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FACULTY OF FORESTRY AND WOOD TECHNOLOGY

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Effect of seed treatment on the germination of different provenances of *Dodonaea angustifolia*; a recommendation for degraded land restoration through direct seeding

Bachelor's thesis

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Abstract

Lucia Petrovičová

Effect of seed treatment on the germination of different provenances of *Dodonaea angustifolia*; a recommendation for degraded land restoration through direct seeding

In Jara Jinesa nursery site in Ethiopia near Awassa city an experiment on germination rates of *Dodonaea angustifolia* was realized in 2015. To examine this rate, three different provenaces were evaluated for four different seed treatment methods and compared with control sample of untreated seeds. Hot-water treatment at both time intervals prove significantly positive effect on seed germination. After this treatment seeds germination rate reached 70 – 100 %. The positive effect of seeds soaking in cold water has not been recorded, in some cases even reduced germination over any untreated seed. Within 3-6 days of sowing, especially in warm water treated seeds, the number of germinated seeds increases steeply. The impact of provenance is evident especially in the various time-span optimization, since each provenance is adapted to specific environmental conditions. Treating seeds with warm water before sowing increased the uniformity of seedlings, thereby increased the quality of seed production without significant technological equipment and financial costs.

Keywords: Dodonaea angustifolia, seed germination, provenance, water soaking treatment, land restoration

Abstrakt

Lucia Petrovičová

Vplyv ošetrenia osiva na klíčenie rôznych proveniencií *Dodonaea angustifolia*; odporúčanie pre obnovu degradovanej pôdy prostredníctvom priamej výsadby

V roku 2015 bol v lesnej škôlke Jara Jinesa v blízkosti mesta Awassa realizovaný experiment s cieľom vyhodnotiť hodnoty klíčenia druhu *Dodonaea angustifolia*. S týmto cieľom boli vyhodnotené tri proveniencie a štyri rôzne spôsoby ošetrenia a porovnané s kontrolným výsevom neošetrených semien. Preukázateľne pozitívny vplyv na zvýšenie klíčivosti malo ošetrenie horúcou vodou v oboch hodnotených časových intervaloch. Klíčivosť takto ošetrených semien dosahovala 70 - 100 %. Pozitívny vplyv máčania semien v studenej vode nebol zaznamenaný, v niektorých prípadoch dokonca došlo ku zníženiu klíčivosti oproti akokoľvek neošetreným semenám. V časovom horizonte 3-6 dní od výsevu dochádza najmä u teplou vodou ošetrených semien k prudkému nárastu počtu vyklíčených semien. Vplyv proveniencie je zjavný najmä v rozličnom časovom optime máčania, nakoľko každá z proveniencií je adaptovaná špecifickým podmienkam prostredia. Ošetrenie semien teplou vodou pred výsevom zvýšilo uniformitu semenáčikov/sadeníc a tým zvýšilo kvalitu semennej produkcie bez výrazného technologického vybavenia a finančných nákladov.

Kľúčové slová: Dodonaea angustifolia, klíčenie semien, proveniencia, ošetrenie máčaním, obnova krajiny

Table of Content

1 Introduction

Ethiopia is one of the largest African countries in both in terms of land area (1.1 million km^2) and population (70.7 million). The Ethiopian economy is based especially on agriculture which provides employment for 85 percent of the labour force and accounts for a little over 50 percent of the GDP and about 90 percent of export revenue. However, low productivity defines Ethiopian agriculture. The low agricultural sector productivity has made it difficult to attain food self-sufficiency at a national level (Tadesse & Belay, 2004).

The present estimated area of drylands in Ethiopia is about 75 % of the total area of the country (EFAP, 1994, UNDP, 2015). These enormous areas of dryland vegetation resources are facing severe problems of degradation. This has been attributed to the fact that land has been used as a mine, rather than a revivable source, for centuries in this country (Egziabher, 1989). The prolonged degradation of dryland areas continues to affect the productivity and genetic forest diversity, woodland and bushland resources. Increased by the recurrent drought, the ultimate outcome of deforestation and degradation of these resources may be desertification. Sustainable conservation and utilization of the remaining dryland vegetation resources and rehabilitation of those that have already been decreased would provide economic, social and ecological benefits (Mengistu et al. 2005). In recent years, few similar studies were realized on many other localities in Ethiopia, such as Tigray (Kindeya, 1997; Haile & Gebrehiwot, 2001; Birhane, 2002; Mebratu, 2002), Welo (Tekle, 1998; Tefera, 2001) and Shewa (Tefera, 2001).

Land degradation is nowadays the most spread environmental problem in Ethiopia. It is one of the major causes of low and declining agricultural productivity and continuing food insecurity and rural poverty. In addition, land degradation directly affect the type of plant grown on the area, reduce availability of potable water, minimize volumes of surface water, depletion of aquifers and biodiversity loss. The major causes are rapid population growth, serious soil loss, deforestation, low vegetative cover and unbalanced crop and livestock production. Topography, soil types and agro-ecological parameters are also additional factors affecting the land degradation processes in Ethiopia influenced by man. Throughout history, efforts to combat land degradation is focused on physical conservation structures (Gashaw et al. 2014).

2 Literature review

2.1 Effect of seed treatment on seed germination

2.1.1. Germination characteristics

In terms of reforestation is important generative propagation, in which the growth of new plant seed germination begins. Germination can be defined as the resumption of growth of the embryo in the seed is separated from the mother plant. After maturing seeds pass into a state of metabolic rest, which is usually caused by reduced water content and inactivation of enzyme systems. During germination restoration of physiological processes occurs, along with number of morphogenetic changes that result in the transformation of seed in physiologically independent seedling. Most seeds have a similar internal structure. The most important seed part is embryo, which forms the basis of future plants and storage materials stored in megagametophyte seeds of conifers, in the endosperm of the seeds of some broadleaved (e.g. *Fraxinus* sp., *Eonymus* sp.), or stored directly in the embryo, usually in the cotyledons, which are thickened, so embryo fills the entire space seed (e. g. *Quercus* sp., *Fagus* sp., *Acacia* sp.). Embryo storage uses of the substance stored in the maintenance tissues in the early stages of germination, which does not have its own active photosynthetic apparatus and nourishes the heterotrophically. Germination is displayed visually by penetration of radicular testa. However, this is the final manifestation of a process that can be divided schematically into four phases (inhibition phase, hydration and activation phase, elongation phase, growth phase) (Palátová, 2008).

Inhibition phase

It can be described as physical phase. It is connected with water absorption. In many types of seed, maturing is associated with reducing the water content. In order to germinate the seed must receive water and rehydrate itself. The amount of water consumed is considerable. Simultaneously, the seed volume increases (seed swelling). Water intake at this stage is a passive process and subject only to the laws of physics (from an initial intake of water one cannot distinguish between live and dead seeds). Seed cell membranes are not fully functional at this stage (Palátová, 2008).

Hydration and activation phase *(biochemical phase)*

In the dry status, the seed cell membrane is not fully functional, but after a few minutes or hours, the integrity and function of the membrane and organelles restores. Only then the water starts to be taken to actively seed and begins to increase metabolic activity.

Enzymatic systems present in dry seeds are not active, but with the water intake leads to their activation - hydration and activation phase. At the same time, they are activated and nucleic acids (DNA, RNA) leads to the synthesis of new enzymes. The physiological activity increases, the storage matters are decomposed by the action of hydrolytic enzymes and releases energy. The resulting monomers (simple sugars, amino acids, fatty acids), are translocated into the embryo, where they serve to make proteins, membranes and other cellular structures of growing embryo. Enzyme activity is influenced by temperature, light and pH (Palátová, 2008).

Elongation phase

Growth of embryos is result of cell replication and elongation of the existing and newly formed cells. Cell elongation is assisted by transport of sugars, which increase the embryo possibility to absorb water. In this process, water intake has important role in growth regulators, because they affect the permeability of cell membranes (Palátová, 2008).

Growth phase

Growth of the primary root is accompanied by increased water pressure. As the cells grow after water intake, the radicula grows too. Seed space gets smaller for growing embryo, testa ruptures and visual expression of germination is visible – a germ emerges (Palátová, 2008).

2.1.2 Factors influencing germination

To germination success number of conditions must be fulfilled. It is possible to divide these conditions into two groups - external and internal (Palátová, 2008).

2.1.2.1 External conditions

Water

Water is crucial factor for germination. In order for germination to take place, it is necessary to have a minimum water content for the enzyme activation and the next stages of germination.

The need for water in each stage of germination corresponds to the dynamics of its intake. Initially, water intake is very fast and is controlled mainly by physical laws. This initial phase takes place in both live and dead seeds. Then there is a slowdown in water intake (corresponding to the hydration and activation phase). With increasing metabolism, cell dividing and prolonging, the need for water rises again and its intake is accelerating again (Palátová, 2008).

Temperature

Temperature is one of the most important external factors of germination, since water intake, gas diffusion, respiration, and other metabolic processes occur more rapidly at higher temperatures. Germination is dependent on these processes and is therefore heavily influenced by temperature. Germination, as any biological process, can be described by a temperature curve that indicates the minimum germination temperature, optimal, and maximum when the seed can germinate. The spacing between these cardinal points is determined by the species distribution area. Types with a large area usually have a wide range of temperatures at which their seeds can germinate. Seeds of some species are able to germinate in the snow, but germination is slow and lasts for several months. Generally, germination slows down when the temperature drops below 10 ° C. The optimal temperature for germination is species-specific (Palátová, 2008).

Oxygen

In the early stages of germination, respiration takes place and since oxygen is the primary acceptor of electrons during dissimilation, it is a prerequisite for germination. At the same time, carbon dioxide, which can in high concentration inhibit germination, must be removed. Oxygen is indispensable for germination but is not considered a limiting factor (except for flooded soils where the capillary pores are filled with water) (Palátová, 2008).

Light

Although light stimulates the seed germination of many woody plant species, it is only necessary for germination for few species, as some seeds germinate better in the light. The intensity of the light needed for sprouting is low and only a few species require an intensity greater than 100 lux. Intensity 1 - 5 lux is usually sufficient. The germination process is controlled by the phytochrome pigment. Its activity varies depending on the wavelength of the light and can occur in 2 forms. Dark red light at 730 nm wavelength inhibits germination and shortwave light red light (660 nm) stimulates germination as it affects the metabolic activity of embryos and mitosis. In order for the seed to react to light, it must be fully hydrated and less than a second of exposure to red light of 660 nm is sufficient to stimulate germination. Sensitivity to light can be affected by temperature, while the sensitivity to the red light decreases in the cold (Palátová, 2008).

2.1.2.2 Internal conditions

In order to seed germination two conditions must be accomplished. Crucial aspect for germination is the seed must be alive – it means consisting of living cells, capable of all metabolic processes. Next, no less important is physiological maturity of seed.

Seed maturation is associated with reserve formation, embryo differentiation, loss of water and inactivation of enzymes and growth substances. Depending on the water content in the seed, several stages of maturity can be distinguished. In order to germinate the seed, it must achieve physiological maturity. Seeds of certain tree species are matured simultaneously with morphological maturity and physiological maturity, and can be germinated after separation from the mother plant. In nature, seeds of these species are released from the parent plant until the pre-term period, when germination conditions are favourable. However, there are also species whose seeds separate from the mother tree in morphological maturity and are unable to germinate. After a break, they enter the stage of rest. Seeds that have this period of rest as a regular phase in their life cycle are referred to as dormant seeds or seeds with germination calmness and this phenomenon is referred to as dormancy.

Dormancy is a regular phase in the life cycle of woody plant species, especially from temperate zones. It is the result of adapting seeds to seasonal and eventually accidental changes in the environment (frost, drought, excess moisture) and prevents the seed from germinating at an inappropriate time. Dormancy is important for survival of the species because it shifts germination in time and space and also influences the geographical distribution of the species.

Three basic reasons for dormancy are described. Seed testa protects the embryo and endosperm against mechanical damage and chemical effects. Its protective significance, however, can also pass into a barrier and may prevent the intake of water and oxygen by the seed, possibly acting as a mechanical obstacle to penetration of the radicle. Second reason of dormancy is presence of growth inhibitors. The inhibitors form a heterogeneous group of compounds - ammonium, ethylene, unsaturated lactones (coumarin), terpenes, organic acids (acetic, oxalic, tartaric, succinic), most often abscisic acid (ABA). Dormancy can also be caused by the absence of stimulating growth regulators (key tranquillity is the result of the ratio of inhibitors and growth stimulators), and overcoming dormancy consists in shifting the balance between inhibitors and stimulators in favour of stimulators. Inhibitors affect the metabolic processes in the seed, and their effect can be inhibited by the growth of the entire embryo or only embryo part (Palátová, 2008).

2.1.3 Improvement of seed germination qualities

For seed quality improvement, mainly used methods are stratification, scarification, maceration and seed soaking in water.

Stratification

Stratification means the exposure of hydrated seeds to a specific temperature regime for a certain period of time. It can pass by with or without media. Media used are sand, pearlite, vermiculite or their mixtures. The medium task is to maintain moisture and transmit it to the seed, to ensure the gases exchange (medium must be porous), to dissipate the heat generated by breathing, to separate the seeds and to prevent the transmission of possible infections. Before stratification without media the seeds must be pre-soaked. Water-saturated seed can be stored in crates or PE bags. To stratification success a few conditions must be fulfilled. Elementary are sufficient seed hydration, aeration, suitable temperature conditions and sufficient duration (Palátová, 2008).

Scarification

It is a v procedure during which the seed coat is disrupted mechanically. Scarification can be used for seeds with no pulp parts and a treat time should be tested on small sample group. Too long time of scarification can damage a seed irreversibly. Treated seeds cannot be stored (Palátová, 2008).

Maceration (acid scarification)

Maceration is a procedure where seedlings are disturbed by the concentrated strong acid action, most often sulfuric acid (H_2SO_4). The advantage of the procedure is that acid can be used repeatedly and properly macerated seeds can be stored for up to 1 month. The treatment period must be determined in advance (long treatment can kill the seed) (Palátová, 2008).

Soaking in water

The softening of the seed testa can be achieved by dipping the seeds in 4-5 times the volume of water 75 - 100 °C warm and gradually cooling (even repeatedly). This procedure is suitable for pre-season preparation of *Fabaceae* family, especially species with large seeds. Different types and different sections of seed of the same species require different treatment times.

Advantages include that the process is easy and inexpensive and does not require special equipment. The disadvantage is its difficult standardization. The result is influenced by the volume ratio of treated seed and water to the cooling rate of the water depending on the ambient temperature. Seeds are moist after treatment and must be dried before the sowing. Even soaking in cold or mild water (17 - 20 °C) can have positive effect on seed germination within time period of 24 hours (Palátová, 2008).

2.2 Land degradation

Land degradation can be described as an environmental phenomenon affecting dry lands, leads to loss of economic and biological quality of an agricultural land (Mantel, 1997). According to Young (1998) land degradation is the temporary or permanent lowering of the productive capacity of land. It is the primary cause of species loss at local, regional and global scales through urban development, road building, recreation, forest fires, agriculture and tree logging. (Krüger et al. 1997; Scherr & Yadav, 1997; Silva et al. 2008; Laurance, 2010). Land degradation manifests itself in many more ways. Vegetation becomes increasingly scarce, water courses dry up, thorny weeds predominate in once rich pastures, footpaths grow into ravines, and soils become thin and stony (Gashaw et al. 2014). In addition, land degradation can lead to many issues like soil crosion, soil acidification, soil alkalinisation, soil salination, soil water logging and destruction of the soil structure (Wasson, 1987). Recent estimates suggest that 5 – 6 million hectares of arable land worldwide are irreversibly lost each year as a soil erosion result, salinization and other degradation processes (Hamdy & Aly, 2014). About 2.6 billion people are influenced by land degradation and desertification in more than 100 countries, affecting over 33% of the earth’s land surface (Barman et al. 2013).

Some environments are naturally more at risk to land degradation than others. Factors such as steep slopes, coast line area, high intensity rainfall and soil organic matter influence the probability of the incidence of degradation. Milder forms of land degradation can be reversed by changes in land management techniques, but more serious forms of degradation may be extremely costly to reverse (e.g. salinity) or may be, for practical purposes, irreversible. Soil erosion, when serious and prolonged, is effectively irreversible because, in most circumstances, the rate of soil formation is slow. In humid, warm climates formation of just a few centimetres of soil may take thousands of years and in cold, dry climates it can take even longer. Soil loss through erosion happens far faster: up to 300 times faster where the ground is bare (Stocking & Murnaghan, 2000).

Soil degradation aggravate soil erosion, and vice versa. In some cases, in soil quality, especially the weakening of structure units, leads to erosion. In other, erosion may lead to decline in soil quality and set in motion degradative course. In fact, soil erosion can be manifestation of soil degradation because it involves physical soil removal in vertical and/or horizontal direction and decreases soil quality. It is a natural process that shaped the landscape and formed the fertile alluvial and loess soils. However, the process acceleration through anthropogenic perturbation have serious impacts on environmental and soil quality (Lal, 2001).

Special form of land degradation connected to arid, semiarid and dry subhumid areas is desertification. It is caused by accelerated wind and water erosion in dryland and mainly by adverse human impact (Dregne & Chou 1992; Balba, 1995).

2.2.1 Land degradation causes

The causes of the degradation can be either natural or human (Barman et al. 2013). The natural causes include earthquakes, tsunamis, droughts, avalanches, landslides and mud flow, volcanic eruptions, flood, tornado, wild fire (Reynolds, 2001). As the natural causes are out of control, the human induced degradation is very important in view of sustainability. Climate change, as result of human intervention over ecology is a great reason for the degradation (Barrow, 1991). Major reasons are land clearance, deforestation, overgrazing by live stock (Reynolds et al. 2007). Many other activities, such as inappropriate irrigation and over drafting, urban sprawl and commercial development, unbalanced fertilizers use, land pollution including industrial development, vehicle-off loading, quarrying of stone, minerals sand or ore can also lead to land degradation (Young 1994, Salvati & Zitti, 2009). Some of the most serious causes described widely below.

Climate change

Changes is earth's atmosphere have great influence on land. The terrestrial vegetation depends on temperature and precipitation. With reduction in rain fall the vegetation becomes thinner. High temperature and low precipitation leads to low organic matter production in soil and rapid oxidation, leads to low aggregation, vulnerable for erosion by water and wind. In Africa, 25 % and 22 % of land is prone to water and wind erosion, respectively (Reich et al. 2001). The climate stress is reaching 62.5 % of the land stress there (WMO, 2005).

Soil erosion

Erosion is a three-stage process of detachment, transport and deposition od aggregates (soil particles). Energy for this process is supplied by erosion agents. The sources of energy can be physical (e.g. wind, water), gravity, chemical reactions and anthropogenic factor (tillage) (Govers et al. 1999).

Soil erosion start with detachment, which is caused by aggregates breakdown by impact of raindrops, force of water and wind, or dissolution of cementing agents through chemical reactions. Water or wind transport detached particles of microaggregates (Lal, 2001). Both wind and water erosion selectively remove the fine organic particles in the soil, leaving behind large soil particles and stones (Pimentel, 2006). Deposition happens when carrying capacity of the overland flow or wind is reduced by velocity decrease, surface roughness, vegetation cover or presence of an obstruction (Hairsine & Rose, 1991). The spacing of physical displacement may vary from a few millimetres to thousands of kilometres and the time lapse from detachment to eventual deposition may vary from a few seconds to thousands of years (Lal, 2001).

Deforestation

Deforestation is the conversion of forested areas to non-forest land use such as arable land, urban use, logged area or wasteland (Tejaswi, 2007). It is a clearance of large expanse of forest for agriculture and other uses, when a forest is removed, the total amount of water and minerals that flow into the streams increase dramatically (Alemayehu & Demel, 2007). It can also decrease the water content in soil, and can cause fast soil water evaporation and dried atmosphere and less rain which will makes the river system dry up and it will affect the natural fish biodiversity and germplasm as well (Barman et al. 2013).

Deforestation in Ethiopia was growing at alarming level and the rate of afforestation was very negligible in light of the very high rate of clearing for fuel, expanding agricultural land, for construction, urban development purposes, and also lack of awareness creation for the communities have contribution for deforestation (Mohammed, 2011). In stable forest ecosystems, where soil is protected by vegetation, erosion rates are relatively low, ranging from only 0.004 to 0.05 t/ha-year (Roose, 1988; Lal, 1994). Tree leaves and branches not only intercept and diminish rain and wind energy, but also shade the soil under the trees to further protect the soil. However, these changes dramatically when forests are cleared for crop production or pasture (Daily, 1996).

Overgrazing

Over grazing is abuse of grassland, due to decrease in grassland and increase in livestock numbers. The plant density is reduced by overgrazing. It does not leave any time for plants re-grow. It leads to soil infiltration, accelerated run off and soil crosion. The soil fertility is developed by action of microorganism. Overgrazing can reduce their action and also rises the concentrations of ammonium-N and nitrate-N which are toxic to root system at higher concentrations (Radácsi, 2005).

Intense grazing at the end of the annual dry season, and during periods of drought, does not necessarily lead to degradation. The vegetation can recover during the succeeding rains. Degradation occurs when the vegetation recovery and soil properties during periods of normal rainfall does not reach its previous statue (Young, 1994).

Irrigation practise

The quality of water used for the irrigation is crucial. If the water has high salinity, it will accumulate and leads to desertification. Irrigational practice which leads to cracking the lands or bypass flow, by flooding influences the soil structure and nitrate leaching (Barman et al. 2013).

Urban sprawl and commercial development

Urban sprawl is described as the physical pattern of low-density expansion of large urban areas mainly into the surrounding agricultural areas (Ludlow, 2006). Urban sprawl is an outcome of increasing urban population. As the urban population grows, the infrastructure requirement (e.g. transportation, water, sewage and facilities - housing, school, commerce, health, etc.) also increases and it is known as urban sprawling (Ujoh, 2010). It consumes agricultural productive areas, so the green vegetation is replaced by built-up area. Development of infrastructure (e.g. roads and electricity) leads to the destruction of fertile land (Geist & Lambin, 2002).

2.2.2 Land degradation control

The land degradations can be controlled by management of deforestation, afforestation, managing irrigation, managing urban sprawl, managing mining and quarrying, managing agricultural intensification and land reclamation. Intensification of sustainable agriculture-aquaculture can be implemented to reduce the ecological effect without harming the productivity. Thus, is necessary to have local and global policies and regulations to manage the land degradation (Barman et al.2013). Conservation practice also includes the formation of protected area as well as management strategies based on beneficial balance between resource development and satisfaction of human needs (Uhlig, 1988; Fenta, 2000).

2.2.3 Land degradation in Ethiopia

Ethiopia is a country with different landscapes and one of the countries with the widest cultural diversities in eastern Africa (Negusse, 2007; Alelign et al. 2007; Birhane et al. 2011). The forest situated in high altitude of Ethiopia form part of the Afromontane forest zone, which covers most of the highlands of Africa (White, 1983). The Ethiopian highlands create more than

45% of the total area of the country (Anonymous, 1997). The conversion of forests to crop fields and pasturelands has been carried out for a long period of time in Ethiopia and this has reduced the present forest cover (Tigabu et al. 2014). Forests of the mountainous landscapes of Ethiopian highlands were degraded and fragmented for decades (Egziabher, 1988). The major causes of land degradation in Ethiopia are the rapid population increase, severe soil loss, deforestation, low vegetative cover and unbalanced crop and livestock production (Taddese, 2001). Intensive logging for fuelwood damages the structure and composition of natural woody plant species and leads to the declining of forest diversity and agricultural yield in Ethiopia (Alemayehu & Demel, 2007). Cultivation on steep slopes and clearing of vegetation has accelerated erosion in the highlands (Bhan, 1988).

Every year Ethiopia loses over 1.5 billion tons of topsoil from the highlands by erosion. During the dry season wind erosion is severe in arid and semiarid regions. In the rainy season water erosion and tillage erosion removes soil layers. It leads to valuable nutrients loss that are necessary for crops to grow (Taddese, 2001).

2.3 *Dodonaea angustifolia* L. f. (1781)

Dodonaea angustifolia or sand olive of family *Sapindaceae* is variable evergreen thin-stemmed shrub or evergreen tree (Appendix 1), usually 2-8 metres tall (Orwa et al.2009).

The taxonomy of the species had been confusing. *Dodonaea angustifolia* is considered to be *Dodonaea viscosa* (L.) Jacq., because of its similarity and widespread distribution (Orwa et al.2009). *Dodonaea viscosa*, is sea shore plant and has not been collected in Ethiopia yet (Hedberg, 1989, Van Herdeen et al. 2000).

2.3.1 Botanical description

Leaves simple lanceolate, pale green, margins untoothed and leaf tip pointed or round, 5 - 10 cm long, 5 - 8 mm wide, alternately or spirally arranged (Appendix 2) (Orwa et al.2009). Petiole 1 - 5 mm long, lamina narrowly elliptic to narrowly obovate, 2 – 15.5 cm long; 0.7 - 3 cm wide. All parts are glabrous and resinous when young (Hedberg, 1989). Leaves secrete gummy exudate (Orwa et al. 2009). Inflorescences terminal to axillary paniculate 1 - 4 cm long (Appendix 3). Flowers inconspicuous, pedicels 2 - 7 mm long, female flowers up to 15 mm long. 4 sepals, ovate 2 – 3.5 mm long, 1.5 - 2 mm wide pale green to yellowish, shortly connate (Hedberg, 1989). Petals absent (Orwa et al. 2009). Stamens (5) 7 – 9 (-10), brown, subsessile. Anthers *c* 3 mm long, ovary 2 - 3-loecular. Style 4 - 7 mm; 2 - 3 fid; stigmas 2 - 3 mm. Fruit circular in outline, *c* 0.7 - 2 cm long, 1 - 2.1 cm wide. Pale green to yellowish, with 3 - 6 mm wide tinged reddish wings (Appendix 4). Seed black, smooth, lenticular (Appendix 4), *c* 3 x 2 mm, wind dispersed (Hedberg, 1989). It produces about 100 seeds/g and the seeds are dormant (Teketay, 1993; Bekele-Tasemma, 1993). According to Katende et al. (1995) germination rate varies in range of 30-70% and no seed treatment is needed.

2.3.2 Ecology

Dodonaea angustifolia is common in shrub on mountains and rocky soils. Occurred in areas with mean annual rainfall of 450 mm, from 0 to 2 800 m about sea level (Orwa et al.2009). Naturally occurred in edges of upland forest, upland bushland and grassland, secondary forest. Invading areas recently cleared of forest (Hedberg, 1989). The only shrub in Ethiopia which grows on copper-rich soils (Edward, 1976).

Pantropical. Native to Australia, Ethiopia, Eritrea, Kenya, New Zealand, Oman, South Africa and Tanzania (Orwa et al.2009). *Dodonaea angustifolia* is widely distributed in South Africa except for the central parts (Van Wyk et al. 1997, Van Wyk & Van Wyk, 1997). In Ethiopia occurred in Arsi region, Bale region, Gamo Gofa region, Gojam region, Gondar region, Harege region, Kefa region, Shewa region above 1000 m, Sidamo region, Tigray region above 1000 m, Welega region, Welo region above 1000 m (Hedberg, 1989).

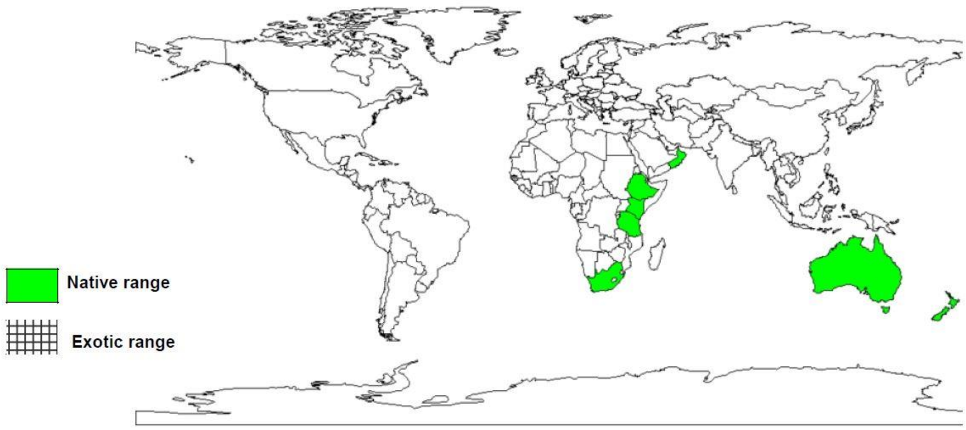

Figure 1 Native distribution of Dodonaea angustifolia (Orwa et al. 2009)

2.3.3 Importance of *Dodonaea angustifolia*

Dodonaea angustifolia is multipurpose shrub/tree. This woody plant is suitable for bee forage (Orwa et al. 2009). Water boiled with leaves is used to cure swellings, backaches and steam for inhalation in cough and colds (Kishore & Sasidharan, 2002; Orwa et al. 2009). It is also used for treating stomach pain and piles and to heal simple ulcer (Perry & Metzger, 1980).

Dodonaea angustifolia should have anti-inflammatory and antimicrobial influence (Getie et al. 2003; Khalil et al. 2006). Leaves have anaesthetic and muscle relaxant properties (Rojas et al. 1996) *Dodonaea angustifolia* provides a shade, hard, termite resistant timber and fuelwood. It is also cultivated as an ornamental plant (Mabberley, 1997). It is used for soil conversation, as a soil binding plant, especially in sandy and marshy areas (Palgrave 1977, Orwa et al.2009). The species can be used as windbreak, live fence for dry areas, susceptible to fire but regenerates rapidly after burning. Twigs are used as toothbrushes (Katende et al. 1995).

Dodonaea angustifolia is also promising species in aspect of forest rehabilitation. As an indigenous and early successional woody plant can colonise barren areas. That suggests that it could be used at early stages of restoration of natural forest before reintroduction of origin species (e.g. *Juniperus procera*, *Olea europaea*) (Friis, 1992; Tekle et al. 1997; Bekele, 2000). The regeneration of most of the dominant high forest species in the Afromontane zone is under shade of mature forest (Pohjonen, 1989).

3 Objectives to study

3.1 General objective

To investigate an effect of seed treatment on the germination of three different provenances of *Dodonaea angustifolia* and to recommend a proper provenance for direct seeding in degraded land restoration process.

3.2 Specific objective

This study aims to: (1) collect accessible literature on the tropical tree/shrub species and make a review; (2) collect accessible literature on *Dodonaea angustifolia* species and make a review on their economic importance; (3) collect data on the germinations of different provenances of *Dodonaea angustifolia* seeds which are treated with different seed treatment techniques; (4) analyse and interpret the results of the collected data in the nursery and recommend which provenances along with their seed treatment techniques provide high germination and recommend it for a restoration of degraded land rehabilitation through direct sowing

In order to reach these objectives, an experiment was carried out. To collect the data two factors were monitored: (1) number of seedlings and (2) time from sowing to visible germination.

4 Material and methods

4.1 Description of study area

Seed material for this study was collected on three different localities, which vary in altitude and amount of annual rainfall.

Halaba

First seeds sample was collected in Halaba, located 310 km south of Addis Ababa and about 85 km southwest of the Southern Nations Nationalities and Peoples Regional (SNNPR) State capital of Awasa. The woreda is geographically located 7 °17 ' N latitude and 38 ° 06 ' E longitude (Figure 2) at altitudes ranging from 1 554 to 2 149 m. The Halaba District is located within the Bilate River watershed. The annual rainfall varies from 857 to 1 085 mm, and the annual mean temperature varies from 17 ° to 20 °C. The most dominant soil of the area is andosol (orthic) (IPMS, 2007).

Hawassa Zurya

Second area is located in Sidama Zone, Southern Nations, Nationalities and People Regional state of Ethiopia. The study site is located at 7 º 1 '45 " N and 38 º 16 ' 30 " E (Figure 2). The area has an altitude of 1 700 meter above sea level. The mean annual rainfall of the area is 959 mm, and its mean minimum and mean maximum monthly air temperatures are 12 ºC and 26 ºC.

Gibie

Third group of seeds was collected in Gibie Valley, Abelti-Gibie forest priority area, South Western Ethiopia. Geographically, it is located at 8 ˚10 ' N and 37 ˚34 ' E (Figure 2) in the altitude of the area 1493 m above sea level. Area is characterized by a rugged topography, and dominated by gentle slopes and a localized steep slope ranging from 1 % - 27 %. The climate character influencing the area is derived from the closest climatologic station, which is situated 100 km southwest from the locality. The area prevails unimodal type of rainfall pattern, with the highest rain occurring between June and August. The mean annual rainfall in the area is 1665 mm/year. The mean annual temperature is 22.6 ˚C, with a mean minimum of 15 ˚C to mean maximum of 30.34˚C (Alem & Pavliš, 2012).

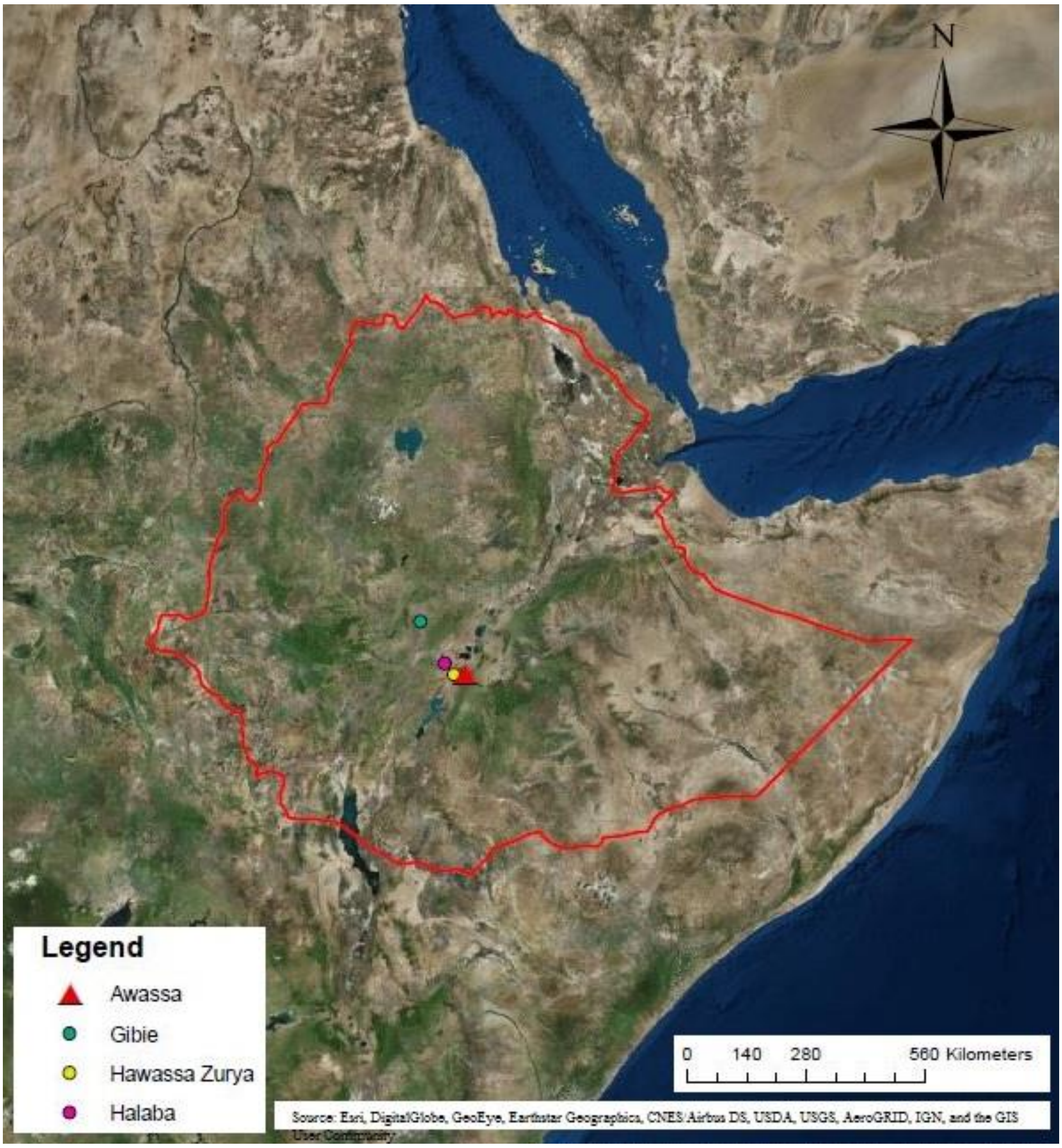

Figure 2 Seed collection sites

4.2 Experimental design

For the experiment a total amount of 500 seeds of every provenance (Halaba, Hawassa Zurya, Gibie) were used. After seed collection, the experiment run in Jara Jinesa nursery site. For every treatment type and so for control sample 100 seeds were used. In this experiment seed germination qualities were detected.

Four treating methods were used along with control sample without treatment. Seeds were exposed to hot water for 20 minutes and 30 minutes, and to cold water for 24 hours and 12 hours. Sowing of every group was held in same time. Seeds were sown to prearranged plastic boxes filled with sand. Shallow grooves were made in sand, regarding the distance of 10 cm from each other (Figure 3). After that, seeds were sown equally to these grooves. Seeds were watered daily during the experiment.

Figure 3 Seedlings in plastic box during experiment

4.3 Data collection and analysis

Data from this experiment was collected during daily seed boxes observation. The number of germinated seeds has been recorded for each labelled box. Boxes were observed for 24 days after the date of sowing and the data was recorded. Subsequently, the notices numbers were analysed in Excel using table elements and transferred to graphical form.

5 Results

In this work, seed germination of *Dodonaea angustifolia* was evaluated from three different sites (Halaba, Hawassa Zurya, Gibie). Furthermore, the effects of seed treatment with cold and warm water with different time intervals on germination success were evaluated.

The chronological course of germination from seed planting to visible germination is given in the table (Appendix 5).

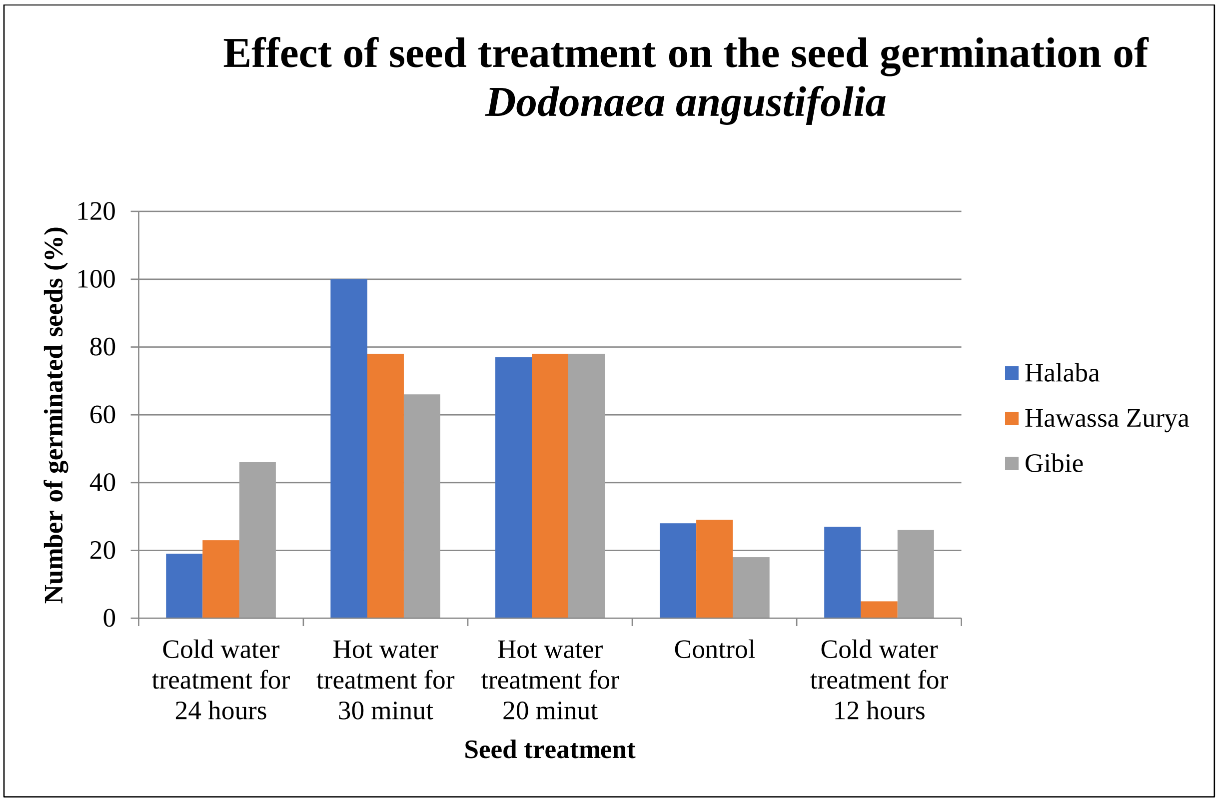

Figure 4 Effect of seed treatment on the seed germination of Dodonaea angustifolia

Significantly positive effect (see Figure 4) has hot water treatment for 20 and 30 minutes at all sites. In this mode of treatment, germination was approximately about 70 %. At Halaba locality, the best treatment mode is dipping in warm water for 30 minutes, to reach 100% germination rate. Cold water treatment did not have a positive effect on seed germination. Only at the Gibie site the germination rate was close to 50 %.

A rapid increase in germinated seeds number was recorded during 3 - 6 days after sowing. In cold-water treated and untreated seed cases, growth progression lasts longer and stops slowly and later than in hot-water treated seed's case. Hot-water treated seed increase of germinated seeds was bolt, but reaching the final number was very sudden (Figure 5).

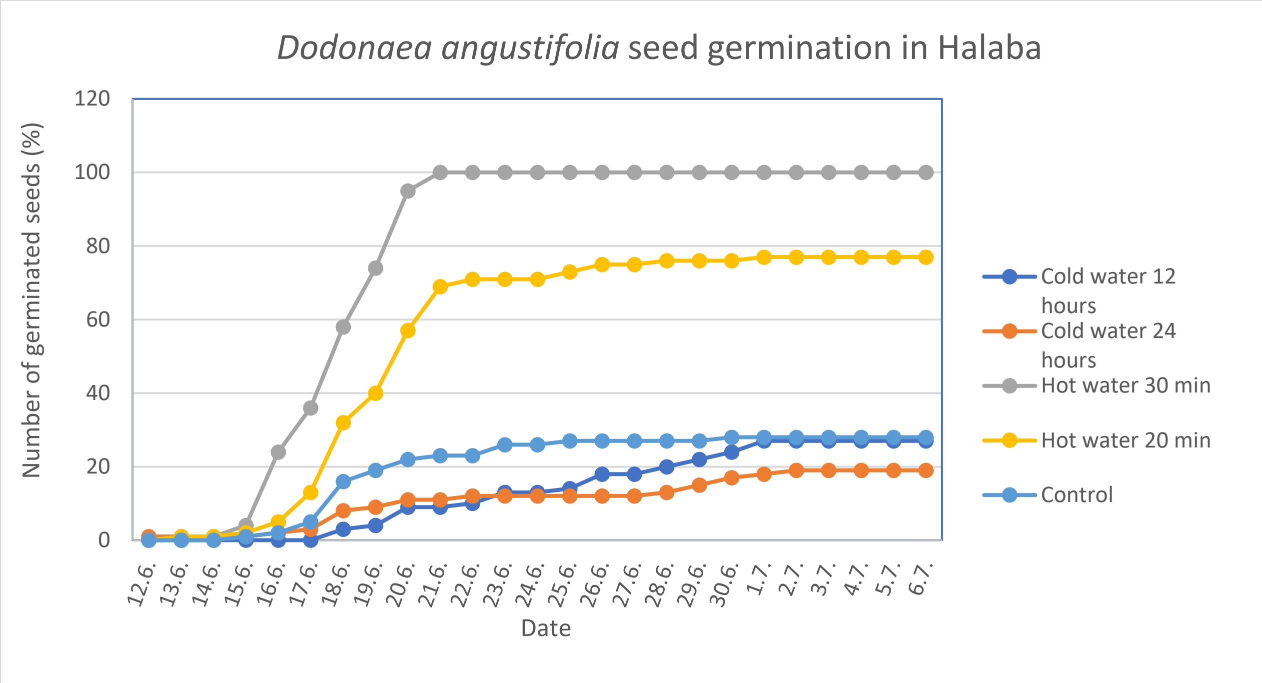

Figure 5 Process of Dodonaea angustifolia seed germination in Halaba

A higher increase in germination rate was recorded during 3 - 6 days after sowing. As in previous case a longer growth progression is visible in cold-water treated and untreated seeds occurs. In comparison to previous control seed germination, in this provenance a few steep growth increases occurred and number increase terminate slowly (Figure 6).

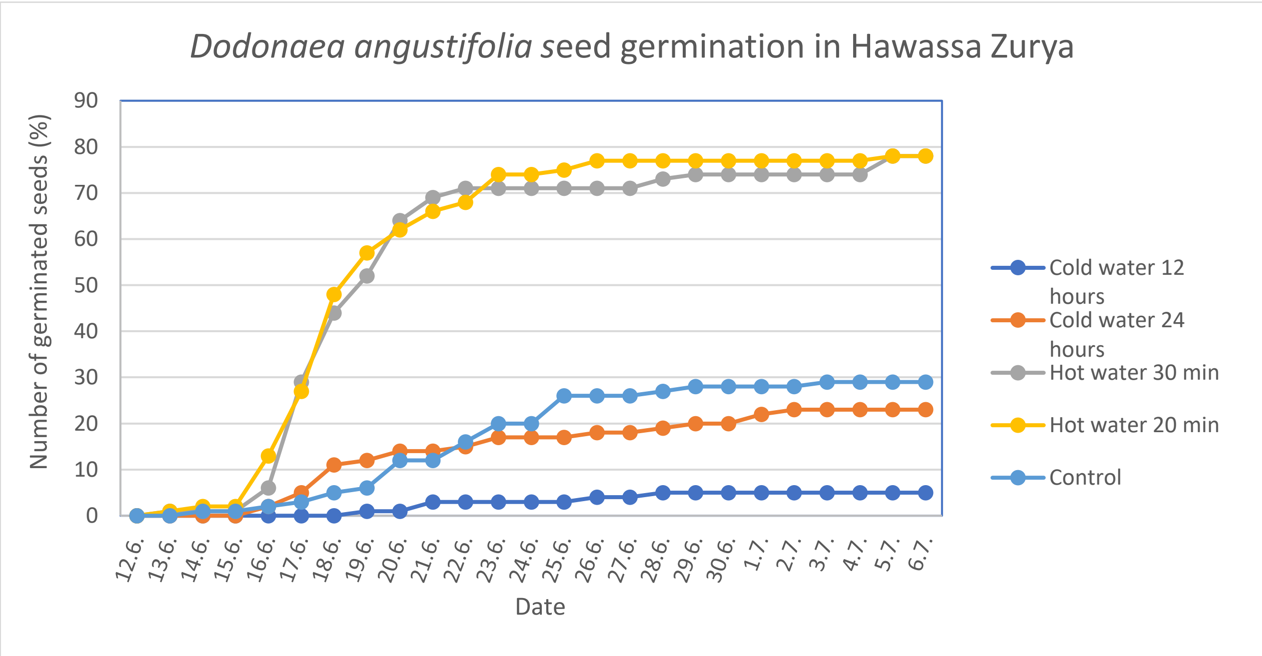

Figure 6 Process of Dodonaea angustifolia seed germination in Hawassa Zurya

Even in this case, the largest increase in germination was recorded during the 3 - 6 days of sowing. The germination process has similar properties to those described above, but there was an interesting steep increase in the number of germinated seeds in case 24 hours cold-water treated seeds (Figure 7).

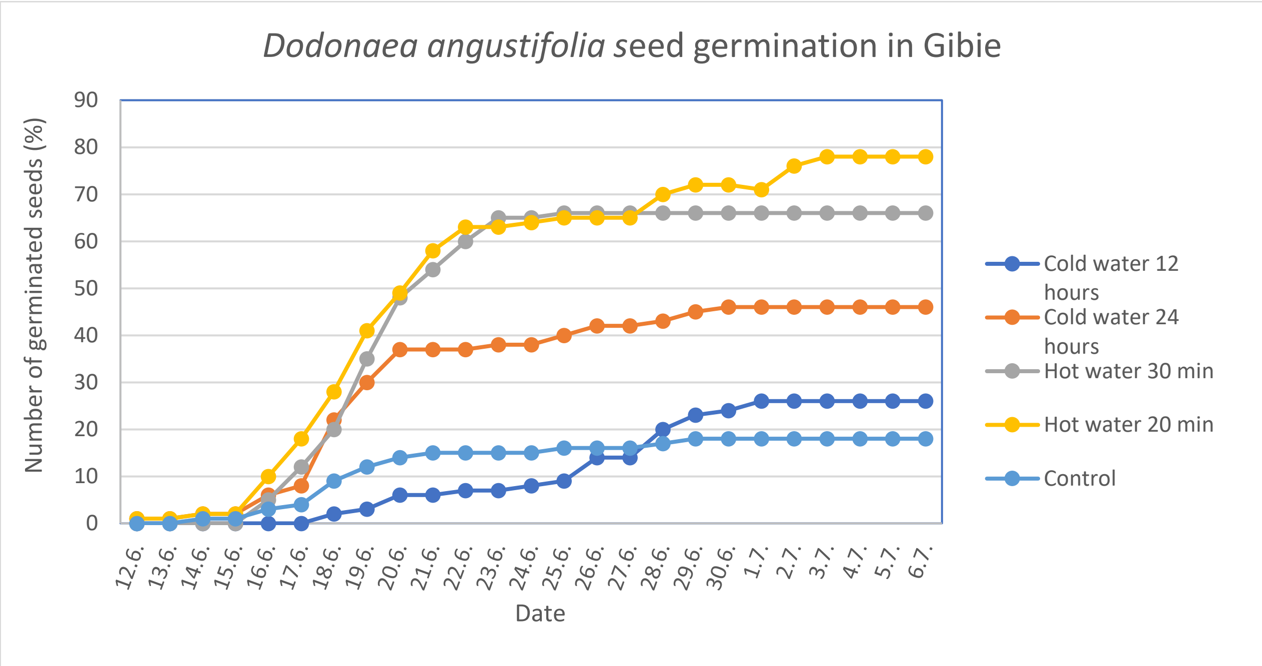

Figure 7 Process of Dodonaea angustifolia seed germination in Gibie

6 Discussion

The aim of this work was to evaluate the seed treatment effect on the seed germination of *Dodonaea angustifolia* collected from three different localities and to determine most successful and appropriate seed treatment technique for seeds. According to uncertain taxonomy of this species there is not many studies focused on *Dodonaea angustifolia*, not even on its germination issues. It is considered no seed treatment is required.

Despite this recommendation of Katende et al. (1995), a positive response to seed treatment was observed. The best germination was recorded after hot water treatment in both time intervals in every provenance. The most positive effect of hot water seed treatment was recorded within Halaba provenance. In this case, the germination level reached 100 % rate after exposition to hot water for 30 minutes. From this, it can be concluded the combination of these two factors can decrease the hardness of seed coats and increase water permeability to seed.

About 70 % rate of germination was obtained after 20 minutes' exposure in hot water in case of every studied provenance. Keeping the seeds in hot water for longer time (30 minutes) can lead to increasing or decreasing of germinated seeds number. This influence extends to the impact of the provenance. In case of Halaba provenance, increasing of germinated seed number to 100 % rate was recorded. Since Halaba locality has lower rainfall annual amount it can be supposed to seeds have a harder seed testa, which protects a seed against drying out. Opposite to Halaba locality, Gibie is precipitously over average (Alem & Pavliš, 2012). Thus, it can be assumed the testa is thinner and it is reason why there is negative difference between hot water treatment for 20 or 30 minutes.

Despite the cold water does not have a significant effect of seed germination in comparison to untreated seeds Gibie provenance showed higher germinated seeds number after longer exposition to cold water (24 hours). This positive effect can be explained by adaptation of this provenance to higher precipitation.

A control sample of untreated seed reached a germination rate up to 30 %. It disagrees to claim of Katende et al. (1995) that seed can reach germination rate of 30-70 % without treatment. This difference can be caused by different considered provenances which Katende et al. (1995) evaluated.

The germination process of untreated seeds did not show such a rapid increase in amount of germinated seeds as the treated seeds did. After cold water treatment for a longer period of time (24 hours), the seeds of the Halaba provenance were visibly germinating after two days from sowing. This phenomenon may present that they were not in a state of dormancy. However, their activity can be connected with a fact that even rehydration of seed, related with a seed swelling, can improve seed germination. But this alone cannot ameliorate the seed germination process to the higher rates. Results of this treating methods show 12 % germinated seeds after 16 days. On the 20th day rate of germinated seeds stops at final 19 %.

Cold water used for a seed treatment of Halaba provenance seeds did not show any significant germination acceleration. The seeds started germinating visibly after 6 days from sowing and increasing of germinated seeds amount was slow, but stopped at higher rate than in longer exposure to cold water (24 hours) case. The rate of germinated seeds reached final 27 % after 19 days. In comparison to untreated seeds germination rate, 27 % after 13 days and 28 % after 18 days, the cold-water treatment has none effect of Halaba provenance seeds. This may have two causes. A seed exposing time to cold water is not adequate for seed to consume sufficient amount of water to swell. Second cause can be inhibition of germination by cold water but this theory cannot be significantly proven because of lack of data available.

Result from the Halaba seeds treated with hot water for 20 minutes shows the quick germination start and gradual rise up to 77 % of germinated seeds in 19 days. Longer exposure of Halaba seeds to hot water (30 minutes) increased germination rate rapidly up to 24 % of germinated seeds in 4 days and 100 % of germinated seeds in 9 days after sowing. This is in accordance to Palátová (2008), who mentioned the positive effect of hot-water seed treatment.

Untreated seeds of Hawassa Zurya reached similar germination rate of 29 % in 21 days, as previous provenance did. Hawassa Zurya provenance exhibited more serious inhibition effect of cold water to seeds. Visible germination occurred 7 days after sowing, 5 days later than untreated seeds, and germination rate reached only 5 % in 16 days and changed no more. Longer Hawassa Zurya seeds soaking (24 hours) in cold water showed earlier germination in comparison to shorter time exposure, and reached 23 % germinated seeds rate in 20 days, so it corresponds to previously described inhibitory effect theory.

The data from third provenance (Gibie) mostly correspond to the results from previous two sites, but there is a significant variation in the seed treated with cold water for 24 hours. The seed germination rate reached almost 50 % in 18 days and showed high increase of germination rate during the 6th day after sowing. This phenomenon can be described by a provenance adaptation to higher precipitation at its original site, so exposure to cold water for 24 hours can simulate natural occurrence of higher rainfalls amount during a rainy season. This fact is in accordance with Palátová (2008), who described a positive effect of cold water soaking for longer exposure (24 hours).

These results can be used for optimisation of pre-sowing seed treatment in order to obtain a sufficient and time-balanced amount of *Dodonaea angustifolia* seedlings. Obtained seedling material can be used in restocking and reforesting plantings as a preparatory tree following the growth of target species. Understanding of provenance issue is very important in order to choose the right seed material in terms of natural conditions to limit after-planting losses and to increase the possibility of successful ingraining of seedlings. In addition, the hot-water soaking technology is economically and technologically unassuming and therefore very suitable for use in conditions with insufficient technological equipment.

An increase in the number of germinated seeds brings future possibilities to establish a planting technology of containerized plants, which regarding general rules reduces planting losses and increases the planting success probability. It is recommended to continue with this type of research to achieve the best results in planting mainly on degraded soils.

7 Conclusion

In general, raising large number of high quality seedlings plays an important role for better growth performance and adaptation of seedlings to field conditions. In order to get high, rapid and uniform seed germination, seeds require appropriate seed pre-sowing treatment methods.

Determination of influence to seed germination of *Dodonaea angustifolia* by different types of treatment (cold-water soaking for 12 hours, cold-water soaking for 24 hours, hot-water soaking for 20 minutes, hot-water soaking for 30 minutes) within three provenances (Halaba, Hawassa Zurya, Gibie), plus a comparison with untreated seeds germination rate, was the aim of the work. During experiment data of germination rates were observed and evaluated. As a result, soaking seeds in hot water greatly improved seed germination as compared to others. In a contrast to hot-water treatment positive effect, cold-water treatment showed none, or even negative influence on seed germination. The effect of provenance on seed germination further revealed that different soaking time is required, according to different natural conditions adaptation of seed (e.g. harder testa, adaptation to high precipitation).

Simplicity and technological unassuming of performed methods can lead to higher effectivity in seedlings production, because it can increase the amount of seedling rapidly and uniformly with no financial investment needed. This optimisation can be followed by shortening the germination process and faster seedlings production.

8 Súhrn

Vo všeobecnosti je pre produkciu vysokokvalitných semenáčikov/sadeníc vo veľkom počte dôležitý priebeh klíčenia a stanovištná vhodnosť výsadbového materiálu. Spôsoby pred-osevnej prípravy využívame za účelom zlepšenia podmienok pre klíčenie a časovo jednotného klíčenia.

Cieľom tejto práce bolo z hľadiska úspešnosti klíčenia zhodnotiť rôzne spôsoby pred-osevnej prípravy (máčanie v chladnej vode po dobu 12 hodín, máčanie v studenej vode po dobu 24 hodín, máčanie v horúcej vode po dobu 20 minút, máčanie v teplej vode po dobu 30 minút) semien druhu *Dodonaea angustifolia* troch proveniencií (Halaba, Hawassa Zurya, Gibie) a porovnať ich s úspešnosťou klíčenia neošetrených semien. Počty vyklíčených semien boli zrátané a následne vyhodnotené pre každú provenienciu. Výsledkom práce je zistenie, že horúca voda má preukázateľne pozitívny vplyv na klíčenie semien a to na celkovú úspešnosť, aj na rýchlosť nástupu. Narozdiel od ošetrenia horúcou vodou, ošetrenie studenou vodou neprinieslo žiaden, alebo v niektorých prípadoch aj negatívny efekt na klíčenie. Vplyv proveniencie sa prejavil v rozličnom optimálnom čase máčania, nakoľko každá proveniencia je prispôsobená svojím prírodným podmienkam (napr. tvrdšie osemenie, prispôsobenie sa vyššiemu úhrnu zrážok).

Jednoduchosť a finančná nenáročnosť zvolených spôsobov ošetrenia je vhodným podkladom pre zvýšenie efektivity produkcie semenáčikov/sadeníc, nakoľko dokáže zvýšiť a zjednotiť dobu klíčenia bez potreby finančných investícií. Optimalizácia tohto procesu môže priniesť zrýchlenie klíčiaceho procesu a urýchlenie produkcie semenáčikov/sadeníc.

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10 Appendix

Appendix 1 Habitat of Dodonaea angustifolia (Source: http://botany.cz)

Appendix 2 Leaves of Dodonaea angustifolia (Source: http://keys.lucidcentral.org)

Appendix 3 Inflorescence of Dodonaea angustifolia (Source: http://drfarrahcancercenter.com)

Appendix 4 Fruits and seeds of Dodonaea angustifolia (Source: http://www.plantbook.co.za/)

Appendix 5 Daily germination process of all provenances with different treatment methods

Replication	Date of germination												
	12.VI.	13.VI.	14.VI.	15.VI.	16.VI.	17.VI.	18.VI.	19.VI	20.VI.	21.VI.	22.VI.	23.VI.	24.VI.
Halaba soaking in cold water for 24 hour	1	1	1	1	2	3	8	9	11	11	12	12	12
Durie soaking in cold water for 24 hour	0	0	0	0	2	5	11	12	14	14	15	17	17
Gibie soaking in cold water for 24 hour	1	1	2	2	6	8	22	30	37	37	37	38	38
Durie with hot water treatment for 30 minut	0	1	1	1	6	29	44	52	64	69	71	71	71
Halaba with hot water treatment for 30 minut	0	0	1	4	24	36	58	74	95	100	100	100	100
Gibie with hot water treatment for 30 minut	0	0	0	0	5	12	20	35	48	54	60	65	65
Halaba with hot water treatment for 20 minut	0	1	1	2	5	13	32	40	57	69	71	71	71
Dorie with hot water treatment for 20 minut	0	1	2	2	13	27	48	57	62	66	68	74	74
Gibie with hot water treatment for 20 minut	1	1	2	2	10	18	28	41	49	58	63	63	64
Dorie control	0	0	1	1	2	3	5	6	12	12	16	20	20
Gibie control	0	0	1	1	3	4	9	12	14	15	15	15	15
Halaba control	0	0	0	1	2	5	16	19	22	23	23	26	26
Halaba soaked in cold water 12 hours	0	0	0	0	0	0	3	4	9	9	10	13	13
Gibie soaked in cold water 12 hours	0	0	0	0	0	0	2	3	6	6	7	7	8
Durie soaked in cold water 12 hours	0	0	0	0	0	0	0	1	1	3	3	3	3

Replication	Date of germination											
	25.VI.	26.VI.	27.VI.	28.VI.	29.VI.	30.VI.	1.VII.	2.VII.	3.VII.	4.VII.	5.VII.	6.VII.
Halaba soaking in cold water for 24 hour	12	12	12	13	15	17	18	19	19	19	19	19
Durie soaking in cold water for 24 hour	17	18	18	19	20	20	22	23	23	23	23	23
Gibie soaking in cold water for 24 hour	40	42	42	43	45	46	46	46	46	46	46	46
Durie with hot water treatment for 30 minut	71	71	71	73	74	74	74	74	74	74	78	78
Halaba with hot water treatment for 30 minut	100	100	100	100	100	100	100	100	100	100	100	100
Gibie with hot water treatment for 30 minut	66	66	66	66	66	66	66	66	66	66	66	66
Halaba with hot water treatment for 20 minut	73	75	75	76	76	76	77	77	77	77	77	77
Dorie with hot water treatment for 20 minut	75	77	77	77	77	77	77	77	77	77	78	78
Gibie with hot water treatment for 20 minut	65	65	65	70	72	72	71	76	78	78	78	78
Dorie control	26	26	26	27	28	28	28	28	29	29	29	29
Gibie control	16	16	16	17	18	18	18	18	18	18	18	18
Halaba control	27	27	27	27	27	28	28	28	28	28	28	28
Halaba soaked in cold water 12 hours	14	18	18	20	22	24	27	27	27	27	27	27
Gibie soaked in cold water 12 hours	9	14	14	20	23	24	26	26	26	26	26	26
Durie soaked in cold water 12 hours	3	4	4	5	5	5	5	5	5	5	5	5