimum availability of water (Maestri and Barros, 1977; Estanislau, 2002; De Castro *et al*., 2004).

The initial expansion of the fruit is due to the growth of the transient perisperm that is originated from the maternal nucellus tissue (Wormer, 1964; Ramaiah and Vasudeva, 1969). The fully differentiated coffee embryo (225 to 255 DAA) is enveloped by the soft endosperm tissue (Krug and Carvalho, 1939; Mendes, 1941; De Castro and Marraccini, 2006). During embryo development hypocotyl formation was once thought to be preceded by that of the cotyledons, with embryo development occurring after endosperm development (Arcila-Pulgarín and Orozco-Castaña, 1987). However, recent observations suggest that hypocotyls formation precedes that of the cotyledons and that embryo development occurs after a lag, but in synchrony with endosperm development (Estanislau 2002; De Castro and Marraccini, 2006).

During the initial stages of coffee fruit development water content is relatively high at around 80 % (fresh weight basis), but decreases during further development with an increase in dry weight. There are distinct patterns of dry weight changes in the whole fruit, the seed and the embryo, as cell division and differentiation are completed and the maturation phase is initiated (Wormer, 1964; Ramaiah and Vasudeva, 1969; Estanislau, 2002; De Castro *et al*., 2004). The variation in water content between whole fruit and its component parts appears to be related to the coffee species, cultivar and climatic conditions during development (Wormer, 1964; Ramaiah and Vasudeva, 1969; Guimarães, 1999).

Generally, as observations made at the Coffee Gene bank the length of the seed maturation process is different depending on the species. *C. arabica* seeds are mature after 210-250 DAA, while *C. canephora* seeds take 300-350 days, *C. dewevrei* and *C. liberica* around 360 days, and *C. racemosa* only 90 days (Medina Filho et al., 1984; Carvalho *et al*., 1991).

Coffee Seed Germination

Coffee seeds germinate slowly in the field (Rena *et al*., 1986); *C. arabica* seedling emergence from the soil starts 50 to 60 days after sowing in the warmer periods of the year (Maestri and Vieira, 1961). When temperatures are lower around high land area, the emergence period may increase to 90 days (Went, 1957). This may be very essential for planning good seedling transplant in the field which saves seedling from death in the field after transplant. Following germination, the coffee cotyledons grow by absorbing the endosperm and turn green (Wellman, 1961; Giorgini and Campos, 1992). The first seed parts to emerge from the soil are the cotyledons, characterizing epigeal seedling growth, and 3 to 4 weeks are required for the cotyledons to completely deplete the endosperm and be free from any residuum of it (Huxley, 1964).

Production of Quality Coffee Seed

For quality coffee seed production, selection of improved coffee variety of high yielder having acceptable quality, disease resistances, insect pest tolerant and adaptable to areas are preliminary work. Coffee seed quality is produced by harvesting red ripe cherries then processing (pulping the harvested red-ripe cherries with machine carefully, washing by clean water, removing husks and broken seeds) and drying takes place under shade. The attainment of optimum moisture content (14-18 percent optimum for coffee seed for storage) and all unwanted part need to be removed (pea-berry, deformed seed and broken) before packing the sack. Also, germination percent is other seed quality parameters to be considered (Melkam, 2015).

For good seed quality preparation, the pulped harvest cherry put into the water holding tanker, and pure seed not visible it sinks to the bottom of tanker holding water. The sunken seed used as the sources of seed; but floaters cannot be used as a seed source. Also, during harvesting avoid long period to pick or harvest upper, lower parts of coffee tree and those fruit/seed dried on coffee trees and shaded on ground are also not used as a source of seed. Therefore; use as sources of seed the medium parts and the ripe cherries (harvesting fresh red cherry) only.

Production and supply of coffee with excellent quality seems more crucial than ever before for coffee exporting countries. Consequently, some countries consider assessment of coffee quality as important as disease resistance and productivity in their coffee variety development program (ITC, 2004). Hence, inorder to provide such important quality that enhances country to be competent in world market with demanded worthy, pure seed production and distributing for producer play vital role.

In view of the present situation, making effort to overcome challenges and threats only through expansion of production does not seem visible for countries like Ethiopia. Thus, it has been authenticated that providing pure seed of high yielder and good quality coffee seed for producer is the only way out and viable option to get into the world market and to remain competitive (Behailu *et al.,* 2008).

Hybrid Coffee Seed Production

In Ethiopia, Jimma Agricultural research center (JARC) considered as a source for coffee technologies. JARC which is a national coffee research coordinator released 7 coffee hybrid verities up to date. Scholar revealed that *Coffea arabica* L. is 76% out crossing perennial crop (Gezahegn, 2014), which indicates that to keep homogeneity or true to type of hybrid seed the parents (two parents) have to crossed manually and sheltered from external anther dust. Taking this in deliberation, the hybrid coffee seed production is unlike pure line coffee seed production. Thus, seed production from hybrid coffee is tedious, labor intensive (emasculation before anthesis, removing very young bud, opening flower and ready to open), time limited (complete flowering in 2-3 days) and require serious management of newly emerging bud on selected branch for cross which may cause seed deterioration. Also, manually hybrid seed production demand skill full human power who have or has detail experience on branch selection for cross and marking selected branch area, which flower bud need to be removed, when to emasculate, how to emasculate and use momentous protocol for cross to protect from other anther dust contamination during crossing.

As consequences of hybrid coffee seed production by hand cross, time specificity (anthesis in a short period of time) and its dependency on rainy season alone, the produced seed in Ethiopian is very low in amount. Hence, hybrid coffee technology distribution by producing seed is serious problem and only very small number of users' demand could be respond per year in the country. To surmount this crisis, today hybrid coffee technology multiplication is carried out by tissue culture under laboratory of biotechnology and stem cutting. Stem cutting method is less expensive and easily applicable when compared with tissue culture method which require expensive growth media, skill full and experienced human powers. However, stem cuttings are difficult to root. Thus, the best way to grow save coffee trees on farmers' farm, technology distribution using seed may be the most important.

Factors Affect Production of Quality Coffee Seed

Pre-harvest Factors

Field Management Practice

Agronomic practice is one of principal factors for persistence quality coffee seed production. Mesfin and Taye (1998) reported the use of decomposed coffee husk at a rate of 10 ton ha -1 (4 kg tree -1 on dry weight basis) was found to be superior in terms of yield performance of coffee trees. A significant improvement in growth and yield of mature coffees was reported in response to coffee pulp and husk compost application (Chane, 1999). Good growth conditions (weed control, appropriate planting density and pruning) usually have a positive effect on bean size (Wintgens, 2004).

Pest and Diseases

Pests and diseases attacks can affect the cherries directly or indirectly by causing them to deteriorate and weakening the plants which will result to produce immature or damaged fruits. As a result of this, the produced coffee seed will be non normal which is not momentous for seed. Disease and insect attack (such as leaf miner and mites) may also result in lower quality beans (Wintgens, 2004). For instance, as reported by Wintgens (2004) the coffee berry borer (*Hypothenemus hampii)* feeds and reproduces inside the coffee beans and causes their seed quality and other quality traits to deteriorate. Also, the antestia sting bug as a vector of micro-organisms damages the bean. Hence, using coffee variety that is resistance to pests and diseases problem is critically important for producing quality coffee seed for user.

Climatic Factor

Apart from physiological aspects, both internal (genetic) and external factors like, climate and edaphic factors like light, temperature, rainfall, humidity, soil nutrients, soil moisture, aeration and soil temperature play a vital role in the coffee production (https://ecofriendlycoffee.org/). Climatic factor has an effect on coffee seed before harvesting starting from flowering to picking ripe cherry and after harvesting (during drying, storage and up to seed sowing). According to the research done over two decades, it was described that as there is a strong relationship between temperature and coffee flowering. Therefore, the presence or absence of appropriate (optimum) temperatures during this critical stage determines the success or failure of flowering and fruiting which is a key factor in stabilizing coffee yield; also which is critical for coffee seed production.

Arabica coffee prefers an optimum daily temperature of between 20° to 24°C. Temperatures greater than 30°C cause plant stress leading to a cessation of photosynthesis. Mean temperatures of less than 15°C limit plant growth. The optimum temperatures for floral initiation are reported around 17°C to 23°C, (Mes, 1957; Gopal and Vasudeva, 1973). High temperatures (33°C) inhibit floral development (Mes, 1957). Also, ideal rainfall for Arabica coffee is greater than 1200 to 1500 mm per year. Rain should be uniformly distributed over seven to nine months of the year. Coffee needs a dry (stress period with little or no rain) to induce a uniform flowering because without a stress period, flowering may extend over many months making harvesting more difficult (http://www.fao.org/document/).

Stage of Fruit Maturity

Stage of harvest of the cherries affects coffee seed quality and its germination (Netsere *et al*., 2006). In line with this, results revealed that deep red, buni (stage after deep red) and reddening stage of maturity show no significant difference in germination percentage but, yellow and green stage of maturity show very low germination percentage (Figure 3) (Anteneh *et al.,*2008). Similarly, it has been reported that coffee seeds acquire maximum germination capacity when the fruits are between buni and deep reddening stages (Ellis *et al*., 1991). Generally, the two results show that as the stage of fruit maturity affects coffee seed germination percentage. Therefore; to supply important quality seed for user, all governmental, NGOs and others coffee seed Producers Company have to take in to consideration the stage of coffee fruit maturity during seed preparation.

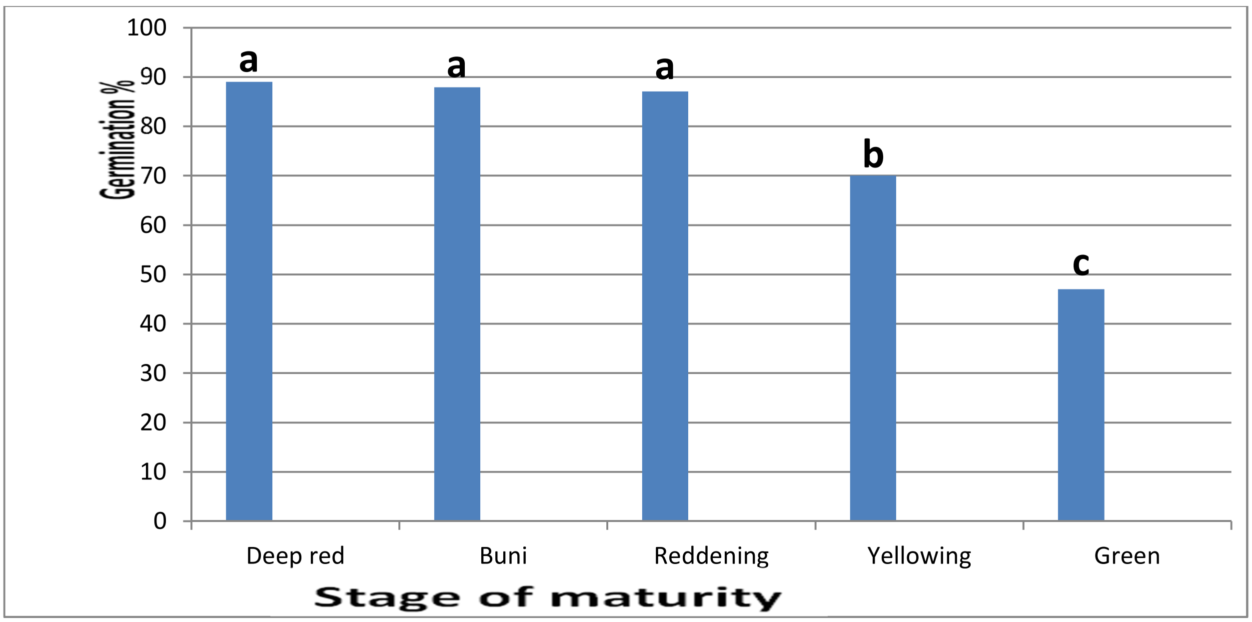

Figure 3. Germination of coffee seeds as effect by stage of fruit maturity
Note; **-** Bars capped with same letter(s) are not significantly different at 0.05 probability level. Source: Anteneh *et al*. (2008).

Post-harvest Factors

Climatic Factor

Woe lore (1995) reported that factors such as total rainfall, relative humidity, maximum-minimum temperatures with effect on water vapor content of the air and storage duration, greatly influence storability and quality of stored parchment coffee. Periods of prolonged drought may also result in lower quality beans (Wintgens, 2004).

Mature seeds can tolerate desiccation to varying degrees. The most common kinds of seed are orthodox and recalcitrant; orthodox seeds are shed at low water contents, and can tolerate further drying without damage. However, recalcitrant seeds are shed from the parent plant with high water contents, are desiccation-sensitive and lose viability at relatively low water content (Roberts, 1973; King and Roberts, 1979). In addition to the orthodox and recalcitrant categories of seed storage behavior, Ellis *et al*. (1990, 1991) introduced the “intermediate” category of desiccation tolerance to describe seeds which can tolerate some drying but do not survive complete desiccation or the combined effects of desiccation and low temperature.

Concerning the storage physiology of coffea seeds, literature is often contradictory. Coffee seeds (C. arabica) were first classified as recalcitrant (King and Roberts, 1979). That classification could not be substantiated, as coffee seeds survive drying to water contents less than 0.20 g H2O/g dw, which is typically the threshold water content defining recalcitrant seeds (Ellis *et al*., 1990; Hong and Ellis, 1995; Vertucci and Farrant, 1995; Eira *et al*., 1999). Also, some study revealed, the seeds do not survive complete desiccation or the combined effects of desiccation and low temperature (Ellis *et al*., 1991; Hong and Ellis, 1995; Dussert *et al*., 1997). Coffee seeds are now considered to have storage behavior defined as intermediate (Ellis *et al*., 1990, 1991; Hong and Ellis, 1995). The major impediment to storing seeds with intermediate physiologies is an understanding of the limit to which Coffea seeds can be dried and the interaction of temperature and water content on seed survival.

Species of *Coffea* display a broad variability in seed desiccation sensitivity (Hong and Ellis, 1995; Dussert *et al*., 1999; Eira *et al*., 1999). Hence, Ellis and his colleagues reported that the minimum water content to which seeds of *C. arabica, C. canephora* and *C. liberica* can be dried without damage is about 0.09gH2O.g-1dw, 0.10-0.12g H2O.g-1dw and 0.24 g H2O.g-1dw, respectively (Ellis *et al*., 1990, 1991; Hong and Ellis, 1995).

Low temperature has detrimental effects on survival of *Coffea* spp. seeds. The temperature, water content of the seeds and the genetic line affect the survival observed following low temperatures. Wellman and Toole (1960) reported that “chilling” has an adverse effect on germination. Similarly, Van der Vossen (1979) reported that storing arabica coffee seeds containing 0.15 to 0.50 g H2O.g-1 dw at 5°C results in an immediate loss of viability.

Seed Drying Methods

Drying methods and the condition of processing affect coffee seed quality (Netsere *et al*., 2006). The same result show that after pulping the cherries and removing the floaters, drying parchment intact seeds in a well aerated, cool and shaded condition till they attained the desired moisture level before sowing/planting ensured higher germination percentage (Figure 4) (Tesfaye, 1998; Anteneh *et al*., 2008). From figure the seed dried under corrugated iron show good germination percentage than those dried under albizia and in open sun. The least germination percentage had recorded for seed dried under open sun. This shows that as coffee seed germination affected by drying methods. Hence, as indicated on figure bow it is advisable for good germination percentage if corugated iron and grass tukel used with necessary condition.

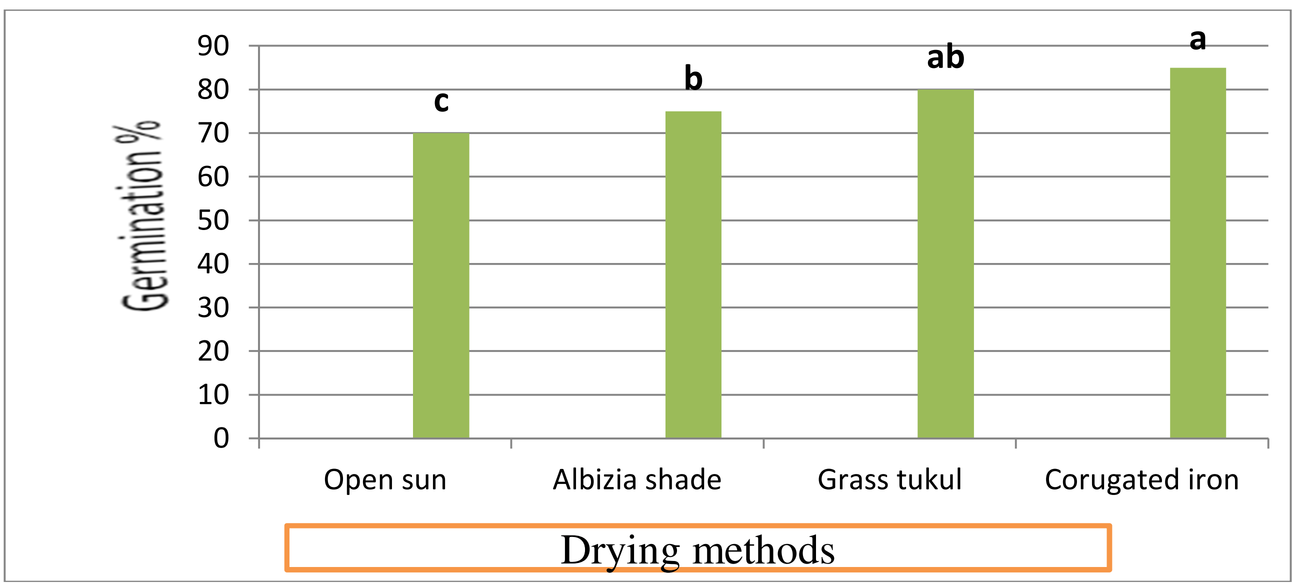

Figure 4. Germination of coffee seeds as effect by drying methods
Note: - Bars capped with same letter(s) are not significantly different at 0.05 probability level.
Source: Tesfaye (1998) and Anteneh *et al*. (2008).

Seed Storage Time

The viability of seeds of *Coffea arabica* L. decreases rapidly after 4-6 months at ambient temperatures, and seeds of commercial cultivars have to be distributed to the coffee nurseries within a few months after harvesting (van der Vossen, 1979; Dias and Barros, 1993; Miranda et *al*., 1993). Similarly, Wondyifraw (1994) reported that percentage of seedling emergence (%SE) and seedlings attained first true leaves (%FTL) decreased gradually after the second month and rapidly after the third month of storage. Besides, mean days to germination (MDG) and FTL mean days attained first true leaves (MDFTL) consistently delayed with prolonged storage time (Table1). Thus, immediate sowing after harvesting and processing is always the best option for higher germination and subsequent growth.

Table1. Effect of time of storage on coffee seed germination and subsequent growth performance of seedlings

Storage time in month	%SE	%FTL	MDG	MDFTL
0*	93.9a	88.4^{a}	32.2^{f}	94.2^{f}
1	84.4b	76.2^{b}	39.6^{e}	99.4^{e}
2	81.0c	76.9^{b}	41.6^{d}	105.4^{d}
3	78.0d	69.2^{c}	$44.^{7c}$	109.5^{c}
4	55.5e	51.7^{d}	52.1^{b}	114.2^{b}
5	51.0f	43.6^{e}	59.9^{a}	116.3^{a}

Those followed by same superscript letters within a column are not significantly different at 0.01 probability level. *****The time just at the date of storage. Source: Wondyifraw (1994).

Seed Moisture Content and Types of Container for Seed Storage

A combination of high initial seed moisture level (not less than 40%) and moisture vapor barrier containers relatively better preserved coffee seed viability longer and improve growth of coffee seedlings (Netsere *et al*., 2006). In line with this result, Wondyifraw (1994) reported that a combination seeds with moisture content of 55.2% and glass jar resulted 97.5, 89.1 and 84.5% values for seed viability, seedling emergence and seedlings attain first true leaf stage, respectively, after five months of storage. While seeds stored at 45.2% moisture content in plastic bag resulted 89.0, 86.3 and 82.0% values for the respective parameters (Figure 5 a, b and c). Thus, plastic bag showed better seed viability, emergency and first true leave next to glass jar with initial moisture content of 45.20%.

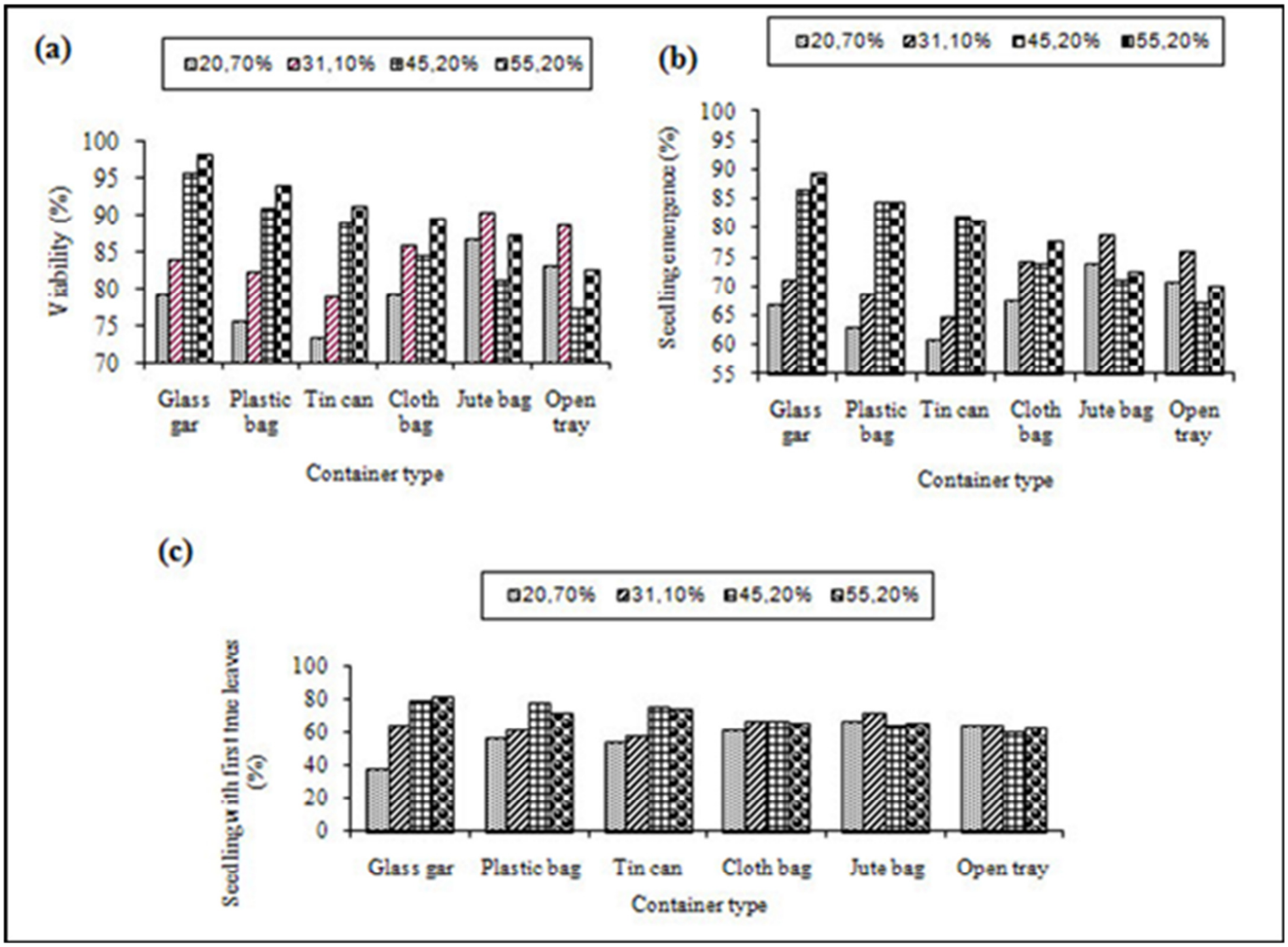

Figure 5. Effect of initial seed moisture level and type of container on percentage of seed viability (**a**), seedling emergence (**b**) and seedling attain first true leaves growth stage (**c**).
Source: Wondyifraw (1994).

Parchment Removal and Seed Soaking

The presence of the endocarp severely restrains the germination of coffee seeds (Valio, 1980). Sowing parchment removed coffee seeds had significantly promoted mean days to emergence as compared to parchment seeds (Figure 6). This practice could also enhance seedling growth (Table 2) and shortens the nursery period by about four weeks (Taye and Alemseged, 2007). Though the difference is not considerable, soaking coffee seeds in cold pure water for 24 hours immediately before sowing had improved rate of emergence, particularly during the early stage after sowing (Figure 6), and produced vigorous seedlings than unsocked seeds (Table 2).

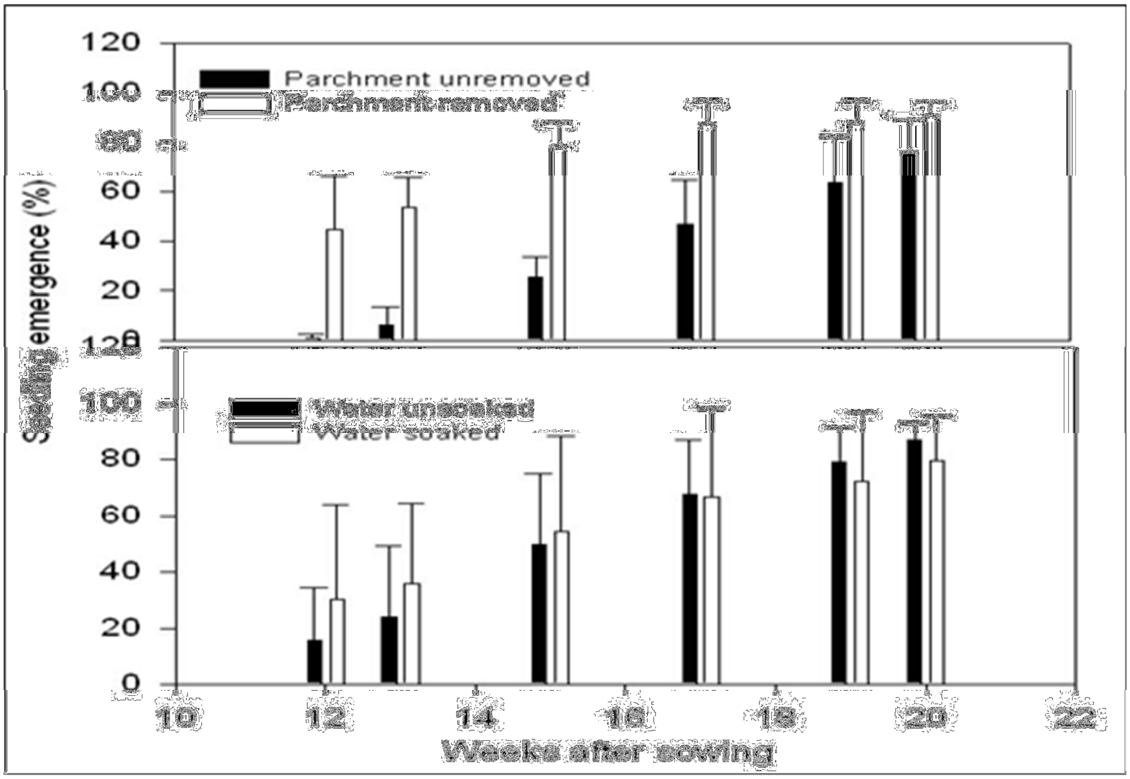

Figure 6. Effect of pre-sowing seed treatment on rate of seedling emergence of Arabica coffee seedling, Source: Taye and Alemseged (2007)

Table 2. Growth parameters (means ± SD) of coffee seedlings as influenced by pre-sowing seed treatments.

Growth character	Parchment removal		Water soaking	
	Unremoved	Removed	Unsoaked	Soaked
Height (cm)	28.02 ± 6.16	28.77 ± 2.89	27.33 ± 3.24	29.46 ± 5.78
Stem diameter (cm)	0.46 ± 0.08	0.49 ± 0.05	0.46 ± 0.04	0.48 ± 0.08
No. of true leaf pair	7.00 ± 0.32	7.50 ± 0.89	7.00 ± 0.71	7.50 ± 0.63
Shoot dry matter (g)	2.88 ± 1.03	3.60 ± 0.86	3.15 ± 0.63	3.32 ± 1.30
Root dry matter (g)	0.70 ± 0.22	0.77 ± 0.16	0.72 ± 0.19	0.74 ± 0.20
Total dry matter (g)	3.58 ± 1.22	4.36 ± 1.01	3.88 ± 0.78	4.06 ± 1.50
RGR* (g $month^{-1}$)	0.58 ± 0.26	0.74 ± 0.20	0.62 ± 0.21	0.70 ± 0.31

*RGR = Relative growth rate, Source: Taye and Alemseged (2007).

Current Coffee Technology Distribution in Ethiopia

Jimma Agricultural Research Center is known for its nucleus of coffee technology distribution in Ethiopia. Starting from its establishment since 1966 to the current scenario, JARC plays a predominant vital for organizing and generating new coffee technology at national level. Even though, coffee propagates via seed, cutting and tissue culture, around 99% coffee technology distribution to different stakeholders is using seed. In order to address all coffee growing areas in Ethiopia by improved coffee varieties, JARC has establish five implementing centers (sub-centers) in major coffee producing zones with the intension of developing local landrace variety.

In addition to its own station, JARC established seed orchards of improved coffee varieties at these implementing centers to response the high demand from different stakeholders. Hence, up to 2010 JARC distributed 175.641 ton

(Taye *et al.*, 2011), and 166.18 ton from 2011 to 2019(Table 3), up to date, a total of 341.821 ton seed of improved coffee varieties distributed to different coffee producing areas of stakeholders. Additionally, JARC distributed 269,220 pureline seedling and 78,088 hybrid seedling, entirely, 347,308 seedling of improved varieties disseminated for different users (Table3). Coffee seed distribution over three physical years (from 2016 to2018) showed increasing trend; in 2018 year, coffee seed and pureline seedling distribution recorded highest amount than others; but from 2011 to 2014 physical years, pureline seedling didn't distributed. Highest hybrid seedling distribution recorded in 2011, and followed by 2012, 2013 and 2014 respectively (Table 3). However, rapidly decreasing in others physical years of hybrid coffee seedling distribution. Also, when 2019 compared with 2018 in coffee seed, pure-line seedling and hybrid seedling distribution, decreasing trends observed. Hence, in addition to JARC which is coordinating national coffee research, government must give attention for seed orchards establishment at different regional levels which are major coffee producing areas.

Table 3. List of distributed coffee seed, seedling from 2011 to 2019 in Ethiopia

Distributed coffee technology	**Distribution years**									**Stakeholders**
	2011	2012	2013	2014	2015	2016	2017	2018	2019	
Coffee seed(Kg)	13,450	10,500	10,000	16,000	15,000	17,500	29,030	30,000	24,700	Farmers, NGOs, Investors and Governmental organizations
Pureline seedling	20,720	-	-	-	35,000	28,500	35,000	100,000	50,000	
Hybrid seedling	15,000	12,900	12,600	9,500	4,000	5,848	4,740	7,000	6,500	

Source: Ethiopian Institute of agricultural Research Jimma Agricultural research Center (JARC) progress report from 2011 to 2019.

Coffee Seed Supply System

Coffee seed production and supplying is not like others crop seed production and supplying system. This is because of almost all the governmental institution that responsible for multiplication of genetically pure seed of Arabica coffee in the Ethiopia is given to Jimma Agricultural Research Center (JARC) (Taye *et al.*, 2011). From this it is possible to understand that greatest burden of formal coffee seed supply system in the country is from JARC. At research center coffee seeds are mainly produced from seed orchards of released and adoptable coffee varieties and managed coffee technology multiplication and from different field experiment existing in different centers. Accordingly, a total of 341.821 ton (from 1978 to 2019) and 347,308 (from 2011 to 2019) of improved coffee seed and seedling (hybrid and pureline seedling) had been produced over the last five decades and disseminated to different users in the country respectively.

Hence, JARC cannot meet the rapidly growing demand for improved coffee varieties in the country as described by (Negusie *et al.*, 2008). To overcome the shortage of coffee seed required for users, recently a small number of the informal coffee seeds system is practiced by private and public coffee farms in major coffee producing regions of the country like state farm of Limu, Babaka and Tepi. From these state farms over 59,287 kg of coffee seed had produced and distributed to different users. This implies that the informal seed system contribution in the country is very low when compared with formal seed system and from year to year increments of demand. Thus, according to informal seed supply system information, the contribution of farmers' coffee seed system in the major coffee growing area of the Oromia and South Nation nationalities and people (SNNP) regional states of the country are inadequate and wait for investigation (Taye *et al.*, 2011); require more number of informal seed supply and governmental encouragement for ample seed supply for all coffee seed technology users through the country.

Factors Affecting Coffee Seed Supplying System

Ethiopian coffee seed is produced by small-scale farmers in small quantity. Also in Ethiopia there are limited numbers of private or nongovernmental bodies responsible for coffee seed production which is informal way of coffee seed supply system. Due to formal coffee seed supply system is limited to small number of users and the informal system is incapable of producing enough improved quality seed in the existing situation, there is scarcity of distributing of seed to different user. Therefore; it become main factor for demand and supply of coffee seeds incompatible (Negusie *et al.*, 2008 and Melkam, 2015).

Supply and Demand of Coffee Seed

The coffee seed varieties demand from different regions is higher than production (supply); the highest demand recorded on the varieties 74110 and 74112, the lowest was locally known as yaci, merdacherico, weshi -weshi and buno - weshi these newly released has need higher popularization, demonstration and scaling up to the end users (Melkam, 2015). If the users don't know the newly released varieties very well, it will expose negative impact on seed supply system in the country; thus, the extension works is highly important to eradicate such unnecessary technology information gap.

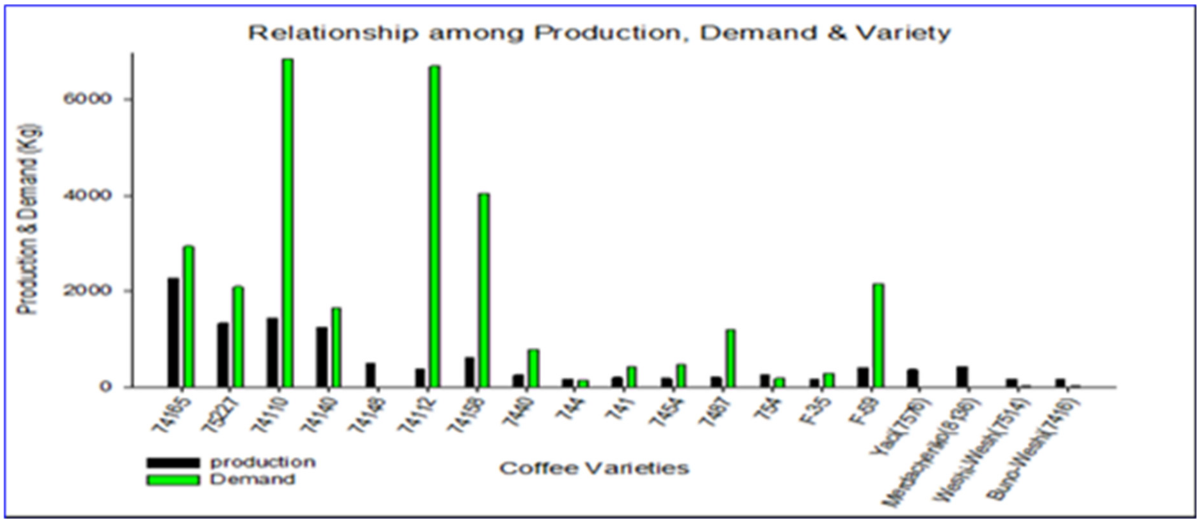

Figure 7. The relationship among coffee seed production, demand (demand vs supply) and variety, **Source:-**Melkum, 2015

CONCLUSIONS AND FUTURE DIRECTIONS

Quality coffee seed production and well organized seed supply system are prerequisites step in increasing coffee production in all coffee producing countries including Ethiopia. Providing genetically pure coffee seed supported by technology and addressing the demand from user is the basic for increasing coffee production and becoming capable of competent in world market. In order to produce good quality coffee seed, knowing the management practice and its physiological characteristic like seed development is very important. Additionally, to protect genetic deterioration or to have true to type seed, the hybrid seed must be prepared by crossing the two parents all round the year. Therefore, to do this it is must to know the coffee flowering characteristics starting from anthesis up to seed development and also closely follow up is essential to remove unnecessary flower bud and fruit.

Quality coffee seed production is affected by two basic factors (pre-harvest and post-harvest factors) starting from field up to storage. For quality seed production the responsible organ should care for the factors affecting seed quality like disease, insect pest, stage of maturity, inappropriate storage and climatic condition. Reddening and deep reddening stage resulted greater than 80 germination percentage, but less at yellow and green stage. Therefore; to ensure higher germination percentage, after pulping cherries the seed should be dried under well aerate and cool shade such as corrugated iron and grass tukul. The percentage of seed emergence, attain first true leaf and viability of seeds of *Coffea arabica* L. decreases rapidly after 3-5 months; hence, it is advisable for seeds of improved variety to be distributed to the coffee nurseries before one months after harvesting. Also, parchment removal and water soaking (for 24hr) have positive impact on early seedling emergence and seedling growth traits. Jima Agricultural Research Center (JARC) has released 35 pureline and7 hybrid, entirely, 42 coffee varieties in up to date. Over 341.821 ton (up to 2019) and 347,308 (from 2011 to 2019) of improved coffee seed and seedling (hybrid and pureline seedling) had been produced over the last five and one decades, and disseminated to different users in the country respectively.

Hybrid coffee seed production should not be depending on rain fail only. The government should give attention for irrigation production system to ensure high seed production and supply of required amount of quality coffee seeds. Duet to less in number of governmental and private body responsible for coffee seed production, in Ethiopia coffee seed supplying to different users become very low when compared with the existing seed demand. To overcome this problem coffee seed technology multiplication mandate shouldn't be limited at JARC which is national coffee research coordinator, but also at provincial level (by model farmer, Agricultural office and NGO) coffee seed technology multiplication should be diversified specially in major coffee growing area.

JARC which has taken most percentage of governmental mandates of multiplying improved coffee seed should have to multiply the seed in wide areas of its sub center and substation. Up to date most coffee producers did not participate in coffee seed production in wider and efficiently use available improved coffee research technologies due to limited extension services. Hence, considerable improvement on coffee producers' involvement is essential in this regards. Generally; to ensure continuous quality seed, adequate coffee seed production and supplying system in the country there should be capacity building program for the involvement of stakeholders in seed production and supplying system.

REFERENCES

Alvim PT (1973). Factors affecting flowering of coffee. In: SRB, A.M. (ed), Genes, enzymes and population, Plenum Press, New York, pp.193- 202.

Anteneh N, Endale T, Tesfaye S, Taye K, Amanuale A (2008). Preplanting Management of Arabica coffee in Ethiopia. pp 178- 186.

Anthony F, Bertrand B, Quiros O, Lashermes P, Berthaud J, Charrier A (2001).Genetic diversity of wild coffee (Coffea arabica L.) using molecular markers. Euphytica 118: 53-65.

Arcila-Pulgarín MI, Orozco-Castaño FJ ((1987). Estudio morfologico del desarrollo del embrion de cafe. Cenicafé 38:62-63.

Behailu W, Abrar S, Nugussie M, Solomon I (2008). Coffee Processing and Quality Research in Ethiopia. In: Proceedings of a National Work Shop Four Decades of Coffee Research and Development in Ethiopia. 14-17 August 2007, EIAR, Addis Ababa, Ethiopia. pp. 307-316.

Bewley JD, Black M (1994). Seeds: germination, structure, and composition. Seeds: physiology of development and germination, pp.1-31.

Carvalho A, Medina Filho HP, Fazuoli LC, Guerreiro Filho O, Lima MM (1991). Aspectos genéticos do cafeeiro. Rev. Bras. Genet. 14:135-183.

Central Statistical Agency (CSA) (2019). Agricultural sample survey 2018/ 19. Volume I. Report on area and production of crops (private peasant holdings, Meher season), Addis Ababa, Ethiopia. pp1-54.

Chane AM (1999). Management of coffee processing by-products for improved and sustainable coffee production in Ethiopia, PhD dissertation, University of Giessen, Germany, pp1- 175.

Couturon E, Raharimalala NE, Rakotomalala JJ, Hamon S, de Kochko A, Guyot R, Hamon P (2016).Wild coffee-trees: a threatened treasure in the heart of tropical forests. *Caféiers Sauvages: Un Trésor en Péril au Cœur des Forêts Tropicales (Private publication, 2016)*.

De Castro RD, Estanislau WT, Carvalho ML, Hilhorst HW (2004). Functional development and (pre-) maturation of coffee (Coffea arabica) fruits and seeds. In 20th ASIC conference, 2004 Bangalore. Proceedings of the 20 th ASIC Conference. Bangalore: ASIC.

De Castro RD, Marraccini P (2006). Cytology, biochemistry and molecular changes during coffee fruit development. Brazilian Journal of Plant Physiology, 18: 175-199.

Dedecca DM (1957). Anatomia e desenvolvimento ontogenético de Coffea arabica L. var. Typica Cramer. Bragantia 16: 315-355.

Dentan E (1985). The microscopic structure of coffee bean. In: Clifford MF, Wilson KC(eds), Coffee: botany, biochemistry and production of beans and beverage, The Avi Publishing Company, Westport, pp.284-304.

Desse N (2008). Mapping quality profile of Ethiopian coffee by origin. In: Proceedings of a National Work Shop Four Decades of Coffee Research and Development in Ethiopia. 14-17 August 2007, EIAR, Addis Ababa, Ethiopia. pp. 328-333.

Dias MC, Barros AS (1993). Conservação de sementes de café (Coffea arabica L.)em diferentes embalagens. Rev. Bras. Sem. 15:197-202.

Dussert S, Chabrillange N, Engelmann F, Anthony F, Hamon S (1997). Cryopreservation of coffee (Coffea arabica L.) seeds: importance of the precooling temperature. CryoLetter 18:269 276.

Dussert S, Chabrillange N, Engelmann F, Hamon S (1999). Quantitative estimation of seed desiccation sensitivity using a quantal response model: application to nine species of the genus Coffea L. Seed Sci. Res. 9:135–144.

Eira MT, Walters C, Caldas LS, Fazuoli LC, Sampaio JB, Dias MC (1999). Tolerance of Coffea spp. seeds to desiccation and low temperature. Rev. Bras. Fisiol. Veg. 11: 97–105.

Ellis, R.H., Hong, T.D. and Roberts, E.H. 1990. An intermediate category of seed storage behaviour? I. Coffee. J. Exp. Bot. 41:1167–1174.

Ellis RH, Hong TD, Roberts EH (1991). An intermediate category of seed storage behaviour? II. Effects of provenance, immaturity and imbibition on desiccation tolerance in coffee. J. Exp. Bot. 42:653-657.

Estanislau WT (2002). Modelo funcional de desenvolvimento de sementes de cafeeiro (Coffea arabica). Lavras, Universidade Federal de Lavras. MSc

Thesis, Lavras.

Farah A, Ferreira dos Santos T (2015). The Coffee Plant and Beans; Coffee in Health and Disease Prevention.pp.73-81. https://doi.org/10.1016/B978-0-12-409517-5.00001-2

Fazuoli LC (1986). Genética e melhoramento do cafeeiro. In: Rena AB, Malavolta E, Rocha M, Yamada T (eds), Cultura do cafeeiro – fatores que afetam a produtividade. Associação Brasileira para Pesquisa da Potassa e do Fosfato, Piracicaba. for growers, processors, traders and researchers. Weinheim Germany, pp.87- 113.

Gezahegn B (2014). Genetic Diversity, Pollination Ecology and Organoleptic Characteristics ofCoffea arabicaL. in Ethiopian Moist Forests of Different Management Intensity. Dissertation for the degree of Doctor in Science (Biology), pp 215.

Giorgini JF, Campos CA (1992). Changes in the content of soluble sugars and starch synthesis and degradation during germination and seedling growth of Coffea arabica L. Rev. Bras. Fisiol. Veg. 4:11-15.

Gong X, Bassel GW, Wang A, Greenwood JS, Bewley JD (2004). The emergences of embryos from hard seeds are related to the structure of the cell walls of the micropylar endosperm, and not to endo-ß-mannanase activity. Ann. Bot. 96:1165-1173.

Gopal NH, Vasudeva N (1973). Physiological studies on flowering in Arabica coffee under South Indian conditions. 1. Growth of flower buds and flowering. Turrialba, 23, 146-53.

Guerreiro Filho O (1992). Coffea racemosa Lour. Une revue. Café Cacao Thé XXXVI:171-186.

Guimarães RM (1999). Fisiologia de sementes. Lavras, Universidade Federal de Lavras/ FAEPE, pp129.

Hong TD, Ellis RH (1995). Interspecific variation in seed storage behaviour within two genera – Coffea and Citrus. Seed Sci. Technol. 23:165-181.

http://www.fao.org/docrep/008/ae939e/ae939e03.htm (on November 14/2016)

https://ecofriendlycoffee.org/the-impact-of-climate-change-on-coffee/ (on November14/2016)

Huxley PA (1964). Some factors which can regulate germination and influence viability of coffee seeds. Proc. Intern. Seed Test Assoc. 29:33-60.

ITC (2004). Bitter or better future for coffee producers? International Trade Centre.The magazine of the International Trade Centre. **2**: 9-13.

King MW, Roberts EH (1979). The storage of recalcitrant seeds - achievements and possible approaches. Rome, IBPGR.

Krug CA, Carvalho A (1939). Genetical proof of the existence of coffee endosperm. Nature 144:515.

Maestri M, Barros RS (1977). Coffee. In Ecophysiology of tropical crops. Academic Press, pp. 249-278.

Maestri M, Vieira C (1961). Nota sobre a redução da porcentagem de germinação de sementes de café por efeito do ácido giberélico. Rev. Ceres 11:247-249. management. M.Sc. Thesis Submitted to Graduate Studies of Haramaya University, Haramaya, Ethiopia.

Medina Filho HP, Carvalho A, Sondahl MR, Fazuoli LC, Costa WM (1984). Coffee breeding and related evolutionary aspects. Plant Breed. Rev. 2:157-193.

Melkam A (2015). Coffee Seed Production and Supply at Research Centre in Ethiopia. Journal of Biology and Medicinal Sciences, 2: 82-88.

Mendes AJ (1941). Cytological observations in Coffea. VI. Embryo and endosperm development in Coffea arabica L. Am. J. Bot. 28:784-789.

Mes MG (1957). Studies on the flowering of Coffea arabica L. I. The influence of temperature on the initiation and growth of coffee flowering buds. Portugaliae Acta Biologica, 4, 328-41.

Miranda JM, Carvalho MM, Carvalho ML, Vieira MG (1993). Estudos de alguns fatores que influenciam a viabilidade de sementes de café. Rev. Bras. Sem. 15:215-220.

Mirian TS, Eira EA, Amaral da S, Renato D. de Castro, Stéphane Dussert, Christina Walters J, Derek B, Henk W M (2006). Brazilian Journal of Plant Physiology., 18(1):149-163.

Netsere A, Tefera W, Belachew B (2006). Pre-Sowing Arabica Coffee Seed Management in Ethiopia: a Review. Jima Agricultural Research Center, P. 0. Box 192, Jima, Ethiopia *E- mail: anetsere18@ygmail.com P. and Pot, D. 2006. Genetics of coffee quality. Braz. J. Plant Physiol. **18 (1)**: 229- 242.

Negusie E, Derese T, Berhanu M and Getachew WM (2008). Research Center-based extension interventions on improved coffee technologies. Coffee Diversity & Knowledge. Proceedings on Four Decades of Coffee Research and Development in Ethiopia, A National W orkshop, 14-17 August 2007, Ghion Hotel, Addis Ababa, Ethiopia. pp: 345-356.

Ramaiah PK, Vasudeva N (1969). Observations on the growth of coffee berries in south India. Turrialba, 19:544-464.

Rena AB, Malavolta E, Rocha M, Yamada T (1986). Cultura do cafeeiro - fatores que afetam a produtividade. Potafos, Piracicaba.

Roberts EH (1973). Predicting the storage life of seeds. Seed Sci. Technol.1:499-514.

Seyoum S, Singh H, Bellachew B (2004). Diversity in the Ethiopia Coffee (*Coffea arabica* L.) Germplasm. In ASIC 20th Colloquium, India, Bangalore.

Silva, E A, Toorop PE, van Aelst AC, Hilhorst HW (2004). Abscisic acid controls embryo growth potential and endosperm cap weakening during coffee (Coffea arabica cv. Rubi) seed germination. Planta 220:251-261.

Taye K, Alemseged Y (2007). Emergence and growth of Arabica coffee seedlings as influenced by some pre-sowing seed treatments. p. 1188-1195. In Int. Conf. Coffee Science, 21st, Montpellier, 11th – 15th September 2007. ASIC, France.

Taye K, Ashenafi A, Alemseged Y, Teshome K, Wondiyfraw T (2011). The contribution of coffee research for coffee seed development in Ethiopia. E3 Journal of Agricultural Research and Development Vol. 1(1). pp. 009-016, December, 2011 Available online http://www.e3journals.org/EJARD.

Mesfin A, Taye K (1998). Response of Arabica Coffee (*Coffea arabica* L.) to Various Soil Fertility Management

Tesfaye Sh, Yacob E, Alemseged Y, Taye K (1998). Research achievements and transferable technology in coffee agronomy. In Proceedings of the Third Technology Generation, Transfer and gap Analysis Workshop. 12-14 November 1996, Nekemet, Ethiopia, Pp 70-79.

Valio IF (1980). Inhibition of germination of coffee seeds (Coffea arabica L. cv. Mundo Novo) by the endocarp. J. Seed Technol. 5:32-39.

Van der Vossen HA (1979). Methods of preserving the viability of coffee seed in storage. Seed Sci. Technol. 7:65–74.

Vertucci CW, Farrant JM (1995). Acquisition and loss of desiccation tolerance. In: Kigel J, Galilli G. (eds) Seed development and germination. Marcel Dekker, New York, pp.237-271

Wellman FL (1961). Coffee: botany, cultivation, and utilization. London, Leonard Hill, pp1-191.

Wellman FL, Toole VK (1960). Coffee seed germination as affected by species, diseases and temperature. Proc. Caribbean Region Am. Soc. Hort. Sci. 4:1-6.

Went, F.W., 1957. The experimental control of plant growth, pp17.

Wintgens JN (2004). Coffee: growing, processing, sustainable production. A guidebook for growers, processors, traders, and researchers. WILEY-VCH Verlag GmbH & Co. KGaA.

Wintgens JN (2009). Factors influencing the quality of green coffee. Coffee: growing, processing, sustainable production. A guidebook for growers, processors, traders and researchers, pp.797-817.

Woelore WM (1995). Parchment arabica coffee storage. In COLLOQUE Scientifique International sur le Café, 16. Kyoto (Japón), Avril 9-14.

Wolfrom ML, Laver ML, Patin DL (1961). Carbohydrates of coffee bean. II. Isolation and characterization of a mannan. J. Org. Chem. 26:4533-4536.

Wolfrom ML, Patin DL (1964). Isolation and characterization of cellulose in the coffee bean. Agric. Food Chem. 12:376-377.

Wondyifraw T (1994). The influence of duration of storage, initial moisture content and type of container on the viability of coffee (Coffea arabica L.) seeds. M. Sc. thesis, Alemaya University of Agriculture, Alemaya, Ethiopia.

Wormer TM (1964). The growth of the coffee berry. Am. J. Bot. 28:47-55