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Effects of planting-hole size, composting animal manure and sack on survival and growth of *Eucaliptus camaldulensis*, *Ziziphus spina- christi* and *Pistasia atlantica* planted in Mehran Plain, Iran

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Abstract

This study tested three methods thought to maintain soil moisture availability and thereby improve the performance of three species (*Eucaliptus camaldulensis*, *Ziziphus spina-christi* and *Pistasia atlantica*) when planted in permanent landscape of Mehran plain: increased planting-hole size, composting animal manure and sack addition. Seedlings of the three species were grown in two planting-hole sizes (30*30*30 cm and 100*100*100 cm), with and without composting animal manure, and with and without sack. The experiment was conducted in site (Mehran plain) in Ilam Province, Iran. Seedling growth and survival were monitored over 30 months. Seedling survival was >90% for all three species and did not differ significantly among any of the treatments. High rainfall in winter and autumn throughout and irrigation during the dry season the first year of the experiment may have enhanced seedling survival. Deeper planting-hole had the strongest effect on seedling growth for species, composting animal manure addition and sack had a positive effect on growth for all three species especially *Eucaliptus camaldulensis*. Seedlings growing in one-meter holes with composting animal manure and sack had most height and diameter. The development and total number of roots were much better at this depth as compared to surface planting. Deep planting provides resistance to cyclones and induces earlier flowering and higher yields.

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Introduction

The demand for faster-growing, bigger and better seedlings has been ever-growing. As a result, forest seedling production is a continually evolving new technology in afforestation. Evaluating seedling quality is crucial for understanding seedling development in the nursery, as well as subsequent field growth and survival (Ffoliot *et al*, 1995; Iqbal, 1986; Kaul, 1970).

The success of afforestation depends on a wide range of factors, including site conditions, species characteristics, the specific planting techniques and treatments applied, as well as social and economic factors (Evans, 1996). While there has been extensive silvicultural study for plantation establishment in the dry lands generally (Evans, 1996), the information available for planting native and non-native tree species in Iran remains limited (Ahmadi *et al*, 2013; Jazireiee, 1998). Seedling establishment is considered a crucial stage of tree regeneration, and it has been fairly widely reported that the success of Seedling establishment depends on planting methods (Alexander and Stuart, 2003; Davies, 1988). A detailed understanding of the factors controlling seedling growth and survival is required for developing areas of enrichment planting.

Planting method is one of factors that affect most seedling performance in the field. Whether big planting hole is a favorable practice to tree growth or not, remains as a controversial issue. There are lots of reports in both side of the opinion. Some authors agree about the advantages of seedlings in bigger hole (Shipman, 1960; Stroempl, 1990; Paterson, 1997). Specifically for Eucalyptus, Goes (1977) and Ahmadi (2013) recommended seedling planting in deeper holes size. Also FAO (1981) recommended seedling planting the root collar a little below the surface of the soil. The deeper planting-hole supposed advantages for proximity to get more underground water reserves. In disagree with previous reports, other showed negative impacts of planting-hole (Rose *et al.*, 1997; Amidon *et al.*, 1982; Bainbridge, 1994; Landis and Dumroese, 2006). The planting hole may be filled with topsoil from the surrounding area, mixed with the recommended quantity of fertilizer or manure. Animal manure is very beneficial to the seedlings, due to its great water holding capacity and the micro-nutrients that will become available with its decomposition.

In this study, we conducted a field experiment to test three methods thought to enhance below-ground humidity availability, and thereby improve the performance of seedlings when planted to enrich degraded dry lands. The three methods were: animal manure addition, sack addition to floor on hole-planting, and increased planting-hole size. Composting animal manure availability may strongly limit seedling performance. Sack is thought to help in soil moisture retention (Evans, 1996; Suhaili *et al.*, 1998). The size of the hole into which seedlings are planted may also significantly affect seedling survival and growth through changes in soil aeration, rooting density, or rates of infiltration. The survival and growth of seedlings of *Eucaliptus camaldulensis*, *Ziziphus spina- christi* and *Pistasia atlantica* under these three different planting methods were monitored in barren land of Mehran plain in western of Iran.

Material and methods

Study sites

The experiment was conducted in Mehran plain, which is located in the Southern Ilam province of Iran. Mehran county including arid regions of Iran and the vegetation is not appropriate and Being turned into desert. This site are in the lowlands (<300 m) with a similar topography of low undulating hills (Fig 1). Mehran County contains some of the most important human habitations in the South Ilam province and Agriculture is one of the main sources of income for the population. The agriculture is dependent on groundwater and on managed surface runoff water resources are critical sources of water for this region. The average annual temperatures range from 22 to 26 C° and the average annual precipitation for the studied area amounts to 290 mm, most of which occurs in April and May.

Fig 1. The view of the sites studied (This area is part of a massive reforestation project in Mehran Plain).

Study species

Three species, *Eucaliptus camaldulensis*, *Ziziphus spina- christi* and *Pistasia atlantica*, were selected for this experiment. These species were chosen due to their importance for Iran's dryland and their purported suitability for large scale planting (Arekhi and Jafarzadeh, 2012). They have been widely used in enrichment planting and are thought to be among the more promising plantation species due to their relatively fast growth.

Eucalyptus is a diverse genus of flowering trees and in the myrtle family, Myrtaceae. There are more than 700 species of eucalyptus, mostly native to Australia. Species of eucalyptus are cultivated widely in the tropical and temperate world. Since their introduction into Iran, Eucalyptus species remain superior in terms of fast growth, multiple uses, and suitability to small scale farmers and overall support to key sectors of the economy.

Ziziphus is a genus of about 40 species of spiny shrubs and small trees in the buckthorn family, Rhamnaceae, distributed in the warm-temperate and subtropical regions throughout the world. *Ziziphus spina-christi*, the Christ's Thorn Jujube is an evergreen tree native to northern and tropical Africa and southern and Western Asia (Zohary, 1972). This species have been indigenous of study area.

Pistacia atlantica is a native species to a section of Eurasia from the Iranian Plateau to North Africa. (Martinez, 2008). *P. atlantica* is the most economically important species in many parts of Iran, including the Zagros forests, where it is managed as a valuable forest tree. The resin and fruit were historically used for a variety of medicinal purposes. The resin, known in west of Iran as saqez, is still an important commodity. This species are adapted to desert or summer drought typical of Mediterranean and semi-Mediterranean climate and can survive in temperatures ranging from - 10°C in winter to 45°C in summer (Pourreza *et al*, 2008).

Experimental design

The experiment involved three species, two planting-hole sizes (30*30*30 cm and 100*100*100 cm) and four treatments (with and without composting animal manure, and with and without sack). For each, the eight treatment combinations (two planting-hole sizes by four treatments) occurred. In each treatment combination, 25 seedlings were line-planted in five rows with spacing of 5 m between adjacent seedlings. In total, 2400 seedlings were included in the experiment. The seedlings of this species were transplanted to the permanent landscape at the beginning of the wet season (October 2011). Their survival and growth monitored over 30 months (February 2013).

Experimental treatments

Container seedlings were planted into either 30 cm * 30 cm * 30 cm (wide*height *depth) or 100 cm * 100 cm * 100 cm holes (Fig 2). The smaller planting-hole was dug with a hand-held. The larger planting-hole was dug with an excavator. Removed soil was repacked around the roots of all seedlings after planting. The four treatments were animal manure addition, embed of sack and a combination of sack and manure addition. For sack addition, after digging holes and before seedlings planting, in the holes floor were placed cotton sacks. For animal manure addition, 100 g of this manure was buried in ca. 5 cm deep holes around the seedlings.

Fig 2. Seedlings planting holes with 1*1*1 meter dimension (*Eucaliptus camaldulensis* is the right and *Ziziphus spina-christi* is the left).

Statistical analysis

Seedling stem height and diameter, and survival were assessed immediately after planting, and after 30 months. Plant height to the tip of the apical shoot was measured to the nearest 1 cm. Stem diameter was measured at 10 cm above ground level with electronic calipers. A nested-factorial analysis of variance (ANOVA) was used to analyze treatment effects on seedling relative growth rates. So treatment effects were analyzed separately for each species. Post-hoc comparisons following significant ANOVAs were tested with Tukey HSD tests.

Results

Seedling survival

Seedling survival was high among all treatments for both species in this experiment. Mortality over 30 months was 3.5% for *E. camaldulensis*, 2.5% for *Z. spina- Christi* and 4% for *P. atlantica* with a total of only 240 of 2400 seedlings dying over the 30-month period. Mortality rates did not differ significantly between species, or among planting treatments. Although there was a lower proportion of dead seedlings in the larger planting-hole compared to seedlings growing under smaller planting-hole.

Diameter and height growth

Treatments had a significant effect on diameter and height growth for all three species. By the end of the experiment the relative growth rate of surviving seedlings had changed significantly with seedling holes. Seedlings planted under big holes had greater increases in maximum stem height than seedlings planted in the small holes (Table 1).

Table 1. Height and diameter growth increments for seedlings of *E. camaldulensis*, *Z. spina- christi* and *P. atlantica*.

Treatment	Planting-hole sizes	Diameter growth (mm per year)	Height growth (cm per year)
E. camaldulensis			
Control	Big	2.2 (0.22)	62 (2.7)
Control	Small	2.1 (0.17)	56 (2.2)
manure	Big	2.6 (0.24)	69 (2.5)
manure	Small	2.5 (0.24)	67 (3.3)
sacking	Big	2.9 (0.27)	78 (4.5)
sacking	Small	2.7 (0.32)	66 (4.0)
Manure plus sacking	Big	3.2 (0.35)	85 (3.4)
Manure plus sacking	Small	3.0 (0.28)	64 (3.2)
Z. spina- christi			
Control	Big	1.8 (0.28	24.8 (1.2)
Control	Small	1.55 (0.35)	22.4 (1.4)
manure	Big	2.3 (0.32)	27.6 (2.0)
manure	Small	1.9 (0.27)	26.8 (2.5)
sacking	Big	3.1 (0.24)	31.2 (1.5)
sacking	Small	2.6 (0.24)	26.4 (1.2)
Manure plus sacking	Big	3.5 (0.17)	34 (1.4)
Manure plus sacking	Small	3.15 (0.22)	25.6 (1.7)
P. atlantica			
Control	Big	1.65 (0.18)	14.8 (1.2)
Control	Small	1.45 (0.25)	12.4 (1.4)
manure	Big	1.9 (0.22)	17.6 (2.0)
manure	Small	1.7 (0.17)	16.8 (2.5)
sacking	Big	2.1 (0.14)	21.2 (1.5)
sacking	Small	1.98 (0.14)	16.4 (1.2)
Manure plus sacking	Big	2.5 (0.17)	24 (1.4)
Manure plus sacking	Small	2.21 (0.12)	15.6 (1.7)

However the response to treatments varied between the three species (Figs. 3, 4 and 5). For *E. camaldulensis*, there were strong treatment effects. Manure addition significantly enhanced seedling Height growth rates for all three species in study site. Seedlings with added manure had higher relative growth rates than control seedlings. In addition, seedlings in manure plus sack treatments had significantly higher growth rates than seedlings treated with manure alone. Seedlings with added manure plus sack treatments in big holes had ca. 35% higher relative growth rates than control seedlings in small planting holes.

In the area, manure addition significantly increased seedling growth of *Z. spina- christi* and *P. atlantica*. For this species Seedlings, sack treatment had weak significant effects on growth rates (Figs. 4 and 5). Although, seedlings planted in big planting-holes grew significantly better with sack addition.

Embedded sack treatment had a much weaker affect on seedling growth than manure addition (Figs. 3, 4 and 5). For *E. camaldulensis*, height growth rates were significantly increased by sack addition for seedlings grown in large planting-holes. In both cases (planting holes type), height growth was significantly greater in sack addition treatments than in control treatments, and in manure plus sack treatments than in nutrient-only treatments.

Planting-hole size did have a consistent significant effect on seedling growth rates in all species (Figs. 3, 4 and 5). For *E. camaldulensis*, plants in big holes had significantly higher growth rates than plants in small holes for other treatments -added plants. There were also significant planting-hole size effects on *Z. spina- christi* and *P. atlantica* growth in study site (Figs. 4 and 5). However, there was consistent trend, with control plants doing better in big holes, and sack plus manure plants doing better in big holes. Planting-hole size significantly affects the growth of three species seedlings in all of treatments. In this study diameter growth showed similar patterns to height growth for each species.

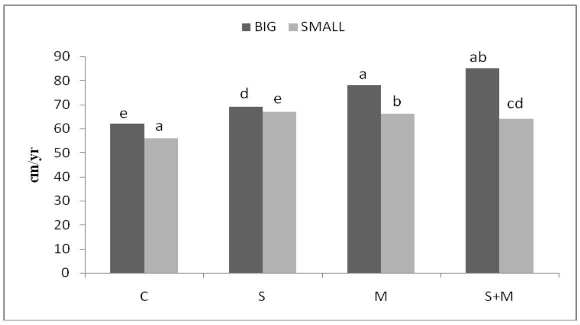

Fig. 3. Mean relative Height growth rates of seedlings of *E. camaldulensis* grown in four treatments (C: control, S: sacking, M: manure addition, and S+M: sack plus manure addition) and two planting-hole sizes (big and small). Different letters indicate significant differences (P < 0.05) between the means.

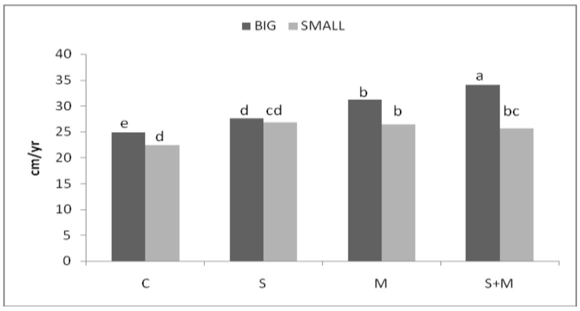

Fig. 4. Mean relative Height growth rates of seedlings of *Z. spina- christi* grown in four treatments (C: control, S: sacking, M: manure addition, and S+M: sack plus manure addition) and two planting-hole sizes (big and small). Different letters indicate significant differences (P < 0.05) between the means.

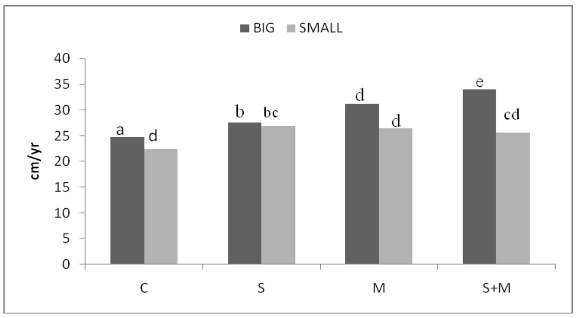

Fig. 5. Mean relative Height growth rates of seedlings of *P. atlantica* grown in four treatments (C: control, S: sacking, M: manure addition, and S+M: sack plus manure addition) and two planting-hole sizes (big and small). Different letters indicate significant differences (P < 0.05) between the means.

Discussion

Ziziphus spina- christi and *Pistasia atlantica* are the most important species on the basis of low ecological needs and high tolerance against summer heat and winter dry. It is very current in forest plantation in degraded ecosystems and dry and semi-dry lands in Iran (Pourreza *et al*., 2008; Ahmadi *et al*., 2013).

In this study seedlings survival rates of >90% over 30 months are exceptionally high for *Eucaliptus camaldulensis* plantation experiments. Most other studies involving afforestation have reported substantially higher mortality rates. For example, Suhaili *et al*. (1998) found seedling mortality rates of 22% for *E. camaldulensis* over the first 6 months in degraded land in Peninsular Malaysia. In several other afforestation studies in Southwest Asia, mortality rates have been 20–40% in the first few years and sometimes even higher (Martin, 1946; Nussbaum *et al*, 1995; Gupta, 1991; Pourreza *et al*., 2008). It seems that the high survival rates in this study were due to a highly favorable soil water environment, Because in mehran plain, water availability is one of the most important variables that contribute to successful establishment and growth of seedlings. High rainfall in winter and autumn throughout and irrigation during the dry season the first year of the experiment may have enhanced seedling survival.

The seedling planting method is a one of the agents that affect most plant efficiency in the permanent habitat. Planting-hole size shows strong and consistent effect on seedling growth of all three species in this experiment. This agrees with other authors (Shipman, 1960; Stroempl, 1990; Paterson, 1997), but controversial results sere showed for different authors. Where some of them reported that deeper planting give results of lower growth rates (Paterson and Maki, 1994; Alexander and Stuart, 2003; Ruiz *et al*, 2014). Increased planting-hole size might benefit seedling efficiency through increased infiltration and hence water availability, reduced compaction in a larger soil volume surrounding the roots, or through decreased root competition in the early stages of establishment and growth. Ohler (1999) found that in the dry climate of Karnataka (India), planting at depths of 60 and 90 cm gave better results than at depths of 0 and 30 cm. The best results in earliness and cumulative yield were observed at a planting depth of 60 cm. Deep planting hole in our study area provides resistance to warm winds and induces higher yields. Results of treatments have shown that planting at one meter holes resulted in 30 months increased annual yields compared to the control.

The result of this study shows that *Eucaliptus camaldulensis* under conditions of low and irregular rainfall can be successfully established by big planting holes. In dry and semi-dry lands such as west of Iran, the best time for planting seedlings in the permanent field is at the beginning of the rainy season, after the rains have started to fall regularly. Seedlings planted late in the rainy season may not be able to develop a root system large enough to survive the dry season (Ahmadi, 2013).

Composting animal manure addition plus sacking had the strongest affect on seedling growth of the treatments applied in this experiment. Positive responses to soil manure addition have been found in other field experiments in seasonal Southeast Asia (e.g., Nussbaum *et al*., 1995), however very few species have been tested for a manure response and these studies have been done in only a few sites. Mehran plain have relatively low soil- nutrient status for tropical soils, for this reason, all three species responded strongly to manure addition at mehran plain. It is suggested that in future studies, tissue nutrient analysis be conducted to assess whether the seedlings received the nutrients in the sites. This would also enable a more critical assessment of the nature of nutrient limitation for these species (Webb *et al*., 2000).

Sack or gunny sack is an inexpensive bag made of burlap usually formed from jute or other natural fibers. They are considered to be environmentally friendly and high breathability allows air to pass through them and have a high ability to retain moisture and water absorption. Sack addition significantly improved the growth of seedling than control plots especially for *E. camaldulensis*. However, the effect was much weaker than the soil manure effect and it was not consistent among treatments; e.g., plants of *P. atlantica* given mulch did not grow better than control seedlings, but sack plus manure plants grew better than sack-only seedlings. Sack addition is thought to enhance seedling survival and performance in plantations by aiding in soil moisture retention (Davies, 1988; Evans, 1996).

The overall conclusion is that, this experiment demonstrated that hole-planting size strongly limits the growth of *Eucaliptus camaldulensis*, *Ziziphus spina- christi* and *Pistasia atlantica* species when planted in a low rainfall areas, post-shifting cultivation, secondary succession site in the west of Iran. Manure addition may positively affect seedling growth, depending on other site conditions. Putting sack in the bottom of the planting hole had a relatively minor effect on seedling growth. An important implication of this study is that the results of seedling planting experiments may often be specific to the particular areas and environmental conditions in which the study is conducted. Experimental studies across a wider range of areas, in which resource availability and fluxes are carefully measured, are required for the development of protocols for planting the studied species. Such research is essential if the recent initiatives by Iran and other Southwest Asian countries to expand the area of plantation forests are to be successful.

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