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Effects of different seed treatments, provenance and size on germination and early establishment of *Olea europaea*

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Knowledge and understanding of the factors affecting germination and growth of tree species is of paramount importance for enhancing the efforts towards afforestation. Hence, the prime objective of this study is to evaluate the effects of seed treatment methods, provenance and size on germination and early nursery performance of *Olea europaea.* The experiment was arranged in a factorial combination and laid out in randomized complete block design with three replications. Factor A was seed treatment methods (soaking in three levels of hot water, soaking in four levels of concentrated H_2SO_4, heating with fire, de-coating and control). Factor B was two seed provenances and factor C was two seed size classes. Interaction of seed size and provenance had no significant effect ($p > 0.05$) on all parameters. Different seed soaking method showed highly significant difference ($p < 0.01$) in all parameters. Seed de-coating had maximum value for all parameters but seeds treated with fire had lowest value. Hence, the germination percentages under nursery condition were 85.8 and 2.5% for de-coated and fire treated seeds, respectively. It was concluded that seeds from both provenances and seed size class germinated and were established equally; de-coating improved germination and early nursery performance; whereas, fire affected germination and early nursery performance negatively. Seed de-coating has to be done widely for the improvement of germination and early establishment of *Olea europaea* and further research is needed on the use of fire for breaking dormancy.

Key words: Dormancy, germination, *Olea europaea*, provenance, seed treatment, seed.

INTRODUCTION

The indigenous trees of Ethiopia are on the decline because the country has rapidly converted its habitat to arable lands and continues to utilize the land without caution. These conditions are triggered mainly by rapid population growth, their increased importance and skill and knowledge gap on means of propagation. It is very complicated to establish indigenous tree species due to management problems in the nursery, problems of seed

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availability and slow growth performance. The high rate of deforestation has affected the ecosystem as a whole adversely. The indigenous forest ecosystem occupies the diversified and interlinked interaction with the existing fauna and flora. There are easily decomposable plant materials on the forest floor and diversified plants, bird and animal species (EFAP, 1994).

The dry Afromontane forests of Ethiopia majorly contain tree species such as *Juniperus procera, Olea europaea, Podocarpus falcatus* (*Afrocarpus falcatus*) *etc. O. europaea* subsp. *cuspidata* is identified as a dominant late-successional species in the Afromontane zone. *O. europaea* is a highly esteemed tree in Ethiopia and other places; it has a great variety of uses. The high demand for *Olea* coupled with the continued degradation of the Afromontane forest has threatened the species very extensively. The consequence is that its population is dwindling from natural forest and plantations (Demel, 2003).

Many studies suggested that the highlands of Ethiopia were once covered by diverse forest dominated by *J. procera*, co-dominated by *O. europaea* supposed to be the natural vegetation of the region (Friis, 1992; Demel, 1996; Alemayehu, 2007). According to Darbyshire et al. (2003), pollen and charcoal analysis has further substantiated that *J. procera* forests with Olea and *Celtis africana* had been the predominant vegetation of the Northern Highlands of Ethiopia. African wild olive (*O. europaea* ssp. *cuspidata*) is a valuable secondary climax tree of dry Afromontane forest, that is able to regenerate naturally in ex-closures under the protective cover of specific pioneer shrubs (Aerts et al., 2006a). Abera (2009) reported that the trees are protected by early ancestors and passed to their generation. He also identified that from the total population of Dallo kebele, about 10.7% have been growing olea by retaining naturally and some 2.7% were found to have planted olea trees. Once *O. europaea* is established, it is a drought resistant and long living tree, but due to its multiple uses (durable timber, traditional ox-ploughs, traditional medicine, furniture making, firewood and charcoal), both young and mature trees have been over-harvested dramatically in Ethiopia. As a result, this valuable tree is now under threat of local extinction (Legesse, 2003). Rainfall seasonality is a dominant factor in regulating establishment, recruitment, survival and growth of *O. europaea*, particularly during the seedling stage. Moreover, shade and herbivory are factors that need consideration (Tesfaye, 2005). Since *O. europaea* grows better under shade than in the open sun, successful regeneration for this species relies on shade from other plants and on protection from grazing animals, at least during the seedling stage. Under protection, *O. europaea* seems to have a possibility to regenerate naturally (Tesfaye, 2005).

Raising of Olea seedling is discouraging, because the species has different problems; for example low germination percentage, extended germination period, irregularity in germination and slow growth. The seed of this tree stays in the soil up to five month until it starts to germinate and even for germinated seeds the germination is not uniform. Local attempts in Eritrea to re-afforest *O. europaea* have been unsuccessful due to poor seed germination ranging from 0-5% and long germination period. The seedlings take about 12 months to reach field plantation stage (ICRAF, 2010). A noticeable increase in germination is obtained by removing the endocarp; it imposes a mechanical constraint to germination. Cracking with a hand device or by rolling a stone over seeds can cause the endocarp to break along or across the suture line, which bisects it. By mechanically scarifying and removing the hard endocarp of Olea it is possible to increase its germination up to 92% (ICRAF, 2010).

Olea is one of the indigenous tree species that has been grown in most parts of the country from ancient time up to the present. It was adapted to wide agro-ecological zone, but nowadays the tree is deforested from its natural habitat and restricted to church yards and gardens of few farmers. The degradation of olea was attributed to its multiple uses, slow growth and poor regeneration. Higher market value for the species attracts people to over harvest the tree including illegal loggers. Poor germination status and slow growth of olea have enforced local farmers to grow other fast-growing tree species because poor germination results in higher cost of raising seedlings. The major barrier to olive seed germination is the stony endocarp in addition to other causes of dormancy including seed coat, endosperm and embryo itself (Lagarda et al., 1983b). It is reported that 28% of olive seed dormancy is imposed by the endocarp and 56% by the endosperm (Sotomayor-Leon and Caballero, 1994). To break olive endocarp, chemical scarification has been widely used to overcome physical seed dormancy (Hartmann and Kester, 2002). Germination percentage of three olive cultivars was improved after the stony seeds were scarified with 0.1 N NaOH and H_2SO_4 at 0.1 N (Bandino et al., 1999).

Olea seed supply is also the main problem in the area, because there is no forest of this species in many districts for local seed collection and even when seeds are obtained the germination percentage is too low; hence there is a need to buy more seed to compensate for the non-germinating seeds (Legesse, 1990; Abera, 2009). The extended period of germination has in many cases resulted in the degradation of pot and seed bed and this discourages farmers to raise seedlings of this species. Absence of plantation or natural forest of this species in Burie District of Ethiopia has made it difficult to obtain its seed**.** When the seedlings of this species are available they have good market in the area and the price is higher than other tree seedlings; for example in 2010, the price of eucalyptus seedling was 0.5 cents; whereas, that of *O. europaea* was 4-6 birr per seedling in the local

Figure 1. Laboratory experiment arrangement.

market (OA, 2016).

Olea tree is one of the respected and most preferred species by farmers in the study area for its beauty and multiple uses. The tree is considered as a multipurpose tree because it provides various uses including; farm tool making, for fragrance, for smoking milk containers and traditional beverage vessels, household furniture making, and culturally it is assigned as symbol of good hope if planted around home, shade for humans and animals, medicine for various diseases, useful for biological soil and water conservation and birds prefer the tree for nesting (OA, 2016). Moreover, little attention has been paid until now to enhance seed germination process of this specie in spite of its economic importance (Wang et al., 2007). In this sense, the objective of this work is to evaluate the effects of seed treatment methods, provenance and size on germination and early nursery performance of *Olea europaea.*

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Burie Agricultural and Vocational Education Training College, Burie District, West Gojjam Zone Ethiopia, which is situated at 10°42' N and 37°4' E. The altitude of this particular area is 2100 m.a.s.l. The soil type is a mixture of humic nitosol and eutric vertisols, which is relatively fine in texture and having medium organic matter with pH value of 5.8. The mean annual rainfall and temperatures are 1800 mm and 20°C, respectively (OA, 2016).

Preparation of experimental site and materials

To undertake the experiment, a raised seedbed was constructed from local soil, sand and compost mixture at the ratio of 3:2:1 (3 parts of local soil, 2 parts of compost and 1 part of sand). The seedbed was 1.2 m wide and 15 m long and it was partitioned into plots of 40 cm width and 60 cm length. The line of sowing was 10 cm x 5 cm between rows and seeds, respectively (Chanie and Tileye, 2015) (Figure 1).

The seeds for the study were obtained from two provenances. The provenances were Mertule Mariam and Kofele districts. These two provenances were selected because they are the main seed sources of *O. europaea* for the study area. Untreated seeds of the mentioned provenances were obtained timely. Maturity of seed, seed purity and moisture content (mc) were checked before germination test, and the results of the checkup showed that the seeds were fully matured, 100% pure and 6.8% mc.

Experimental design and treatments

The experiment was conducted under laboratory and nursery conditions. The laboratory experiment was included in the study to support the nursery results. Moreover, as the nursery is exposed to interferences, it is difficult to determine the potential of germination status of the species. Hence, laboratory experiment was incorporated in the study. The nursery experiment was arranged in a factorial combination and laid out in randomized complete block design with three replications. The treatment combination consists of three factors namely: different seed treatment methods, seed size and seed provenance. The seed treatment methods were made on four seed pre-sowing treatment methods. The seed was grouped into two seed size classes (large and small seed) and two seed provenances (Mertule Marium and Kofele). The pre-sowing seed soaking methods were: de-coating, soaking in three levels of hot water, soaking in four levels of concentrated sulfuric acid, heating with fire and control. For nursery experiment fifty seeds were taken randomly in three replications for each seed pre-sowing treatment methods. However, laboratory experiment was conducted in Burie Agricultural and Vocational Education Training College's laboratory. It was laid out in completely randomized design and each treatment was applied three times like that of the nursery experiment and each replication contained 20 seeds; the treated seeds were taken from each seed size class and provenance and sown on a Petri dish. The seeds were covered with soft paper and distilled water was added until the seeds became moist. Then the Petri dishes were covered with the cover lid to protect the seeds (Leishangthem and Rana, 2017). Moistening of the seeds was continued every day until the end of the experimentation. As indicated above factor A was pre-sowing seed treatment method. Hence, the followings are pre-sowing seed treatments methods applied in the experiment.

Soaking in hot water

This treatment method consists of soaking in three levels of hot water for each seed provenance and size classes. The soaking durations were twelve hours, twenty-four hours, and forty-eight hours. For each treatment, sample seeds from each provenance and size class were taken randomly from the seed lots and put into separate beakers as stated by ISTA (1996) and Rómulo et al. (2017).

Soaking in concentrated sulfuric acid (H_2SO4)

Soaking of seed in concentrated H_2SO_4 was assigned in four levels. These were done in 15, 30 min, 1 and 2 h; sixteen treatments were studied by taking sample seeds from each seed provenance and size classes by simple randomization in three replications. Beakers were arranged and 50 seeds were randomly counted from each provenance and size class; they were put in each beaker and then acid was poured into the beaker. The volume of acid was three times the volume of the seed in the beaker and the seed was soaked until the experimental time was achieved following the recommendation of Moya et al. (2017) and ISTA (1996).

Mechanical scarification (De-coating)

This method was designed to remove the hard endocarp completely; to do this experiment, 50 seeds were taken randomly from both provenances and seed size classes in three replications. The hard seed coat was removed by grinding the seeds on grain grinding stone mills (Hallett and Bewley, 2002). Finally, the inner seed part (cotyledon) was taken out and sown.

Heating with fire

Seeds were randomly taken from each seed provenance and seed size class and then put on hot traditional oven until the seeds' coats showed first colour change. Then they were removed from the fire source, soaked in cold water for five minutes and sown on the prepared seedbed (Hossain, 2005) (Figure 3).

Control

Sample seeds were taken randomly from each provenance and each size class randomly in three replications and then the seeds were sown on separate plots without application of any pre-sowing treatment. In this study the second factor was factor B which was seed provenance. Seeds from both provenances were brought to the experimental area and placed under ambient condition until the experimentation was launched. And, the third factor was seed size. Seeds from both provenances were first categorized into two size class as large seeds and small seeds. The small seeds are those with mean diameter of 5- 7.5 mm and large seeds were with mean diameter greater than 7.5 mm. Seed separation was done by filtering with sieves of 5 cm diameter and 7.5 cm diameter. Totally, the combination of the three factors resulted in 40 treatments and 120 plots (Alcántara et al., 2000b; Aerts et al., 2006b).

Method of data collection

Data collection from laboratory experiment was targeted on collecting germination potential of different treatments so that starting from the date of sowing up to end of the experiment and germination counts were done weekly. To facilitate future count germinated seeds were removed and the same data recording procedure was followed.

Germination data for nursery experiment were collected every week. To facilitate future counts germination data of the next were added to the previous data and the cumulative germination was recorded so that the last record showed the total count (Desalegn and Demel, 2010). The germination responses were expressed in germination percentage, mean germination time, peak value, germination value, mean daily germination and germination rate. Germination percentage, mean germination time and peak value were determined by formulas used by Labouriau and Agudo (1987); germination value and germination rate were calculated following the method developed by Johnson (2000); whereas mean daily germination was calculated by using Czabator's (1962) formula.

Germination percentage (Gp)

Gp $= \frac{n}{N} \times 100$, where:

n=total number of germinated seeds;
N=total number of seeds in the sample.

Mean germination time (MGT)

$$(\mathrm{MGT}) = \frac{(\sum niti)}{n}$$, where:

ni= percentage of seeds germinated between two consecutive counts;
ti= time taken since germination experiment started;
n= total percentage of seeds germinated.

Peak value (PV)

$$PV = \frac{\text{Cumulative percentage germination on each day}}{\text{No. of days elapsed since initial imbibitions}}$$

Germination value (GV)

GV = Peak value × Germination percentage

Germination rate (GR)

$$GR = \frac{\text{No of normal seedlings}}{\text{Days of first count}} + \ldots + \frac{\text{no of normal seedlings}}{\text{Days of final count}}$$

Mean daily germination (MDG)

MDG = percentage of full seed at the end of test divided by the number of days to the end of the test.

Data collection on seedling growth

The seedlings were monitored until they were well-established in the nursery condition. The data collected from the seedlings were: height, root collar diameter, number of leaves and the survival percentage of seedlings. From each plot ten seedlings were selected by avoiding border effects and average measurements were taken.

Seedling height

The heights of sample seedlings were measured by using a millimeter ruler. The height was measured from the base to the highest point of the seedlings. Then average height was calculated and recorded for each plot and these seedlings were marked for other parameter measurements.

Root collar diameter

The root collar diameter was measured by a caliper graduated in millimeters. Measurements were taken on sample seedlings and their root collar diameter was measured at ground level, then the average value was taken for the plot.

Number of leaf

Leaf number was counted from sample seedling and the number of leaves that emerged was counted and the average was taken.

Survival percentage (Sp)

Number of wilted or dead and abnormally growing seedlings from each plot were counted and recorded every week. And, at the end of the study period using total number of dead, abnormal and healthy seedlings, survival percentage were calculated by using the following formula.

$$SP = \frac{\text{Number of health seedlings}}{\text{Total number seed germinated}}$$

Statistical analyses

The analyses of data were subjected to ANOVA using SAS version 9.1. ANOVA was used to analyze the results to see whether the treatment method, seed size and provenances show significant differences and Duncan's multiple range tests at $p \leq 0.05$ level of significance was used for mean separation.

RESULTS AND DISCUSSION

Germination

The seed size, provenance and interactions were not significant at p<0.05. However, seed treatment method was highly significant at p<0.01 for all parameters under the study for both laboratory and nursery experiments. Similar result was also found by Aerts et al. (2006a) who found that Olea seeds sown with endocarp dissected resulted in highest and uniform germination

Germination percentage

The germination percentage showed highly significant differences for treatments heating with fire and de-coating having significant difference between them and with the rest of the treatments at p<0.01 (Tables 1 and 2) under laboratory and nursery conditions, respectively. De-coating resulted in the highest germination percentage of 85 and 62.5% under laboratory and nursery conditions, respectively (Tables 1 and 2). The lowest germination percentage was recorded for seeds treated with fire which was 5 and 2.5% under nursery and laboratory conditions, respectively. The minimum germination percentage for fire treatment may be associated with the sensitivity of seed to fire and difficulties to set different rates of firing which might have exposed the seed to either over firing or under firing. The fire treatment breaks the dormancy of species adapted to fire prone areas. Charles et al. (2012) also reported that tree seeds growing in lowland areas adapt to fire treatment for improved germination. However, Nasr et al. (2013) conducted the study to evaluate the effects of scarification treatments on seed dormancy and germination and the highest germination (80.8%) was obtained. ICRAF (2010) reported that *O. europaea* germination is poor with no seed treatment, and this was recorded as low as 0-5%; and the reverse was true when the endocarp was removed.

Peak value

The peak value showed highly significant difference for de-coated seed from the rest of treatments at p<0.01. Heating with fire and control also showed significant difference from the rest with no significant difference between them under laboratory (Table 1). Higher mean peak value was recorded for de-coated seeds with mean value of 6.3 and 4.9 under nursery and laboratory, respectively. However, the lowest mean peak value was recorded for seeds treated with fire that is 0.32 and 0.14 under nursery and laboratory respectively; but has no significant variation from the control.

Table 1. Mean values of laboratory germination parameters as influenced by treatment methods.

Treatments	Germination (%)	PV	MDG	M GT	GV	GR
Soaking in hot water for 12 h	14.2^{b}	0.499^{b}	0.142^{b}	84^{a}	7.49^{b}	0.028^{b}
Soaking in hot water for 24 h	15.8^{b}	0.60^{b}	0.16^{b}	82^{a}	9.6^{b}	0.032^{b}
Soaking in hot water for 48 h	15.4^{b}	0.60^{b}	0.15^{b}	80^{a}	9.74^{b}	0.03^{b}
Soaking in H_2SO_4 for 15 min.	15^{b}	0.57^{b}	0.15^{b}	82^{a}	8.62^{b}	0.03^{b}
Soaking in H_2SO_4 for 30 min.	15.8^{b}	0.56^{b}	0.16^{b}	83.2^{a}	8.90^{b}	0.032^{b}
Soaking in H_2SO_4 for one hour	15.8^{b}	0.59^{b}	0.16^{b}	82^{a}	9.60^{b}	0.032^{b}
Soaking in H_2SO_4 for two hours	15.4^{b}	0.60^{b}	0.15^{b}	81^{a}	9.37^{b}	0.031^{b}
De-coating	85.8^{a}	4.69^{a}	2.45^{a}	35^{b}	404^{a}	0.878^{a}
Heating with fire	2.50^{c}	0.14^{c}	0.025^{c}	29^{b}	0.96^{c}	0.005^{c}
Control	15.8^{b}	0.59^{b}	0.16^{b}	82.6^{a}	9.46^{b}	0.032^{b}
LSD	2.85	0.135	0.045	11.3	11.95	0.013
CV (%)	18.9	20.6	34.5	34.5	39	15.9

Note: Mean values with the same letter within a column are not significantly different at 5% level. PV = peak value, MDG = mean daily germination, MGT = mean germination time, GV = germination value, and GR = germination rate.

Table 2. Mean values of nursery germination parameters as influenced by treatment methods.

Treatments	Germination (%)	P V	MDG	MGT	G V	GR
Soaking in hot water for 12 h Soaking in hot water for 24 h	17^{b}	0.92^{bcd}	0.22^{b}	58^{ab}	18.5^{bc}	0.6^{b}
Soaking in hot water for 24 h	16.7^{b}	1.1^{bc}	0.22^{b}	47^{bc}	22.13^{bc}	0.62^{b}
Soaking in hot water for 48 h	19.2^{b}	1.2^{bc}	0.25^{b}	53^{abc}	26.4^{bc}	0.72^{b}
Soaking in H_2SO_4 for 15 min.	18.3^{b}	1.06^{bc}	0.24^{b}	57^{ab}	22^{bc}	0.65^{b}
Soaking in H_2SO_4 for 30 min.	12.8^{b}	0.8^{cd}	0.66^{b}	59^{ab}	14^{bc}	0.47^{bc}
Soaking in H_2SO_4 for one hour	20^{b}	1.5^{b}	0.26^{b}	48^{abc}	39.4^{b}	0.8^{b}
Soaking in H_2SO_4 for two hours	16^{b}	1.01^{bc}	0.21^{b}	56^{ab}	20.7^{bc}	0.6^{b}
De-coating	62.5^{a}	6.3^{a}	1.76^{a}	21^{d}	391.4^{a}	9.1^{a}
Heating with fire	5^{c}	0.32^{d}	0.06^{c}	42^{c}	2.55^{c}	0.18^{c}
Control	16.5^{b}	0.76^{cd}	0.22^{b}	62^{a}	14.2b^{c}	0.54^{b}
LSD	6.05	0.51	0.087	10.28	27.36	0.317
CV (%)	36.5	42	29	25	58	27

Note: Mean values with the same letter within a column are not significantly different at 5% level. PV = peak value, MDG = mean daily germination, MGT = mean germination time, GV = germination value, and GR = germination rate.

A higher peak value was recorded for de-coated seeds because the removal of hard endocarp creates favorable condition for imbibition and later more seeds germinated in short period and the lowest peak value in fire treatment was attributed to extreme lowest germination percentage due to negative impacts of fire on the seed of Olea. Even though fire treatment showed high speed of germination it did not increase the peak value due to extremely low germination percentage because peak value is affected by germination percentage and speed of germination.

Mean daily germination

The mean daily germination showed significant difference for seed treatment method at p<0.01 significance level under laboratory and nursery, respectively. Highest mean daily germination was recorded for de-coated seeds which were 1.76 and 2.45 under nursery and laboratory, respectively; and the results are in agreement with findings of Tesfaye (2005) but in contrast with that of Seye et al. (2013), in which the highest mean daily germination was attained for seeds treated with sulfuric acid and boiling water. Fired treated seeds resulted in lowest mean daily germination with value of 0.06 and 0.025 under nursery and laboratory conditions, respectively. Fire treatment showed the minimal mean daily germination due to the negative effects of fire on the embryo.

Mean germination time

Mean germination time showed highly significant

Figure 2. Seeds treated by De-coating.

Figure 3. Seeds treated by fire.

difference for seed treatment method at $p<0.01$ under laboratory and nursery, respectively. Seeds treated with hot water, concentrated sulfuric acid (H_2SO_4) and control showed the highest value with no significant variation among them. Fire and de-coated treatments (Figures 2 and 3) showed minimum mean value with no significant difference between them. The longest germination times were recorded for soaking in hot water for 12 h and control which were 84 and 62 days under laboratory and nursery condition, respectively. The result is in agreement with the finding of Mahnaz and Masomeh (2016) who found that untreated seed resulted in delayed mean germination time. The reason for fast germination for fire and de-coated treatment may be due to damages on seed coat which facilitates entrance of water and oxygen that might reduce the time taken for seeds to germinate.

Germination value

The germination value differed significantly for different seed soaking methods at $p<0.01$ under laboratory and nursery, respectively. Maximum mean germination value was recorded for de-coated seeds which were 404 and 391 under laboratory and nursery, respectively; and seeds treated with fire showed minimum mean germination values of 0.96 and 2.55 under laboratory and nursery conditions, respectively. The increment in germination value was directly related to dormancy breaking (Figure 4). Since germination value is the product of germination percentage and peak value, increasing germination percentage and peak value increases germination value. This finding is line with the finding of Moya et al. (2017). Except de-coating and fire treatments, nursery experiment resulted in higher value than laboratory results. This might be related to the exposure of seeds to various weathering process for the nursery condition that enhances germination percentage and shortens germination period; this later improves germination value.

Germination rate

The rate of germination was significantly different for seed soaking methods at $p<0.01$ significance level under laboratory and nursery, respectively. Highest mean value of germination rate was recorded for de-coated with mean germination rate of 0.878 and 9.1 under laboratory and nursery, respectively. On the contrary, seeds treated with fire indicated the lowest germination rate of 0.005 and 0.18 for laboratory and field trials, respectively (Table 3). The higher germination rate was recorded for de-coated seeds because of the absence of germination inhibitors on seed coat. This also improves the germination percentage and speed of germination and finally accelerates germination rate. And the lowest germination rate in fire treated seed was due to reduced seed germination percentage and speed of germination which was caused due to the negative effect of fire on *Olea* seed. This finding is in contrary with Seyed et al. (2013) who found highest germination rate for seeds treated with sulfuric acid.

Early seedling growth

Seed size, provenance and interactions were not significant for early seedling growth ($p>0.05$). However,

Figure 4. Seedlings early emergence performance.

the seed soaking method was highly significant at $p<0.01$ for all growth parameters. This result is contrary to Tinsae et al. (2014) who found that seed provenance significantly affects the establishment of *O. Europea* seedlings. The disagreements of the results might be due to the variation in microhabitat condition.

Seedling height

Seedling height showed highly significant differences for de-coated and heating, with fire having significant difference between them and with the rest of treatments at $p<0.01$. De-coated seeds reached a maximum seedling height of 25.40 cm, and heated seeds showed the lowest seedling height, with a mean height of 11.43cm. Similar results were recorded by Mishra et al. (2013). Shortness in height of seedlings treated by fire may be attributed to the damaging effects of fire on the seed embryo, which might have resulted in the degradation of stored food that can be used until seedlings start photosynthesis. Hossain et al. (2005) presented similar results and reported that early germination of seed increases the growth and early seedling establishment.

Leaf number

Leaf counts on the seedlings showed more number of leaves for de-coated seeds having significant difference with the rest treatments ($p<0.01$). On seedlings of de-coated seeds, a maximum leaf number of 12 were recorded. The rest of the treatments showed no significant difference among them ($p>0.05$). However, the minimum value was recorded for seeds treated with fire which was 5.5 leaves. The higher leaf number for de-coated seeds may be attributed to mean germination time; that means seeds which germinate first produce leaf first and subsequent number of leaves are produced then after. Similar results were found by Santelices et al. (2013a).

Survival percentage

The survival percentage showed highly significant difference for seeds heated with fire from the rest of the treatments except for seeds soaked in H_2SO_4 for one hour and seeds soaked in hot water for 24 h ($p<0.01$). Seeds heated with fire indicated lowest survival percentage whereas de-coated seeds showed maximum survival percentage, with values of 68.3 and 93.8, respectively; and the result is in agreement with that of Tesfaye (2005). However, the result is contrary to that of Emmanuel (2013) who found that fire treated seed has no significant difference from control on seedling survival of woody plant species. The lowest survival percentage for seeds treated with fire may be related to negative effect of fire on endosperm. This means that since the rate of firing was not adequately fixed, the fire might adversely affect the embryo fully or partly. Hence, even though seeds that were partially affected might germinate but it is difficult for successful survival. Hence, seeds treated with fire might result in poor seedlings survival rate.

Root collar diameter

The root collar diameter was significantly different for heated seeds at p<0.01significance level. De-coated seeds showed the highest root collar diameter with mean value of 4.65 mm. And, the minimum value was recorded for seeds treated with fire with mean value of 2.94 mm; and with no significant variation from the rest of the treatments. Higher root collar diameter for de-coated seeds was due to the fact that seeds that germinated early had better chance for continuous growing condition so that they could attain the largest diameter. The result is in line with the work of Wosen et al. (2016) who reported that sturdy root collar diameter was observed for seeds that were treated with their hard seed coat removed.

Effects of seed provenance

The difference in seed provenance had no significant effect on differences for the germination and early nursery growth of *Olea*. This might be attributed to absence of drastic differences in the physical characteristics (altitude, soil type, agro-ecology and rain fall characteristics) of the localities where the seeds were collected.

Effects of seed size

Seed size variation had no significant effect on variation in germination and early growth of *Olea*. The absence of significant difference due to seed size was attributed to the nature of the seed itself. This is because *O. europaea* seeds have a hard and thick seed coat so that the size of embryo and overall size of the species might not have a direct relationship. This finding is not consistent with the finding of Pedro et al. (2004). As it was observed during the study period some seeds having bigger endocarp have smaller embryo and endosperm; and some of those seeds with smaller endocarp have bigger embryo and endosperm.

Conclusion

Dormancy breaking by different pre-sowing treatment methods was tried, but the most effective germination and seedling growth was obtained in seeds treated with removal of endocarp. Fire treated seeds resulted in least germination and growth status of *Olea*. Hence, if growers apply seed de-coating method it is possible to increase germination percentage and shorten the germination period. This reduces the costs associated with long durations of seedling management in the nursery. Moreover, the early readiness of seedlings for field plantation can attract tree planters to grow this species. Seed provenances have no significant effects on germination and growth of *Olea*; hence, sowing seeds of either provenance is equally important for growing of *Olea* in the district. Similarly, seed size has no significant difference on germination and growth of seedlings; hence, sowing of seeds with diameter more than 5 mm is equally successful for this species and growers can use any size more than 5 mm.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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