Ali Reza Kharazipour, Christian Schöpper
and Cora Müller (Ed.)

Review of Forests, Wood Products and Wood Biotechnology of Iran and Germany – Part II

Universitätsdrucke Göttingen

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erschienen in der Reihe der Universitätsdrucke
im Universitätsverlag Göttingen 2008

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2008

Bibliographische Information der Deutschen Nationalbibliothek

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliographie; detaillierte bibliographische Daten sind im Internet über <http://dnb.ddb.de> abrufbar.

Global Forest Decimal Classification: (GFDC) 945.3, 97, (430), (55)

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Satz und Layout: Cora Müller
Titelabbildung : Cora Müller

http://univerlag.uni-goettingen.de
ISBN: 978-3-940344-21-2

Preface

The present book shows our research activities in the joined project "Deutsch-Arabisch/Iranischer Hochschuldialog" of the year 2007. The project is financed by the German Academic Exchange Service (DAAD) with funds of the Ministry of Foreign Affairs. In this book the common research themes on which the Iranian and German young scientists and scientists of both countries work are summarised. It sheds light on the various research approaches between both countries, which are accomplished in continuative cooperations between science and industry in Iran and Germany.

We want to thank all people in Iran and Germany who made and make this joined project and the continuative cooperation possible. My special thanks go to Dr. Asareh, Dr. Farahpour as well as the partnership authorised person in Iran Mr. M. Sc. Hossein Hosseinkhani from the Research Institute for Forests and Rangelands, Teheran for their engagement to continue this project. Thereby also the second year of our intention has contributed to the achievement of the commonly verbalised aims. Beyond I want to thank all colleagues from the University of Mazandaran, Sari for their cooperation.

The project was financed by the Department of Foreign Affairs in the context of the „Europäisch/Islamischen Kulturdialog" (EIK). My special thanks go to the German Academic Exchange Service. Without its engagement and organisation this project would not have been realisable.

For the support and the organisation of the conducted events and conferences I would like to thank Dr. C. Müller, Dr. C. Schöpper as well as Dr. Kai Ludwig from the Büsgen-Institute, Department of Forest Botany and Molecular Wood Biotechnology, University of Göttingen.

For the participation of different events in Germany I thank all institutes from the Faculty of Forest Sciences and Forest Ecology and our industry partners. Special thanks go to the director of the Büsgen-Institute, Prof. U. Kües and to Prof. A. Polle, leader of the department Forest Botany for their support and the good cooperation.

The project leader thanks all who have contributed to this project with their speeches and/ or attendance. I wish that many readers are interested in this book and that the good German-Iranian cooperation in the past will be continued in the future.

Göttingen, January 2008.

Project director Prof. Dr. Alireza Kharazipour

Table of contents

Application of mediators in enzymatical activation of fiberself cohesions for the production of enzyme-bonded, binder-free derived timber products – Methods and Results

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Introduction

The industry of derived timber products is one of the main consumers for binders, which consist conventionally of petrocemical components. The most common are urea-formaldehyde and phenol-formaldeyde resins as well as diisocyanates. By producing derived timber products binders take a bulk of maufacturing costs – for example 25 % according to medium density fiberboards (MDF). Facing fossil resources become more and more rare and expensive it represents a very high expense factor. Therefore a substitution of petrochemical binders by activating the wood fibers cohesions on its own seems to be very important for the derived timber product industries ecology and economy.
Of the regenerating raw materials (cellulose, hemicellulose, lignin, strength, protein, etc.) the lignin is the crucial factor for inner strength of the wood. Otherwise the hardly accessible lignin can be decomposed in nature by enzymes of certain funghi. This non-chemical reaction is used as basic principle to re-activate the lignin on a natural way as "adhesive" for the production for binder-free derived timber products.
Experiments have shown that the enzymatical activation of lignin is suiTable as bonding agent for derived timber products in principle. The activation runs so much the better, the lignin is more “nature-left”, what means that the less changes at its chemical structure were made. Relatively favorable conditions of this kind are given also with the today usual production of wood fibers in the so called “Refiner procedure". Therefore the enzymatical activation of the lignin is suiTable particularly well for the production of fiber boards in the wet and dry process.
Facing the analysis for the enzymatical activation of the lignin extracellular Laccases (Polyphenoloxydases; E.C. 1.10.3.2.) are used, which belong to to the most important lignin-decomposing and lignin-polymerizing enzymes beside the Ligninperoxydases (E.C. 1.11.1.7.) and Manganperoxydases (E.C. 1.11.1.13.) (Leontievsky et al., 1997). Laccasen already can be found in application during many technical processes e.g. with the "Biobleaching" in the paper production (Call and Mücke, 1997; Messner et al., 1993, Messner, 1993 and Messner and Srebotnik, 1994) and the textile industry (Galante and Formantici, 2003). Likewise derived timber products with and without low-emmision additives were manufactured (Kharazipour et al. 1993, 1997 and 1998; Felby et al., 1997, 2002). In these cases lignin as well as Laccases has been used as bonding agent. The Laccase takes over the task as “radical-former” to polymerize lignin, so that at the end a wood-like structure is developed. So far Laccases were taken primarily directly from white rot mushrooms (Kharazipour, 1983 and 1996).
Regarding biotechnological purposes Laccase has the advantage that it uses oxygen as oxidizing agent, while the Peroxidases need hydrogen peroxide, which in view of the high aggressiveness and small sTableility of this chemical causes

sustantial problems in biotechnological procedures (MAY et al., 2004). A disadvantage with the use of Laccases is their small redox potential. Due to this small redox potential, Laccases also need usually a free group of phenols at the aromatic ring for its oxidation, which restrains thier use in the lignin biotechnology. The reason is that in the lignin-synthesis the most phenolic groups are sustituted in radical reactions (Leonowics et al., 2001; Rochefort et al., 2004).
However Bourbonnais and Paice (1990) have been the first, who showed that after an addition of low-molecular redox-connections (so-called Mediators) Laccase is also able to attack non-phenolic connections. Therefore the main objective of this project is to examine the effect of Mediators in combination with wood fibers and Laccases for the production of binder-free derived timber products, especially medium density fiber boards (MDF). The mechanism of the Laccase-Mediator-system will be examined in a model by using lignin with the help of two usual technologies, on the one hand the Gel-Permeation-Chromatograpy (GPC, HPLC-SEC) to get the molecular weight distribution of the lignin and on the other hand the Electron-Spin-Resonance-Spectroscopy (ESR) to measure the radicalisation of the lignin on the fiber´s surface.

Materials and Methods

Wood fibers

The used pinefibers were defibrilated by the TMP process (thermo mechanical pulp). The origin of these fibers is from the Steico Company, from the plant in Czarnkow, Poland.

Laccase

The Laccase for the enzyme-bonded fiber-boards is used from the gentetically modified fungi *Aspergillus sp.* from Novozym, Denmark (Novozym 51003, E.C. 1.10.3.2).

Mediators

Mediators are small redox molecules, which act as electron carrier between lignin and Laccase (ROCHEFORT et al., 2004). With the Mediators the reactivity between both components can be increased. Until now following Enzyme-Mediator systems have been tested: ABTS (2,2'-Azinobis(3Ethylbenzthazolin-6-sulfonate)), HBT (Hydroxybenzotriazole), Methysyringate, Acetosyringone, Syringaaldehyde, TEMPO and HBA (4-Hydroxy-Benzoeacid).
However, special attention is taken on the Mediator HBA, with which better results were determined concerning the yield at phenoxy radicals (Hüttermann, A., unpublished).

GPC (Gel-Permeation-Chromatograpy)

The gel permeation chromatography is used to measure the molecular weight distribution of the lignin after incubation with Laccase and Mediator, whereby the Laccase and Mediator concentrations are varied. As control and comparison samples pure lignin/buffer solutions have been chosen, as well as Laccase incubated lignin/buffer solutions. The sample preparation and measuring method are leaned on Majcherczyk and Hüttermann (1996). The measurements take place at a high pressure liquid chromatography plant (HPLC) from *Waters* with GPC columns TSK gel HXL 4000, as well as HXL 3000 from the company *TosoHas*.
The sample preparation is done as follows:
About 10 mg of lignin (e.g. Wafex) are given in 4 ml McIlvaine buffer (pH 6.0). Depending upon the desired concentration Laccase and Mediator are added. The solution is shaked for 2 hours with a constant temperature of 40 °C. After the incubation concentrated NaOH is given to the solvents. Afterwards from each sample 2 ml are taken and mixed with 2 ml ethyl acetate (50 mm TDMA) at a horizontal shaker for 30 minutes. At room temperature the samples are centrifuged for 5 minutes at 2000 rpm, whereby the organic phase is separated from the aqueous phase. 1 ml is taken from the organic phase and given to 1 ml NaCl solution (1 %). The solutions are mixed at the horizontal shaker for 15 minutes and afterwards centrifuged at 2000 rpm for 5 minutes. This procedure is repeated two or three times, in order to wash the NaOH remainders from the samples. After washing 0.2 ml are taken from the organic phase and given into special sample tubes (Vials) for the GPC. These vials have to be kept in a vacuum dryer at 50 °C for 1 hour.
After this 0.5 ml pure tetrahydrofurane (THF) are added to solve the dry samples. Tetrahydrofurane (THF) is a solvent, which is not only used for the sample preparation, but mainly as carrier-solvent for the GPC plant. The Vials are directly transferred into the GPC-sampler and the samples are measured.

ESR (Electron-Spin-Resonance Spectroscopy)

With the electron spin resonance spectroscopy (ESR) the generation of free phenolic radicals on the wood fiber´s surface can be measured. Samples are in this case wood fibers, which on the one hand are incubated only with Laccase and on the other hand with the Laccase/Mediator system. At about 5 g wood fibers are given into Mc Ilvaine-buffer with a pH of 6,0. The Laccase activities, as well as the Mediator concentrations are varied (for example 10 U/ml, 50 U/ml, 100 U/ml Laccase and 10 mMol, 20 mMol Mediator) in order to attain an effective radicalization of phenolic connections on the wood fiber surface. The total quantity of buffer solution always averages 150 ml, independently of the Laccase and Mediator amounts. The incubation time is two to four hours. After completion of the incubation a small quantity of 0,5 to 1 ml is pipetted from the fibre suspensions into special quartz tubes. These tubes are kept in liquid nitrogen (-196 °C) until the measurements take place. This step is necessary in order to ensure that the enzyme reaction is stopped. The spectra are taken in a magnetic field from 3280 to 3480 Gauss at -196 °C.

Production of Medium Desity Fiberboards

The main objective in this research study is to produce medium density fiber boards (MDF) without any conventional bonding agents, e.g. urea-formaldehyde-resins. The wood fibers are treated only with a Laccase- or with a Laccase–Mediator buffer solution. As a reference woodfibers are pressed without anything that means only the pure fibers are treated with buffer. Afterwards the MDF-boards are taken to different mechanic-technological tests, in order to fullfill the required Norms (European Norms). The production of the MDF – boards takes place at the MDF – pilot plant of the Büsgeninstitute, University of Goettingen.
In the pilot-plant mixer the Laccase-Mediator buffer solution is sprayed on the wood fibers. Transported by a conveyer the fibers are transferred into the fiber bunker, where the fibers remain to incubate for two hours. After the incubation time the fibers are directed to the tube dryer unit with 100 °C to reduce the fibers moisture content down to round about 12 %. The the dried fibers are conveyed back into the fiber bunker and immediately strewed as fiber fleece on the form conveyer. Leaving the conveyer the fleece is pre-formed and transferred into the hot-press. After conditioning the produced fiber boards are grinded, formatted and tested.
In the following Table the most important manufacture parameters for the Laccase bonded fiber boards are represented.

Table 1: manufacture parameters of Laccase-bonded MDF-boards

raw material	Pine fibers
Structure	one-layer
size of board (L x W)	800 mm x 400 mm
Thickness	8 mm gross, 7 mm net
bonding percentage	100 % per atro fiber
molded density (set value)	800 kg/m³
hotpresse	220 bar, 4 minutes, 190 °C – 210 °C
bonding agent	Laccase, 100 U/ml; Laccase and Mediator, 100 U/ml and 10 mM, 2 h incubation

Results

GPC (Gel-Permeation-Chromatograpy)

As shown in Figure 1, the medium molecular weights (MW) of Laccase- and Laccase + HBA treated Ca-Ligninsulfonat (Wafex) are recorded under different laccase concentrations after 2 hours of incubation. With increasing Laccase concentrations the molecular weights of the samples Laccase and Laccase + HBA are also increasing.
The molecular weight of the "control-sample" remains constantly, because the Wafex is only solved in pure buffer solution. The difference of Laccase and Laccase-Mediator incubated Wafex is already significant at a concentration of 10 U / ml. The difference between these two at the beginning is about 10000 Dalton and with concentrations up to 100 U / ml the difference lies at about 70000 Dalton. This result leads to the conclusion that the use of the mediator HBA causes a higer repolymerisation, what means that much more "lignin-fractions" are formed which are able to polymerise again in further steps. This is an important fact for the pressing of MDF-boards because these "lignin-fractions" are in a reactive form.

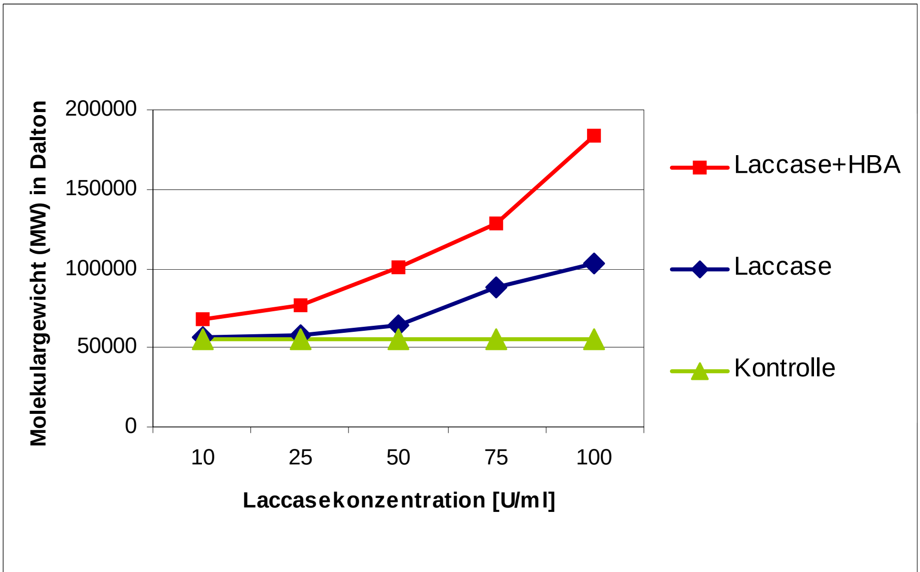

Figure 1: Medium molecular weight (MW) of Ca-Ligninsulfonate (Wafex) after 2 h of incubation

In an experiment with an incubation period of 24 hours samples of Wafex solutions (treated under three conditions) were taken after the first two hours, the 6^{th}, 12^{th} and 24^{th} hour and prepared for the measurements in the GPC-cromatograph. The concentration of Laccase in the incubation solutions amounts

100 U/ml, the concentration of Mediator 10 mM. The high level of the molecular weights of the samples of Laccase + HBA (Figure 2) is clearly visible. Already within the first hour the molecular weight increases up to 125000 Dalton. After two hours the maximum value of more than 180000 Dalton is achieved. After that time the molecular weights decrease slowly beyond 150000 Dalton to the end of the incubation time. Also the sample only with Laccase reaches its maximum value of 100000 Daltons after 2 hours. This value remains relatively constant for the rest of the incubation time. The fact that the maximum molecular weights are reached after 2 hours of incubation leads to the conclusion that under these experimental conditions both in the sample Laccase and at the sample Laccase + HBA no more "lignin-fractions" are generated.

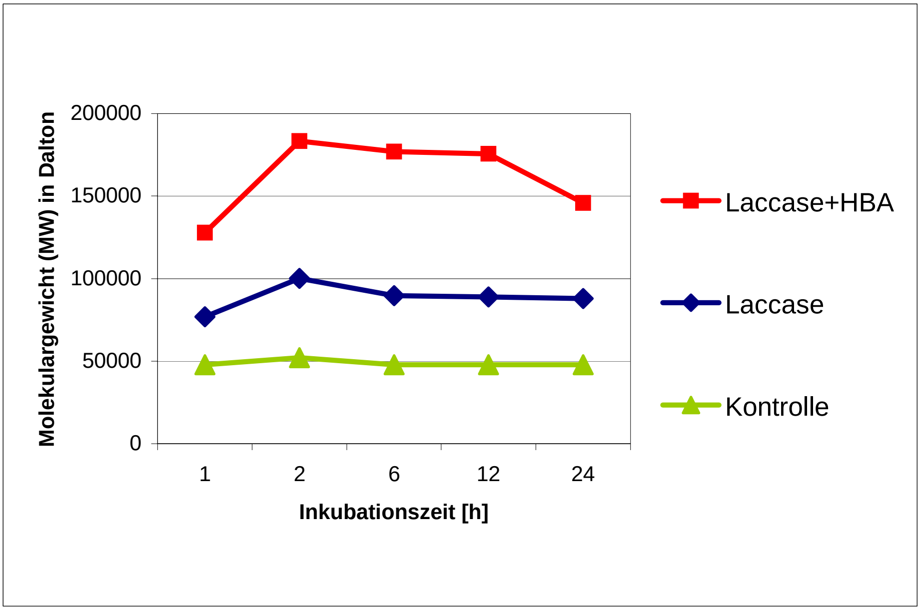

Figure 2: Medium molecular weight (Mw) of Ca-Ligninsulfonate (WAFEX) in dependence on the incubation time

Besides the treatment of Wafex with Laccase and the Mediator HBA all mediators (see chapter2.3) have been tested by using the GPC. As shown in figure 3 it can be recognized, that all maximum molecular weights of Wafex samples are listed, which have been incubated with 100 U / ml Laccase and 10 mM of each mediator for 2 hours. Noticable is the relative high value for HBA. The amount is like in the other experiments around 180000 Dalton. With the other Mediators it is not possible to reach this value. The mediators Methylsyringat and ABTS have the highest amount at 55000 Dalton. The lowest value in this figure is determined with Acetosyringone.

These results indicate that under these conditions HBA has the best potential, to react as mediator in conjunction with Laccase and thus to repolymerize the structure of the lignin.

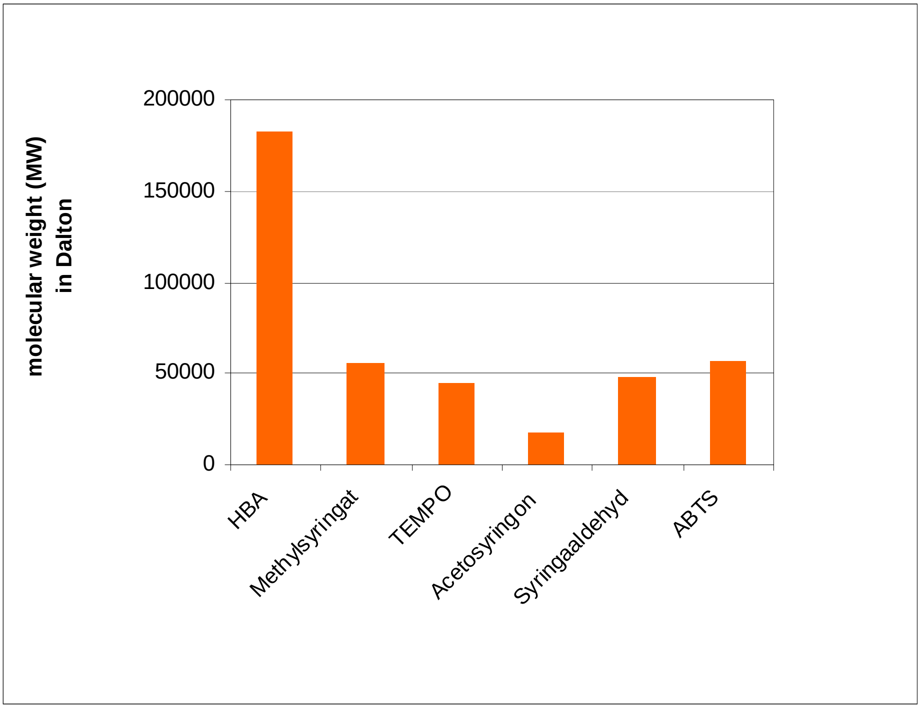

Figure 3: Medium molecular weight (Mw) og Ca-Ligninsulfonate (Wafex) with different mediators

ESR (Electron-Spin-Resonance Spectroscopy)

All spectra are recorded under identical conditions, each with a large scan (400-4400 G, displayed 500-4400 G), and small-Scan (200 G). With the wide scan it is checked whether any characteristical metal signals are available (e.g. Cu_2 +, Mn_2 +, Fe_3 +). The small scan is taken for the analysis of the organic radicals intensity.
The control spectum (“Kontrolle”) shows a strong Mn2 + signal (Figure 4). In the Laccase spectrum a strong type-2 Cu_2 + signal is significant, but no other metals are existing.

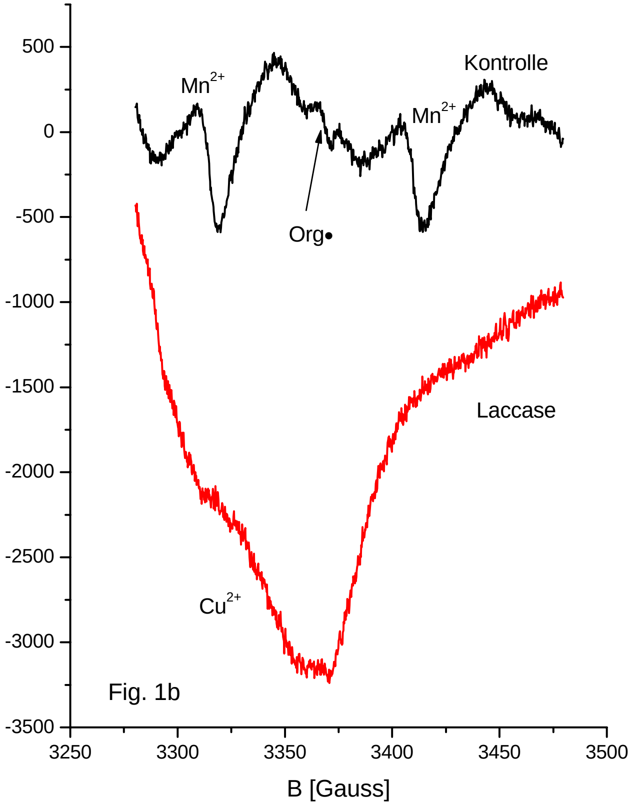

Figure 4: ESR-Spektra of wood fibers and Laccase

By comparing the four spectra it is visible that the organic radical between 3000 and 3500 Gauss rises significant with increasing Laccase concentrations (LS104 <LS1004 <LS1004a). At the same time the Mn-signal decreases (Figure 5).

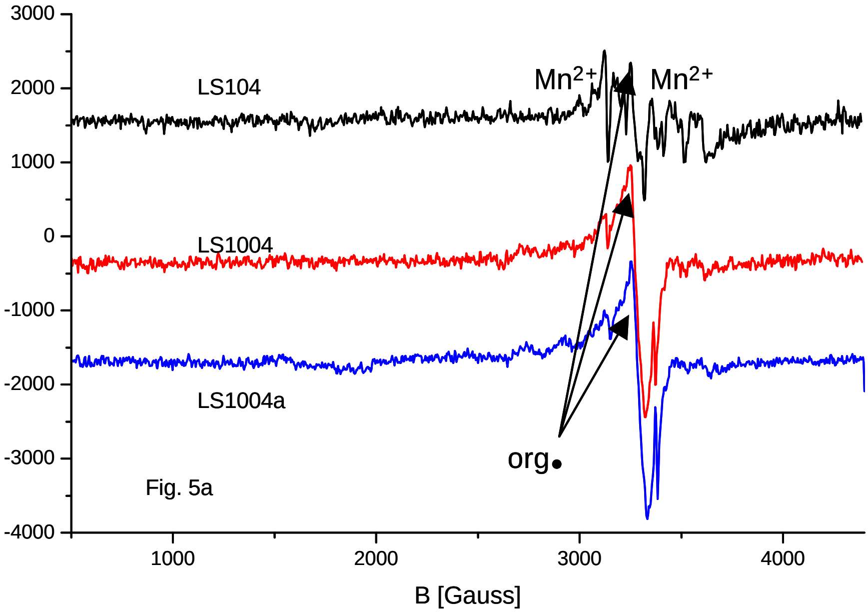

Figure 5: ESR-Spectra of wood fibers, incubated with Laccase

As seen in the last figure with Laccase incubated samples, the intensity of the organic radical (between 3000 and 3500 gauss) of the Laccase-Mediator samples are also raising with increasing enzyme concentration (Figure 6). Furthermore the Mn-signals (at about 3300 Gauss) and the Cu-Laccase-signals (3300-3500 Gauss) are increasing. In direct comparison of Laccase- and Laccase-Mediator-samples the intensities of the samples with mediator are significantly higher, which is determined by the radicalization on the wood fibre's surface.

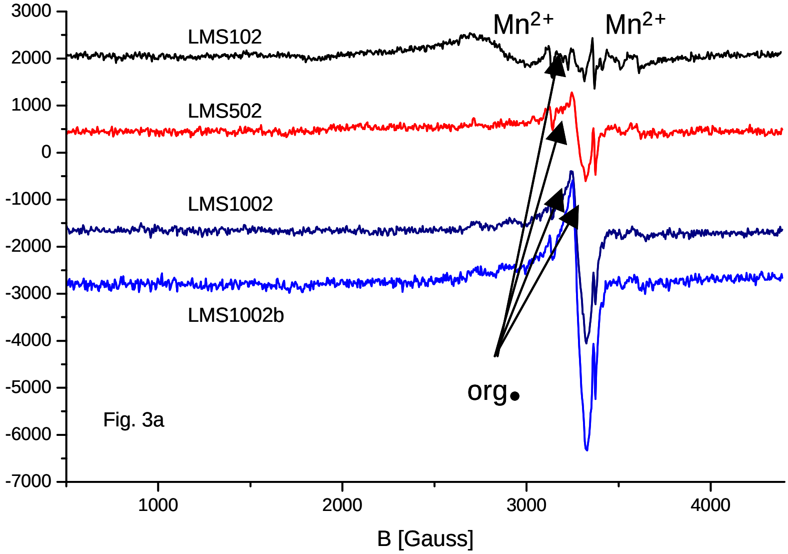

Figure 6: ESR-Spektra of wood fibers, incubated with Laccase and Mediator

The results, however, clearly coincide with other analysis results, in which much more potential for the enzymatical activation of the woodfibers surface is available by the use of mediators, particularly HBA, as by the sole incubation with Laccase is available.

Mechanic technological properties of the binderfree MDF-boards

The figures 7 and 8 show the results of the mechanic technological tested MDF-boards. The samples are control, Laccase incubated and Laccase-Mediator incubated MDF-boards. For the interpretation of the measured datas the characteristic values of the EN-Norms are used (GERMAN INSTITUTE FOR STANDARDIZATION, 1998) (see Table 2)

Table 2: MDF requirements for general purposes, for use in the dry part (GERMAN INSTITUTE FOR STANDARDIZATION e.V., 1998)

property	testing method	unit	nominal thickness (mm)								
			1,8 to 2,5	>2,5 to 4,0	> 4 to 6	> 6 to 9	> 9 to 12	>12 to 19	> 19 to 30	> 30 to 5	> 45
thickness swelling 24 h	EN 317	%	45	35	30	17	15	12	10	8	6
internal bond strength	EN 319	N/mm²	0,65	0,65	0,65	0,65	0,60	0,55	0,55	0,50	0,50
bending strength	EN 310	N/mm²	23	23	23	23	22	20	18	17	15
elasticity modulus in bending	EN 310	N/mm²	-	-	2700	2700	2500	2200	2100	1900	1700

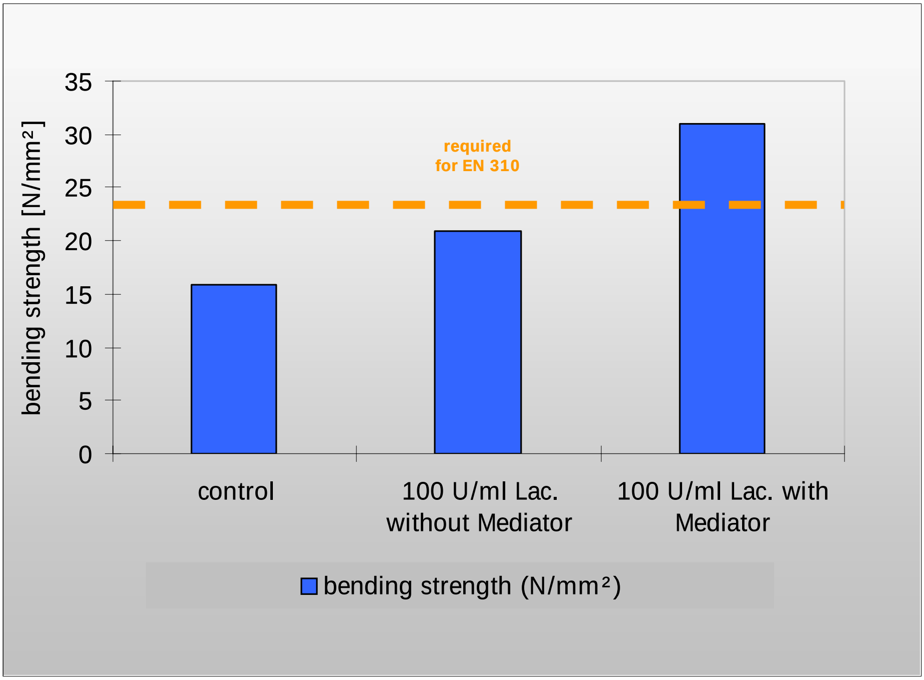

Figure 7: Bending strength of 8 mm thick MDF-boards, molded density 800 kg/m³

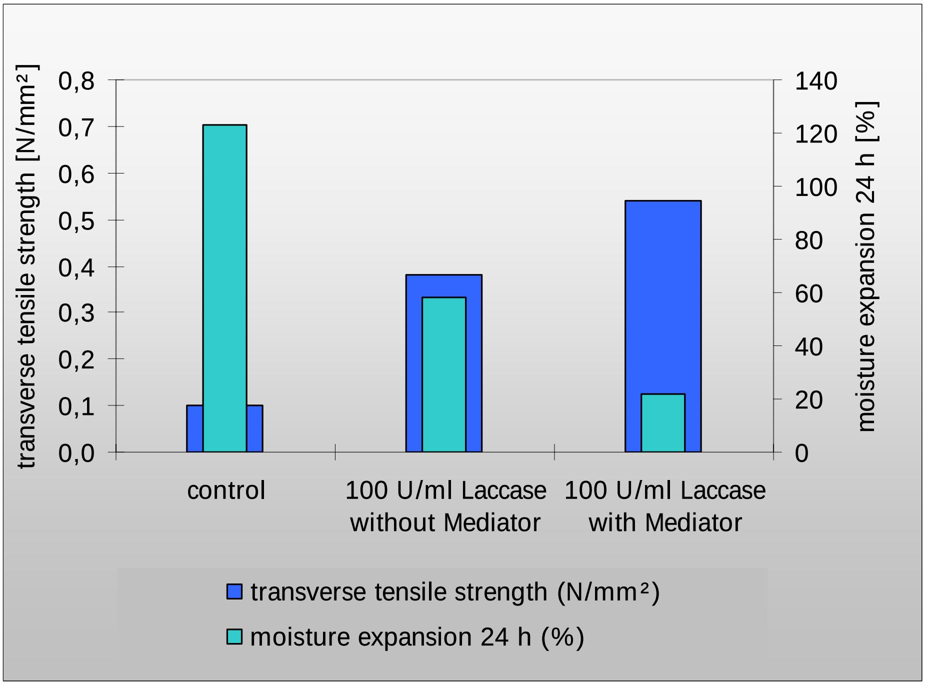

Figure 8: Transverse tensile strength and moisture expansion of 8 mm thick MDF-boards molded density 800 kg/m³

Both the bending and the tensile strength of the MDF-boards increase considerably by the use of the Laccase-Mediator-system (Figure 7 and 8). With a bending strength of about 33 N/mm² the Laccase-Mediator bonded MDF boards already fulfill the European standard. But the tensile strength with a value of 0.54 N/mm² is not yet high enough to reach the standard value of 0,65 N/mm². In the same time the thickness swelling of Laccase-Mediator bonded MDF boards is low and close to the required norm (17 %). In direct comparison the control samples (without any Laccase and/or Mediator) do not fulfill any standard. And also the Laccase-bonded samples neither reach the required values for the bending strength nor the the values for the tensile strength. The thickness swelling is to high to achieve the required value

Summary

The present work shows, that there is a high potential to activate wood fibers with enzymes and use them to produce medium density fiberboards. But in comparison to the conventional bonded fiberboards (for example formaldehyde

resin bonded) the enzyme bonded boards have lower qualities by testing the important mechanic-technological properties according the European Norms.
Therefore this research project is considered to achieve higher reactivity in the enzymatical activation by using Mediators, which operate as redox molecules between enzymes and lignin. Mediators are for example organic aromatic compounts, for example parabenes.
Several analytical tests have shown that the Laccase-Mediator-System effects a noticeable enhancement of the radical density on the wood fiber´s surface.
Laccase-Mediator bonded MDF-boards have higher mechanical-technological properties. So the European Norms are fulfilled by the bending strength. The transverse tensile strength has actually not yet been high enough to achieve the Norms. The values for the thickness swelling are low and are close to the required values in the European Norm. Therefore in future experiments these two lacks have to be clarified.
However, the results altogether lead to the conclusion, that Laccase-Mediator bonded MDF boards, under permanent improvement in their mechanical-technological properties, can be a suiTable alternative for conventional binders in the derived timber products industry.

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Surveillance of emerging arthropod-borne-viruses in wildlife species in Germany

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Abstract

In recent years, infection rates of tick borne encephalitis (TBE) in humans have increased considerably in Germany. In forest ecosystems, deer (*Capreolus capreolus* and *Cervus elaphus*) and especially rodents (*Apodemus spp*., *Microtus spp.* and *Myodes spp.*) could be important reservoirs for TBE and for other arthropod-borne ("arbo-") viruses.

The main objective of this project is to analyse whether infection rates of host species are density dependent, dependent on individual characteristics or influenced by climatic or habitat factors. Therefore, we aim at investigating the relationships of vole, mouse and deer abundances and physical conditions to their virus infection rates, to their infestation with ticks, to the tick infection rates and to climatic and habitat factors.

Sampling of ticks, voles, mice and roe deer, recording data on individual hosts and on indices of rodent population density is carried out in nine forest departments in late spring, mid-summer and early autumn in each of the three project years, respectively. Deer population densities are estimated in early spring. Ticks and blood from roe deer, rodents and ticks from rodents are sampled simultaneously at the same field sites. Number of ticks per host animal and age, sex and physical condition of the sampled roe deer are recorded in the field.

We dispatch the samples to our network partners for virus screening. By using presence/absence data of arbo-viruses in the studied animals and cell types, infection risks of cell types, voles, mice and deer will be calculated in relation to the local population density, the recorded biometric characteristics of the individual hosts, habitat structure and climatic factors of the study area. In this paper, we present preliminary results of the first sampling session.

Introduction

Arbo-viruses are transmitted to humans via an arthropod vector. In central Europe, the tick species *Ixodes ricinus* (L.) is an important vector of Tick Borne Encephalitis Virus (TBEV) (Family: *Flaviridae*) and several other viruses. TBEV can cause Tick Borne Encephalitis in infected persons: The majority (60-70 %) of humans bitten by an infected tick does not show symptoms whereas 20-30 % of bitten people show flu-like symptoms. Approximately 10% of infected humans suffer from meningitis and meningoencephalitis, which may result in permanent neurological deficits (3-10 %) and in death of infected persons (1-2 %) (Gold *et al.* 1992). Effective vaccination against TBEV is available but no specific treatment exists to prevent damages in the central nervous system (Gold *et al.* 1992, Pöllabauer *et al.* 2003, 2007). Since the aetiology of about more than 50 % of aseptic meningo-encephalitis cases is unclear, other neglected arbo-viruses [Eyach Virus, Tribec Virus, Lipovnik Virus, Erve Virus (Family: *Reoviridae*) and Tahyna Virus (Family: Bunyaviridae)] are suspected to cause this syndrome in humans.

In Germany, TBE is subject to registration at the federal Robert-Koch-Institute (Infektionschutzgesetz 2000) which allows specific monitoring of both geographic range and numbers of infections in humans.

Since the implementation of the infection-prevention-law in 2000, a significant increase in human infections per 100 000 inhabitants with TBEV was observed (from 2001 to 2006): $y = 0.0694x - 138.69$; $R^2=0.7649$; $P=0.023$ (calculated from Robert Koch-Institut 2007a). This can mainly be explained by increasing infection rates in high risk areas[1] and only to a lesser extent by range expansion of the virus (Robert Koch-Institut, 2007b).

Due to the increase of infection rates and the absence of specific treatments, means of preventing infections with the focal viruses are essential for reducing encephalitis related diseases and mortality. To formulate effective preventive measures, one clearly requires detailed knowledge of the ecology of the viruses in reservoir populations and of the specific mechanisms which drive infection risks in both wildlife host species and humans.

Reservoir studies

The focal arboviruses (TBE, Eyach, Tribec, Lipovnik, Erve and Tahyna Virus) propagate in vertebrate hosts. During viremia they can be transferred to other host individuals by bloodsucking ticks (Figure 1).

This horizontal virus transmission can be influenced by numerous factors, e.g. the ecology of different host species, tick ecology and sociology of humans, and is thus very complex. In this study, we mainly focus on the ecology of host species. However, the aims are numerous: (i) to identify specific reservoir hosts, (ii) to determine the area in which the specific virus is endemic, (iii) to define relative infection risks of wildlife host individuals and ultimately (iv) to define relative infection risks of humans. Specifically, we want to investigate whether infection risks of wildlife species with arbo-viruses are (a) dependent on population density of the specific host species or vector (b) dependent on individual characteristics of host species or (c) influenced by habitat, weather or climatic conditions.

In this paper we briefly present the research project including the applied methods and give an overview on the first sampling session which took place in September 2007.

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[1] High risk areas are defined as: Administrative district in which the number of recorded TBE cases within the period 2002-2006 was significantly ($p<0,05$) higher than the number of cases one would expect at an incidence of one case per 100000 inhabitants (Robert Koch-Institut 2007b).

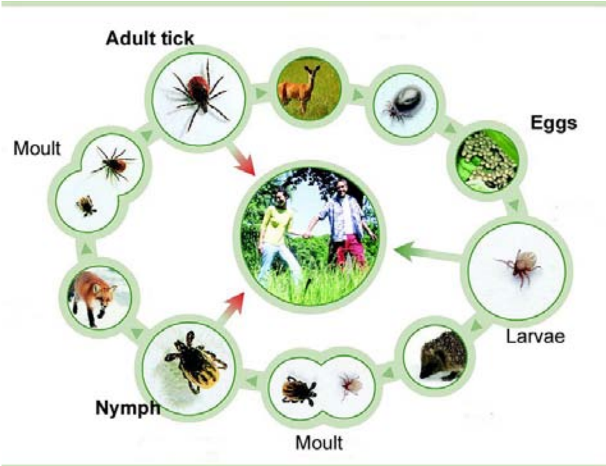

Figure 1: Life cycle of the tick Ixodes ricinus. (Figure adapted from www.zecken.de)

Figure 2: Location of the study area indicated by a larger red dot. The smaller red dots indicate study sites of our network partners. Figure adapted from: www.deutschland.de/images/aeb/karte.de.gif

Material and Methods

The project started in July 2007 and will run for at least three years. The field data sampling is scheduled as follows: Estimation of deer density will be carried out during one week in March. In May, July and September we will spend two weeks each in the study region to sample rodents and ticks on rodents and estimate local rodent densities. During the same period, we will also collect blood and ticks from deer killed by hunters.

Study sites

We selected nine different forest departments which are located in three different forest districts in the southern part of Hesse. The forests are located within high risk areas for TBEV (Robert Koch-Institute 2007b). Mean size of the study sites is 1150 ha (range: 520 – 1710 ha). In all nine forest departments, roe deer (*Capreolus capreolus*) is abundant. In three forest departments, red deer (*Cervus elaphus*) is also common.

Rodent trapping

In each forest department, we placed two trapping grids (Figure 3) on randomly selected intersections of a systematic 1 km x 1 km grid which we superimposed over the entire study area. We defined the coordinates of the intersection as the position of the southern- and western-most trap. Each grid was established by placing 36 Sherman live traps in a 50 m x 50 m square, whereas perpendicular and horizontal distances between neighbouring traps were 10 m. We used fresh apple to bait rodents and placed hay, chipped wood or foliage into the traps to provide nesting material and to enhance survival of trapped mice. Trapping grids were operated for four consecutive nights and were controlled once a day.

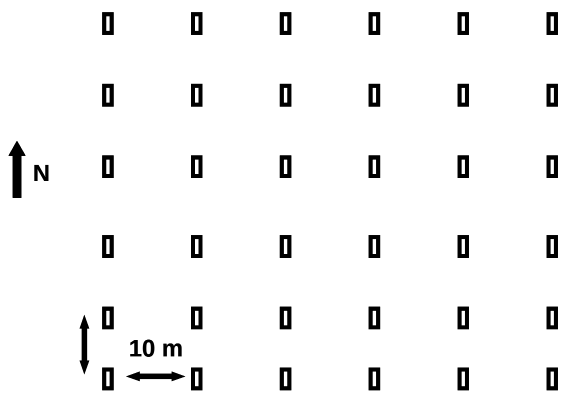

Figure 3: Schematic presentation of a trapping grid showing the relative position of 36 Sherman live traps.

Figure 4: Bank vole (Myodes glareolus). Photo: Christian Kiffner

Caught rodents were collected and sampled according to standardised protocols: Investigators wearing rubber gloves controlled the grid lines and transfer rodents from the trap into a plastic bag, labelled the bag with the grid and trap station number and transported the rodents to a central processing station. When handling the rodents, investigators wore rubber gloves, respirators and face shields to avoid infections with Hantavirus (Family: Bunyaviridae) (Mills *et al.* 1999). Rodents were identified to species level and then killed by filling the bag with CO_2. Eventually trapped non-target animals were set free immediately. A standardised protocol was then used to collect the following data: capture number, trap station number, species, age (subadult, adult), mass (g), length of body (cm), length of tail (cm), reproductive status (males: position of testes, females: description of nipples) and presence of wounds. All rodents were then carefully screened for ticks by combing the fur with a bug comb and by intensively searching the ears and other exposed sites of each individual. All detected ticks were transferred in sterile tubes which were labelled with the unique capture number of the rodent. Ticks were then stored at 4°C and rodents in dry ice at -80°C.

Density estimation of rodents

In contrast to virus reservoir studies in North America where mark-recapture-studies are commonly used (Mills *et al.* 1999) we applied a removal method because the entire bodies of rodents are required to detect viruses in different cell types.
Rodent density will be estimated by the "refined-100-trap-night-index" which corrects for non-functioning traps (Krüger, 2002). Simultaneously, we will apply the "catch-per-unit-effort" method (Borchers *et al.* 2002) and compare both methods with each other.

Deer Sampling

During the field study periods, local hunters were instructed to take blood samples from the fresh carcass. Deer and blood samples of deer were stored in six different central cold storages of the forest districts which were controlled by the research team once a day. The head and neck of each deer carcass was intensively screened for tick infestation by two observers for a maximum of 30 minutes Ticks were removed with tweezers and tick-hooks and were collected - separated by host individual, tick development stage and sex of adult ticks - in sterile tubes which were then stored at 4 °C.
We estimated the age of roe deer by tooth wear (Mysterud & Østbye, 2006). Blood samples of hunter killed deer were centrifuged for ten minutes at 2500 rotations per minute (rpm). Thereafter, the supernatant (blood serum) was pipetted in a sterile and properly labelled tube. The blood serum was stored at 4 °C until serologic screening.

Figure 5: Sampling ticks from a roe buck (Capreolus capreolus). Photo: Martin Scholz

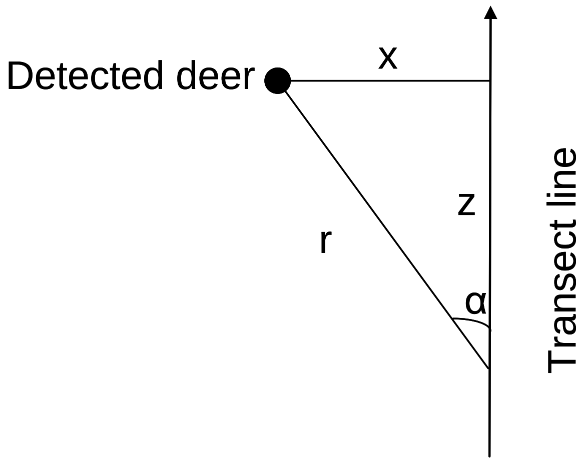

*Figure 6: Computing perpendicular distances of line transect data: When measuring the distance r and the angle a, one can compute the perpendicular distance by x = r * sin (a) (Buckland et al. 2001).*

Estimation of deer density

We intend to estimate both roe deer and red deer densities at the study sites by conducting line transect surveys at night. In early march of each year (2008, 2009 & 2010), we will drive along 20 systematically arranged transects in each forest department. With the help of spotlights - and possibly a thermal imager - two observers will search for deer on and next to the transect (Ward et al. 2004). Apart from recording species, sex and age class of the observed species, we will measure the perpendicular distance between the initial position of the deer and the transect (Buckland *et al.* 2001) to model detection functions of deer species. By incorporating covariates such as observer, vegetation type, study site, deer species and time of the observation we aim at modelling site, species, observer, time and vegetation specific detection functions (Buckland *et al.* 2004). Modelling of detection functions and density estimates will be performed by the software package DISTANCE 5.0, Release 2 (Thomas *et al.* 2006).

Weather and environmental factors

We will assess weather and climatic data such as precipitation and temperature of the current and previous year from meteorological stations of the German weather service and relate these data to population dynamics of rodents and abundance of ticks on host species and in cooperation with the Robert Koch-Institute and local health authorities to infection rates in humans. Additionally, we will acquire data on habitat structure, acorn and beech-nut yield of previous and current years from the forest administration and relate these data to tick, rodent and deer population dynamics (Ostfeld *et al.* 2006).

Preliminary Results

Rodents

During the first sampling period in September 2007, we operated 2628 trapping nights (one trapping grid was operated for five nights). In approximately 9 % of the trapping nights, traps were malfunctioning, leading to a total of 2412 corrected trap nights. Pooling all 18 trapping grids, we collected 97 rodents, giving a mean trapping success of 4 %, whereas trapping success was highly variable between locations ranging from 0 to 21 rodents per trapping grid.
We collected a total of 377 ticks from the caught rodents, whereas 99 % of all ticks were in the larval stage and only 1 % in the nymph stage. Only four rodents carried a single nymph each. On average, larval tick load per rodent was 5 ticks whereas the range of larval infestation ranged from 0 to 24 larvae per individual rodent.

Deer

During the first field data sampling period we investigated a total of 23 roe deer and 1 red deer of which we obtained blood samples and collected ticks.

Table 1: Tick distribution on roe deer (n=23). Total number of collected ticks, separated by development stage and attachment sites of ticks and mean tick infestation rates per roe deer including standard deviation (SD).

	Larva	Nymph	Adult ♀	Adult ♂	Total
Total number on head	45	432	65	26	568
Mean (SD) per animal on head	2 (6)	19 (11)	3 (4)	1 (1)	15 (14)
Total number on neck	38	17	115	38	208
Mean (SD) per animal on neck	2 (7)	1 (1)	5 (5)	2 (2)	9 (11)
Total number on head & neck	83	449	180	64	776
Mean (SD) per animal on head & neck	4 (13)	20 (11)	8 (7)	3 (3)	34 (27)

Average tick burden amounted to 34 ticks per roe deer whereby variability among individual hosts was high (Table 1). More than 55% of all collected ticks were nymphs attached to the head of the deer and overall nymphs made up to 58% of all collected ticks. Surprisingly, the sex ratio of adult ticks was strongly (three folds) skewed towards female ticks.

Laboratory Analysis

Up to date, no serologic or microbiological analyses of the samples have been completed. Rodents are stored in the Virology of the Clinical Centre of the University of Göttingen at -80 °C and ticks of rodents and deer as well as blood of deer are stored at 4 °C. Samples will be processed at the Institute of

Microbiology of the Bundeswehr, Munich, in the Virology of the Clinical centre of the University Göttingen and at the Robert Koch-Institute, Berlin.

Outlook

Upon receiving the data on virus infections in the host species (rodents and deer), we will conduct a logistic regression to identify significant variables which might explain virus infection rates of the vectors and host species. Logistic regression models investigate the influence of multiple factors on the distribution of dichotomous properties (Hosmer & Lemeshow 2000).

In this particular case, we will explore whether infection rates of individual rodents and deer are influenced by the population density of the host species, by the tick burden of different tick development stages on the specific host, the tick infestation rates with the specific viruses, by the species, the age, the sex or the condition of the host.

Similarly we will analyse factors influencing tick infestation rates with the viruses (presence and population densities of virus specific wildlife hosts), and underlying factors which might drive both population dynamics of host species (e.g. availability of food resources) and tick vectors (habitats, weather conditions, climate change) of the focal viruses.

Acknowledgements

We thank the Federal Ministry of Education and Research for financial support (BMBF-1363120: Emerging arthropod-borne-viral infections in Germany: Pathogenesis, diagnostics and surveillance). We sincerely acknowledge K. Ehlmann, M. Ksinsik, C. Lödige and M. Scholz for supporting the team during the field sampling period.

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A concept for the calculation of financial compensations caused by changing the forest management strategy – particularly with regard to water protection

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Introduction

There are mainly environmental objectives like nature conservation, water protection or recreational aspects that lead to a conversion of pure coniferous stands and promote near to nature forest management regimes, preferring native, non-coniferous tree species with continuous crown cover and natural regeneration. These objectives can often only be realized by changing the forest management regimes. So far mainly institutional regulations are established in order to achieve these goals. However, in Germany there is a strong political intention to encourage contract-based forest management: forest owners get a financial compensation for the losses of the changed forest management regime. Such compensations are commonly paid in the German agricultural sector but still lacking in forestry.

When managing the forests under social convenience forest enterprises are faced with economic losses. With regard to practical experience in forestry, there is a considerable lack of information about the economic consequences.

To estimate these losses related to changed silvicultural treatments, a calculation scheme based on the annuity method has been developed and figures have been calculated for different tree species and age classes. The determined annual timber production value per ha and year is documented in Tables and could be used to evaluate typical changes of forest management like the change of tree species.

Standardized annual timber production values for different tree species, yield classes, management schemes etc. can be helpful to estimate the financial compensation of forest land owners when changing the management strategy. Therefore, the scheme turns out to be an important tool for contract-based forest management.

Methodology and Data

In the following an approach to establishing a practical method for appraising the financial losses of forest-land owners when changing their forest management regime will be describe.

Only the changes in the long-term “biological production” are considered. They can be characterized as the changes in the silvicultural treatment of existing forest stands. Financial losses, which might arise from changing “technical production”, will not be considered. They might be very different, e.g. manual felling instead of harvester felling, skidding by horse instead of using a forwarder, manual debarking instead of the application of biocides etc., however, most of them could be calculated quite easily on the basis of additional costs.

A Concept of Economic Valuation

The procedure of economic valuation according to the principle of the capitalized earning value usually follows four general steps (see Figure 1):

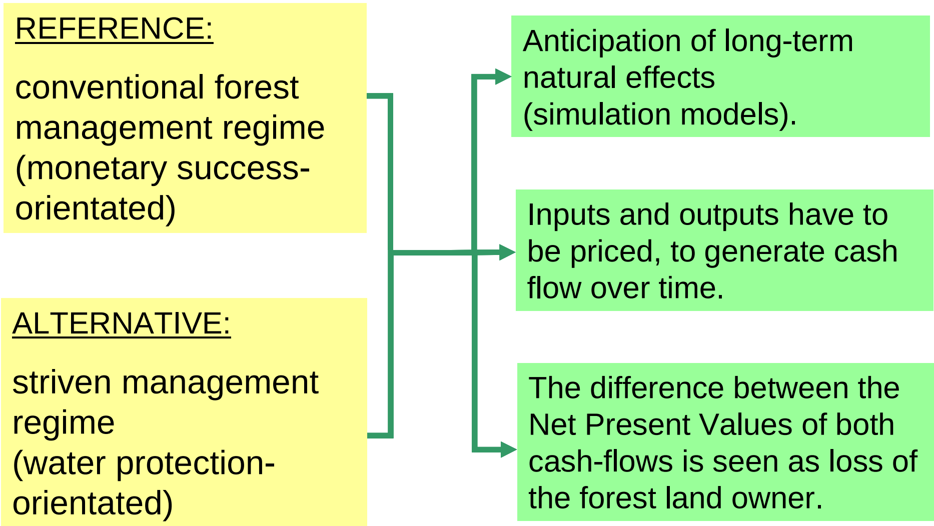

Figure 1: Concept of Economic Valuation

1. The management alternatives have to be developed. The alternative striven for is usually a water protection oriented regime, whereas the reference is normally a conventional, economic orientated management regime. Thus, retaining the current forest management cannot be seen as a suiTable reference in general. For example, if a change of tree species (from European beech to Douglas fir) leads to a bigger economic success, this regime has to be taken as the reference for the economic valuation (Moog and Brabänder, 1994, p. 47). However, the reference must have financial advantages and should also be aspired to in practise.
2. The anticipated long-term natural effects of both reference and alternative have to be exposed. By using simulation models, inputs and outputs over time have to be estimated in physical quantities such as harvest volumes, hours of workload etc.
3. Natural inputs and outputs have to be priced to generate the cash flow over time for both alternatives.
4. The difference between the cash flows of both alternatives builds up the basis for the financial valuation. Here, the net present value (Eq. 1) of both alternatives is usually determined by using dynamic investment calculations.

$$NPV = \sum_{t=0}^{n} \frac{(R_t - E_t)}{(1+i)^t} \qquad (1)$$

NPV:	net present value
t:	point in time (years since beginning of the accounting period)
R_t:	revenues at t
E_t:	expenditure at t
i:	interest rate

The difference between the net present values of both alternatives is considered as monetary loss to the forest-land owner. This scheme is generally accepted, as it represents a conclusive and consistent economic concept by which to evaluate the change of forest management regimes. However, some disadvantages in practical handling occur:

- The anticipation and simulation of long-term natural effects of different management regimes normally requires sophisticated computer applications and a high amount of individual data has to be gathered.
- If compensatory payments have to be determined, there is a strong need for objectifying (Moog and Knoke, 2003). This requires the depiction of typical instead of individual situations.
- The comparison of different net present values is problematic if the valuation periods differ between both alternatives. This is normally the case when conifer forests have to be replaced by broadleaf trees because of the different rotation periods of both alternatives.

Valuation Based on the Annuity Method

In the following, a valuation concept based on annuities as a yearly earning rate is developed instead of the Net Present Value. It appears to be advantageous to base the valuation on standardized annual payments, both for the purpose of evaluation and the communication of the results. By using the so called annuity formula (see Eq. 2) the unsteady cash flow of an investment can be transferred into a constant annual but economically equivalent cash flow.

$$a = \sum_{t=o}^{n} \frac{(R_t - E_t)}{(1+i)^t} \cdot \frac{i \cdot (1+i)^n}{(1+i)^n - 1} \qquad (2)$$

a:	annuity (equal annual payments)
n:	length of accounting period (years)

The annuity can be interpreted as a constant series of equal annual payments. In contrast to the net present value, a capital figure related to a key date, the annuity is a time period related value. Based on the same premises as the net present value method, it is ascertained as a further objective criterion. In contrast to net present value as a current capital value, annuity can be seen as a yearly contribution margin. The annuity corresponds with the yearly constant amount of money which can be removed annually as profit contribution during the investment period under "capital maintenance". In contrast to the net present value, which represents the total surplus of an investment at the decision time, the annuity specifies an annual average surplus during the investment period. Net present value and annuity generate different information but both values are transformable into each other and insofar formally equivalent. With respect to the practical application of these two objective criteria, Götze and Bloech (2004, p. 96) pointed out that the annuity has advantages in relation to interpreTableility compared with the net present value. It represents a specific form of an "average annual profit" and as such it is easier to interpret than the net present value.

Here the ascertained annuity of forest production will be termed as "annual timber production value". This item expresses that the value is directly connected with the forest-wood production (also the planting, tending and harvesting of trees). The "annual timber production value" equates to a yearly contribution margin from silvicultural (biological) production including cost of capital before deducting annual fixed costs.

By applying the annuity equation (2) to the entire forest rotation length (u) from stand establishment to final cutting the formula gets following notation:

$$a_u = \left(\frac{A_u}{(1+i)^u} + \sum_{a=1}^{u} \frac{D_a}{(1+i)^a} - c \right) \cdot \frac{i \cdot (1+i)^u}{(1+i)^u - 1} \tag{3}$$

u:	rotation length
A_u:	clear-cut revenue net of harvesting cost in year u
D_a:	thinning revenue net of harvesting cost in year a
c:	plantation costs

The Data Base for the Examples

The following calculations are based on a data pool which gives a simplified description of good growing conditions in Northern Germany:

- With respect to the general application, standard yield Tables for Norway spruce (1. yield class, moderate thinning grade) and European beech (1. yield class, moderate thinning grade) are the basis for modelling the natural production process (Schober, 1975); however the average stand diameter is adjusted by using the Richards-Function to the present silvicultural situations (Wollborn and Böckmann, 1998). As a consequence the underestimation caused by the convential yield Tables will be avoided and conformity with today's silviculture circumstances will be guaranteed.

- Timber prices and logging costs are derived from average values of the state forest of Lower-Saxony.
- Plantation costs are fixed at 2,250 EUR/ha for Norway spruce and 5,000 EUR/ha for European beech. Calculations are done with and without plantation costs because of natural regeneration or financial subsidies provided by the state.
- Silvicultural treatments are assumed at 10 and 20 years for both tree species with costs of 250 EUR/ha per intervention.
- All other costs are considered as fixed costs and omitted based on the assumption that they occur independently from management regime.
- The interest rate is fixed at a real marginal rate of 1.5%.

All these data are assumed to be constant over time.

Results

Based on the data described, the cash flow of managing Norway spruce (see Figure 2) was calculated. This figure also shows the development of stumpage values over time.

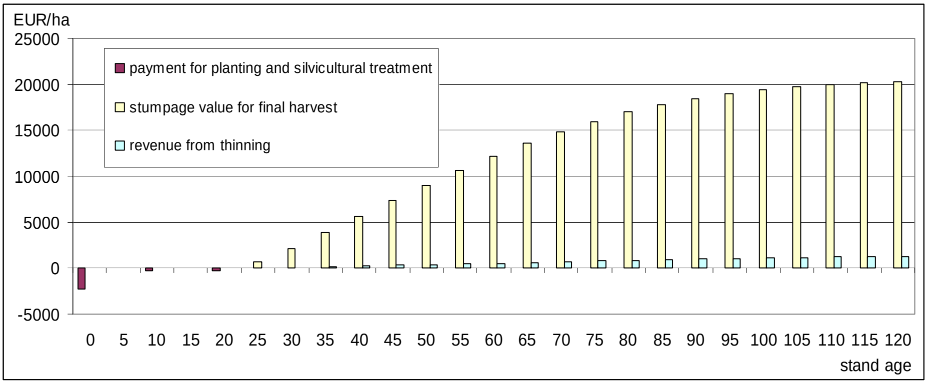

Figure 2: Norway spruce (1st yield class, moderate thinning grade): Payments for stand establishment and silvicultural treatments, revenues from thinnings and stumpage values of standing volume for final harvest.

On the basis of the discontinuous cash flow from plantation to final harvest, the annual timber production value was calculated using annuity formula (see Eq. 3). This calculation contains all revenues and expenditures from stand establishment to final harvest. For Norway spruce with an 80-year rotation (based on the data described above), the annual timber production value amounts to 145 EUR/ha/year (see Table 1).

Table 1: Norway Spruce (1st yield class, moderate thinning grade): Annual Timber Production Value in EUR/ha for different stand ages and lengths of consideration period.

	bis Alter…: jährlicher Holzproduktionswert in EUR/ha/Jahr (Fichte I. Ekl.)											
von Alter…	10	20	30	40	50	60	70	80	90	100	110	120
0 (mit Kulturkosten)	-267	-154	-54	22	64	85	94	96	95	92	88	84
0 (ohne Kulturkosten)	-23	-23	40	97	128	142	146	145	141	136	130	125
10		-23	79	151	182	192	192	187	179	170	162	154
20			198	260	274	270	257	244	229	215	202	191
30				332	321	302	279	258	237	219	203	190
40					309	283	255	231	208	189	171	157
50						253	222	197	172	152	134	119
60							186	162	136	116	98	83
70								133	105	85	66	52
80									73	55	37	22
90										34	14	0
100											-9	-21
110												-35

The Annual Timber Production Value cannot only be used for the entire production cycle from stand establishment to final harvest but it is also possible to calculate the corresponding amount for shorter time periods (see Table 1). This approach corresponds with the ongoing decision process during the forest production cycle. The forester has to decide whether to divest capital by harvesting the standing volume or to invest capital in the stumpage value by leaving the stand untouched to continue forest production. Let us for example look at a spruce stand in the decade from 70 to 80 years. At the beginning of the decade (see Figure 2), the stumpage value of about 14,800 EUR/ha is invested in forest production. Five years later about 800 EUR/ha and ten years later about 850 EUR/ha are gained from thinning and at age of 80 years the harvesTable stumpage value has increased to 17,000 EUR/ha. Using real interest rate of 1.5%, this discontinuous cash flow is equivalent to an annual timber production value of 133 EUR/ha/year for the decade from 70 to 80 years as shown in Table 1. For practical purposes, it is favourable to report the figures for the annual timber production values for different tree species etc. in Tables like Table 1. The first column shows the stand age while the first row specifies the stand age at the end of the considered time period.

The Appraising the Financial Losses when Changing the Forest Management Regime

In the following, it will be shown how these annual timber production values can be used to appraise the financial loss of four typical changes in the forest management regime when water protection objectives are followed.

Forest management can affect the quantity and quality of water. One main silvicultural measure which has an impact on the water is the conversion of coniferous trees which are more productive but not endemic, to near-to-nature but less productive broadleaf trees. This change of tree species influences forest production until the requested species reaches maturity. In the majority of cases for establishment of broadleaf trees initial plantation is necessary.
The calculation of financial losses when changing from spruce to beech can be realised by three different approaches.

Approach A:

Reference: Forest management regime with Norway spruce would achieve an annual timber production value of 145 EUR/ha/year, considering the optimal rotation length of 80 years (see Table 1).

Alternative: Under the given conditions forest management regime with European beech would gain an annual timber production value of -2 EUR/ha/year, considering the optimal rotation length of 120 years (see Table 2).

Financial loss: The difference between the annual timber production value of the two species amounts to 147 EUR/ha/year during the entire production length of European beech.

Table 2: European beech (1st yield class, moderate thinning grade): Annual Timber Production Value in EUR/ha for different stand ages and lengths of consideration period.

	bis Alter…: jährlicher Holzproduktionswert in EUR/ha/Jahr (Buche I. Ekl., Wertabfall)														
von Alter…	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
0 (mit Kulturkosten)	-566	-315	-225	-181	-133	-101	-76	-54	-36	-21	-10	-2	-6	-11	-16
0 (ohne Kulturkosten)	-23	-23	-17	-13	10	26	40	54	66	76	83	88	82	74	68
10		-23	-13	-9	21	41	58	73	87	98	105	110	102	93	85
20			0	0	41	63	82	99	114	125	133	138	127	115	105
30				0	67	92	112	129	145	156	164	167	153	138	125
40					145	149	162	175	189	199	205	206	187	167	150
50						152	172	189	205	215	221	221	196	171	151
60							194	211	228	238	242	240	207	176	151
70								231	250	258	259	254	211	171	141
80									272	274	271	262	205	155	119
90										277	271	258	181	120	77
100											265	246	138	63	16
110												223	59	-26	-73
120													-131	-182	-205
130														-241	-252
140															-264

Approach B:
Taking this extremely long time span into account, a different approach (B) seems to be more suiTable for practical purposes. This approach is based on the consideration that - despite the higher average productivity of Norway spruce - it is advantageous to continue with European beech production when an existing beech stand has already reached a certain age. Therefore, we have to determine the age of a European beech stand from which the annual timber production value of beech is equivalent to the average annual timber production value of spruce. Beyond this age, the beech stand does not cause any financial disadvantage anymore. Thus, the losses accumulated up to this age have to be determined. The following example illustrates this approach.
Reference: The annual timber production value of the Norway spruce management regime is 145 EUR/ha/year considering the optimal rotation length of 80 years (see Table 1).
Alternative: Once a European beech stand reaches the age of 20, the average annual timber production value is 138 EUR/ha/year until its optimal rotation length of 120 years, which means that the annual timber production value is almost equivalent to Norway spruce for the period under consideration from plantation to the end of rotation time (145 EUR/ha/year). However, up to this age (the first 20 years), European beech has a negative annual timber production value of -315 EUR/ha/year (see Table 2).
Financial loss: For the first two decades, the difference of the annual timber production value between the two species amounts to 460 EUR/ha/year. Once having past this period no more losses arise for the forest owner. From 20 years of age onwards the European beech stand is no longer disadvantageous when compared to a newly established Norway spruce stand.

Approach C:
In the case where plantation costs of beech are refunded to the forest owner in the form of subsidies (approach C), the average annual net surplus rises noTablely. For the first 20 years of beech (see Table 2), the negative annual surplus is reduced to -23 EUR/ha, however, the average annual timber production value of 145 EUR/ha for spruce production is forgone. Therefore, the loss of future earnings still equates to 168 EUR/ha for the first 20 years. It is important to note, that even when plantation costs for European beech are completely refunded a financial loss is still incurred which needs to be compensated.

It can easily be shown (see Table 3), that these three different approaches (A, B, C) lead to almost the same net present value. The differences are only caused by truncation and, thus, the three different approaches can be regarded as equivalent from an economic view point. However it is recommended that the approaches B and C should be prioritised in practice due to their shorter timeframe.

It is an important result of these examples that even complete refunding of plantation costs for European beech still leads to financial losses for which the forest owner has to be compensated.

Table 3: Three different approaches (A-C) to calculate the financial losses, when the tree species is changed from Norway spruce to European beech

Approaches	Annual Financial Loss (EUR/ha/year)	Length of period (years)	Interest Rate (%)	Present Value of Financial Loss (EUR/ha)	Refunding Plantation Costs (EUR/ha)	Financial Loss (EUR/ha)
A	147	120	1,50%	8158		8158
B	460	20	1,50%	7898		7898
C	168	20	1,50%	2884	5000	7884

Conclusions

It was the objective of this paper to present a feasible method for providing a transparent basis for the appraisal of the financial losses when the forest management regime changes. We replaced the net present value by the annuity as economic objective criterion. This value we called annual timber production value. This approach provides many advantages:

- The annuity method is a consistent procedure that corresponds to the methods of the dynamic investment theory.
- The calculated annual timber production value can be easily interpreted as annual gross margin of the timber production.
- These annual timber production values can be Tableulated for different tree species, yield classes and management regimes etc. Thus, easy application is guaranteed.
- The conversion of annual payments into present values is possible and can easily be achieved. This is important when a one-time payment is stipulated.
- The Tableulated annual figures can easily be compared with other annual payments, for example from the agricultural sector.

It is assumed that the approach described will be very helpful to appraise the economic losses of forest land owner and to determine the minimum price of compensation payments. However, some disadvantages remain which deserve further comment:

- Valuation based on annual timber production values and the terminology is not common and as such foresters are unaccustomed to the terms applied.
- The premises of the annuity method must be given. In particular this means that a uniform interest rate needs be used for capital investment and also for

procurement of capital. This premise is plausible when the calculation concerns a larger, sustainable forest enterprise which has flexibility regarding capital tied up in stands and which is able to commit capital on a short term basis when harvests fail and release capital during bumper harvests.

- Standardised Tables might be interpreted as true values and the underlying assumptions and conditions could be ignored. There are many assumptions in the evaluation, e.g., concerning the production model, the prices and costs and the chosen interest rate. All of these have to be proven before applying the data.
- The valuation only covers the objective of economic success as far as it results from timber production. Other objectives and non-timber outputs are not taken into account. Also risk is not included in the calculations.

All in all this paper deals with the description of a consistent approach to appraise financial losses when changing the forest management regime. Thereby, yearly values of the forest wood production, here termed as annual timber production values, come to the fore.

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Production of innovative hemp based three-layered particleboards with reduced raw densities and low formaldehyde emissions

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Abstract

By partly replacing the commonly used wood (pine, spruce, beech) for the production of wood based panels by hemp we want to find a substitute for wood on the one hand and to achieve lower densities in the produced boards on the other hand. The regular density of three-layered particleboards is about 650 kg/m^3. By the utilisation of hemp with its lower own weight we want to realise densities of 400 kg/m^3 and lower. This would be very important for the wood based panel industry because the amount of wood required by this industry is no longer available or too expensive. The increase of the thermal utilisation of wood with low quality and/or low age leads to a supply shortfall for the particleboard and Medium Density Fibreboard producing companies. Hemp is an annual plant the can be produced in huge amounts during a very short time. By using hemp in combination with the commonly used wood for the production of wood based panels the companies could be sure of an adequate supply with wood and they could satisfy the growing demand for wood based panels with low densities. Another quite interesting development for the wood based panel industry that we want to achieve in line with his project is to reduce the formaldehyde emissions of urea-formaldehyde-, melamine-formaldehyde- or phenol-formaldehyde-resin bonded wood based panels. By using pure natural bonding agents and mixed condensates – a mixture consisting of natural bonding agents and conventional resins – we want to decrease the formaldehyde emissions of the wood and hemp based three-layered particleboards. As natural binders we mainly want to test different kinds of proteins and starches.

Introduction

In recent years the price for wood, especially for the so called "industrial wood" and wood of low quality, which is required in huge amounts by the wood based panel industries, increased enormously. This kind of wood is the major ingredient (80 %) of the produced wood based panels like three-layered particleboards, medium density fibreboards, oriented strand boards, etc. The missing 20 % in the wood based panels are resins, hydrophobic substances, water and other additives. Due to the increased price for wood the price for the wood based panels increased in the recent years, too. Within the last years the price of industrial wood increased about 23 % (VEREIN DER HOLZWERKSTOFFINDUSTRIE, 2007).

The thermal utilisation of wood gained in importance in the last years based on the steadily increased oil and gas prices. Mainly wood of low quality and small dimensions is sold for thermal use mainly to pellet and briquette producing companies. In the next years the price for gas and crude oil will still increase so

that a thermal utilisation of wood will gain more and more in importance in next years and the price for wood will increase, too. Based on this situation the forest agencies are able to achieve higher prices for this kind of wood that was used in earlier years by the wood based panel industries. For the wood based panel industries it is not possible to pay this high price for this kind of wood because at least the price for the produced panel boards would be too high.
The German Wood based panel industry produced approximately 60 million m^3 of particleboards, medium density fibreboards, oriented strand boards plywood and insulating boards in 2005 as shown in Figure 1 (VEREIN DER HOLZWERKSTOFFINDUSTRIE, 2006, EUROPEAN PANELBOARD FEDERATION, 2007). Round about 30 % of the complete European wood based panel board production is manufactured in Germany. This shows that a substitute for wood must fulfil a lot of requirements. Mainly it has to have properties which are similar to wood but another very important aspect is that this substitute is available in huge amounts throughout the whole year to avoid a material short fall. At best this material would be available not only in Germany but also in all countries of the European Union.

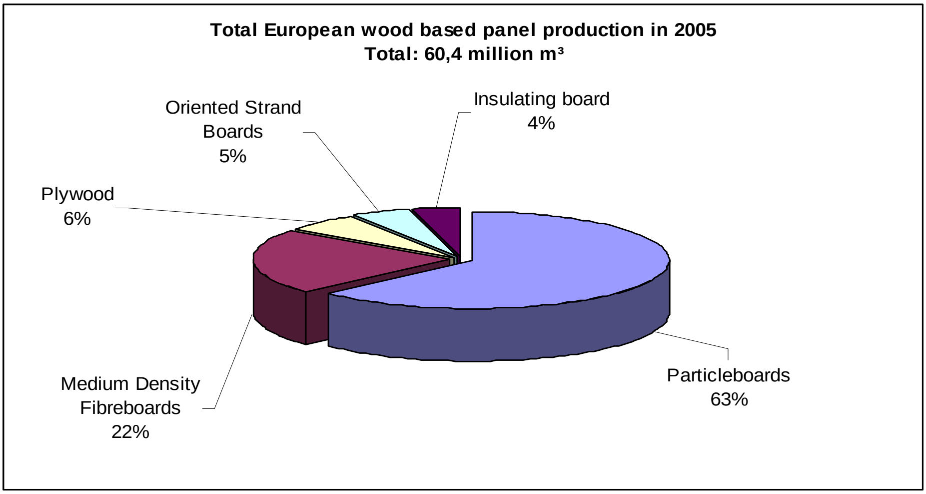

Figure 1: Production volume of wood based panels in Europe in 2005 (VHI, 2006; EPF, 2007)

The planting and harvesting of THC free hemp for industrial applications is allowed in Europe since 1990. In Germany the planting of hemp is allowed since 1996. From 1990 to 1997 the area for planting hemp in Europe increased from 4.000 ha in the beginning to 23.000 ha in 1997 (http://www.inaro.de/Deutsch/Rohstoff_index.htm, 05.08.2006). In Germany 1.422 ha were planted with hemp for a later industrial utilisation. The European community produced in average about 25.000 tons a year of hemp fibres in 2002 and 2003. 30.000 tons of hemp shives and 6.000 tons of hemp seeds were produced as by-products to hemp fibre production in Europe in 2002 and 2003. The main utilisation for hemp fibres is the production of cigarette papers and other technical applications. For the automobile industry the utilisation of hemp fibres for indoor applications is standard nowadays (Cescutti und Müssig, 2005). The production of textile products and technical mats, e.g. roofs are other very important application areas in Europe for hemp fibres (http://www.kommpottpora.de/hanfwerk/produkte.htm, 14.09.2006). Actually there are no application possibilities for hemp shives. The main application for hemp shives is the utilisation as animal straw. Only 5 % of the shives are used in the building industry. Therefore the utilisation of hemp shives in the production of wood based panels would be a great opportunity (Karus, 2005).

The utilisation of hemp for the production of wood based panels is not well developed today. In recent years some wood based panel industries tried to use hemp as raw material for particle boards and wood based panels in general (Bócsa, 2000; Ohlhauser, 2005). The problems using hemp were very manifold. The costs for hemp, the distribution of hemp and last but not least the decortication of hemp were very difficult so that hemp was not a very attractive raw material for these industries. According to References research the production of hemp based fibreboards was not analysed by the wood based industry.

The disadvantage of the hemp shives is the high price that is based on the production process to achieve these shives. They are a by-product of the hemp fibre production which is an expansive production process. Therefore the shives are not of interest for the wood based panel industry today because of the high costs that are combined with this material. But hemp has a lot of advantages that would allow an utilisation within the production process of wood based panels. It grows very fast and the planting and harvesting of hemp is cheap and can be realised within a very short time. The planting time is April and May and the plants can be harvested in August. The plants are 4 meters high in average after this time what implements a high yield per hectare. After harvesting and drying the hemp is not very expansive. That leads to the fact that an utilisation of hemp for the production of wood based panels is only possible if it is used as complete harvested and dried plant.

Aims of the project

This application is about the utilisation of complete hemp plants as raw material for the production of different kinds of wood based panels such as three-layered particleboards and fibreboards. One main topic of our project is the production of three-layered particleboards with low densities. The regular density of a standard three-layered particleboard is about 650 kg/m^3. By the utilisation of hemp we want to realise densities of about 400 kg/m^3 and lower. By the utilisation of non woven fibre mats based on hemp fibres, that can be implemented in one to maximum three layers within the structure of three-layered particleboards the mechanical-technological properties of these hemp based panel boards can be improved. The fibre mats shall be positioned in the middle layer and between the middle layer and the two surface layers. This structure would allow the production of ultra-light particleboards with densities of 200 kg/m^3 and lower with well mechanical-technological properties. The fact that hemp has a lower own weight than wood leads to the possibility to produce this kind of three-layered particleboards with decreased densities without very high investment costs for the wood based panel industry. The development of this low density particleboards would offer on the one hand complete new application possibilities for wood based panels and on the other hand it would lead to panel boards with optimised mechanical-technological properties.

The utilisation of hemp fibres for the production of fibreboards would offer the possibility to produce low density fibreboards by the common industrial used dry method. In general low density fibreboards are produced by the wet or semi dry method that both require huge water amounts – similar to the production process of high density fibreboards. By using hemp water can be saved and fibreboards with similar or better mechanical-technological properties based can be produced. The better properties can be achieved by the fact that hemp fibres are longer compared to nowadays used pine wood fibres.

By using hemp for the production of wood based panels the commonly used raw material - wood of low quality and/or small dimensions - can be substituted by hemp. This would solve one present problem the wood based panel industries are actually forced to – the problem that this kind of wood is no longer available in the required amounts. Therefore it is necessary to find a lignocellulosic material as soon as possible to offer an alternative material to the commonly used wood. This substitute should feature similar properties than wood, it has to be available in huge amounts and the price for this substitute should be lower compared to the price for wood.

Hemp is an annual plant that grows very fast and that is a natural plant in Europe. Over many years hemp cultivation was only allowed in very few countries in the EU; most countries made in their regulations no difference between industrial hemp with low THC content and drug hemp (marihuana) with high THC content. During the last 20 years more and more countries realised the potential of industrial hemp and changed the national regulations. Today in all European Countries hemp cultivation is allowed and supported as “Grand Culture”, if the THC content is below 0,2 % and the processing of the cultivated crops is contracted to a certified processor.

Under the nowadays conditions, that wood is a raw material which is constantly increasing in its price and not available in the amounts that are required it makes sense to start a new application using hemp as raw material for the production of wood based panels in consideration of the problems mentioned above. The utilisation of hemp as raw material for the wood based panel industry can only be realised by using the complete hemp plant and not only the fibres or the shives. This is founded on the one hand in the high price for shives and fibres and on the other hand in the crushing of the hemp plants. The shives do not have an optimal structure that is comparable to the structure of particles made from wood.

Therefore one important aspect of this application is the milling of the hemp plants to receive a raw material that is equal to particles in its structure and behaviour under process conditions. This aspect should be realised by a machine manufacturer that has a lot of experience in milling wood and/or lignocellulosic material. Another important aspect of this application is the hemp plant itself. Therefore different hemp seeds with different properties should be analysed in line with this project. Only hemp with well properties should be used for the cultivation. The hemp seeds that meet the expectations of the wood based panel industry in the best way should be cultivates. The harvest should be done in cooperation with a machine manufacturer to solve possible problems during the harvest and to guarantee a hemp plant raw material that can be further processed by the machine manufacturer.

The development of a natural bonding agent for the production of wood based panels is another main task in this project to develop three-layered particle boards and fibreboards with well mechanical-technological properties. The reduction of the raw density and the optimisation of the strength and swelling of these boards are not the only important aspects in the production of innovative wood based panels. This industry usually applies conventional resins based on formaldehyde for the production of the particle boards and fibreboards. Based on the fact that formaldehyde emissions are very dangerous not only during the production but for the end consumers too it is necessary to develop a bonding agent to produce wood based panels with highly reduced formaldehyde emissions compared to nowadays produced particle boards and fibreboards.

There are a lot of aims in this project that can be divided into technical and scientific goals. The *technical goals* mainly concern the harvesting milling and sizing of the hemp straw to guarantee a material that can be produced in huge amounts under similar conditions with continuous properties to meet the wood based panel industry expectations. The development of a new milling technology is a main technical challenge in line with this project. And last but not least the logistic problem of hemp straw delivery and supply is a kind of a technical problem that should be solved in line with this project to guarantee a continuous and cheap delivery and supply of this material.

The *scientific goals* are manifold in this project. First of all we need information about different hemp seeds concerning their climatic growth conditions and the yield that can be realised under average and certain conditions. Another important aspect of this part is to analyse the structure and the chemical ingredients of hemp plants grown under different conditions. For example the amount of lignin that can differ under changing climatic conditions is very important for a later application in the wood based panel industry.

To find the maximum possible hemp substitution rate for wood during the production of particleboards and medium density fibreboards is the main task of this application. This implicates as well scientific goals as well as technical goals. There are different possibilities to start substituting wood by hemp. First of all we want to produce particleboards with shives and leaf of the harvested hemp. These boards should be prepared under utilisation of urea formaldehyde resin and phenol formaldehyde resin with standard densities of 650 kg/m^3. The boards should contain wood and hemp in different ratios. These hemp-wood based boards are next to standard urea-formaldehyde and phenol formaldehyde bonded particleboards consisting only of wood our reference boards in this project. By changing the ratios of wood and hemp we want to achieve different properties and densities to analyse the positive or negative influences of higher hemp ratio on the mechanical-technological properties of the particleboards. Medium density fibreboards should be produced under utilisation of standard pine fibre material and hemp fibres in different ratios bonded with urea formaldehyde or phenol formaldehyde resin. By changing the fibre ratios, especially increasing the hemp fibre content, we can analyse the influence of higher hemp fibre content on the mechanical-technological properties of the MDF boards.

After a special technique is developed for milling and sizing the complete hemp plants we want to produce particleboards with this material in combination with wood. Under utilisation of conventional resins we want to see differences to the particleboards produced with shives and wood. The structure and geometry of the sized hemp material should be abutted to nowadays used wood particles.

Furthermore the development of a natural binder that can be used in combination with wood and hemp is a main scientific goal in this project. Different binders based on proteins and starches should be used alone and in combination with conventional resins like urea formaldehyde and phenol formaldehyde to achieve well properties and low formaldehyde emissions of the produced hemp/wood based particleboards and medium density fibreboards.

The production of hemp/wood based particleboards with conventional resin and natural binders will be done in laboratory scale in the beginning of the project. Therefore we have small production machines in our plant station. After achieving good results we will transfer these tests in pilot scale. In our technical school we have a pilot plant station for the production of medium density fibreboards (see Figure 2) and another pilot plant station for the production of three-layered particleboards (see Figure). The production of both kinds of wood based panels in pilot scale can be realised under controlled parameters that are equal to industrial production parameters so that reproducibility on the one hand and a transfer to industrial scale on the other hand are guaranteed.

Figure 2: Pilot plant station for medium density fibreboard production

Figure 3: Pilot plant station for three layered particleboards

Materials & methods

Based on the fact that this project will start in august 2007 we do not have a lot of results at this time. But we made some preliminary tests in laboratory scale before we submitted the proposal to this project. These preliminary tests and the achieved results should be presented in this and the following chapter.

Production of three-layered hemp based particleboards with reduced densities

The production parameters for the three-layered hemp based particleboards in laboratory scale with densities of 450 kg/m³ and 550 kg/m³ are given below in Table 4. The production of these particleboards was done analogue to industrial production process in regard to the processing. First of all the shives were separated into surface layer material (finer material, SL, see Figure) and middle layer material (coarse material, ML, see Figure). In a second step the hemp shives for surface layers and middle layer were dried to an average moisture content of 2.5 %. Afterwards the shives were mixed with a bonding agent consisting of urea-formaldehyde resin (BASF, type KAURIT 350), ammonium sulphate (MERCK) and hydrophobic substance (EXXON MOBIL, type HYDROWAX 138), in a small blender and then the material was strewed in form with dimensions of 50 cm x 30 cm x 2 cm (l x b x h). First of all one surface layer is strewed (20 % of total particle amount), then the middle layer is strewed (60 % of the total particle amount) and at least another surface layer (20 % of the total particle amount) is strewed.

Figure 4: Hemp shives, middle layer material (ML)

Figure 5: Hemp shives and leafs, surface layer material (SL)

After strewing the particleboards were first precompressed without temperature and afterwards pressed in an upstroking press. After conditioning the boards were edge bended, sanded and sawed into small parts for testing the mechanical technological properties analogue to the given DIN (DEUTSCHES INSTITUT FÜR NORMUNG) and European engineer standards.

Table 4: Production parameters of three-layered hemp based particleboards in laboratory scale

	Hemp particleboard type 450	Hemp particleboard type 550
Bonding agent		
Surface layer ratio (%)	2 x 20	2 x 20
Particle material	Hemp leaf and hemp stem	Hemp leaf and hemp stem
Urea formaldehyde resin, dry on dry particle (%)	10	10
Ammonium sulphate (33 %), dry on dry particle (%)	1	1
Hydrophobic substance, dry on dry particle (%)	1	1
Middle layer ratio (%)	60	60
Particle material	Hemp shives	Hemp shives
Urea formaldehyde resin (%) dry on dry particle	10	10
Ammonium sulphate (33 %), dry on dry particle (%)	2	2

Hydrophobic substance, dry on dry particle (%)	1	1
Dimensions		
Length (mm) x breadth (mm)	500 x 300	500 x 300
Density (kg/m³)	450	550
Thickness (mm)	20	20
Press factors		
Temperature (°C)	195	195
Pressure (bar)	220	220
Press time (sec/mm)	12	12

Production of three-layered hemp based particleboards with reduced densities and hemp based woven fabric inlays

The hemp based three-layered particleboards under utilisation of hemp based woven fabric inlays to optimise the mechanical-technological properties of the boards are produced under analogue production parameters compared to the hemp based three-layered particleboards described in chapter 0. The densities of these hemp based particleboards (see Table 5) are a little bit higher compared to the particleboards in chapter 0. The reasons for the higher density are the hemp based woven fabric inlay that are integrated in these particleboards. All in all three layers are positioned in each particleboard. Between each surface layer and the middle layer one hemp based woven fabric layer is positioned. The third woven fabric layer is situated in the centre of the middle layer. Each hemp based woven fabric layer is coated with urea formaldehyde resin (KAURIT 350, BASF) before it is integrated in the board to guarantee a good adhesion between the layers and the particles.

Table 5: Production parameters of the three-layered hemp based particleboards in laboratory scale with integrated hemp based woven fabric inlays

	Hemp particleboard type 480	Hemp particleboard type 580
Bonding agent		
Surface layer ratio (%)	2 x 20	2 x 20
Particle material	Hemp leaf and hemp stem	Hemp leaf and hemp stem
Urea formaldehyde resin, dry on dry particle (%)	10	10
Ammonium sulphate (33 %), dry on dry particle (%)	1	1
Hydrophobic substance, dry on dry particle (%)	1	1
Middle layer ratio (%)	60	60
Particle material	Hemp shives	Hemp shives
Urea formaldehyde resin (%) dry on dry particle	10	10
Ammonium sulphate (33 %), dry on dry particle (%)	2	2
Hydrophobic substance, dry on dry particle (%)	1	1
Dimensions		
Length (mm) x breadth (mm)	500 x 300	500 x 300
Density (kg/m³)	480	580
Thickness (mm)	20	20
Press factors		
Temperature (°C)	195	195
Pressure (bar)	220	220
Press time (sec/mm)	12	12
Hemp based inlays		
Surface layer / middle layer	1	1
Centre middle layer	1	1
Surface layer / middle layer	1	1

Results

In the following chapters (chapter 0 and chapter 0) the results of the hemp based three-layered particleboards in laboratory scale without (see Figure) and with hemp based woven fabric inlays (see Figure) are described. As mechanical-technological properties the surface strengths (N/mm²), the internal bond strengths (N/mm²), the tensile strengths (N/mm²) and the swelling (%) after 2 and 24 hours were investigated.

Results of three-layered hemp based particleboards with reduced densities

The achieved results of the three-layered hemp based particleboards made with hemp shives and hemp leafs (see Figure) show, that it is possible to produce lightweight particleboards under utilisation of hemp. The properties of the boards fulfil partly the standards concerning particleboards for indoor use that are given by actual DIN and European Norms. The tensile strength with 15 N/mm² and 16 N/mm² fulfil the given value of 15 N/mm². The results of the swelling test after 24 hours in water and the internal bond strength of the boards with a density of 450 kg/m³ do not fulfil the standards. The swelling should not exceed 12 % and the minimum internal bond strength is 0.35 N/mm². The surface strengths with 0.45 N/mm² and 0.66 N/mm² are lower than the given standard of 0.80 N/mm². The reason for this is on the one hand the lower density of the boards and on the other hand the fact that the structure of the hemp shives and sized hemp leafs is not optimal structure for the production of particleboards. Based on the fact that the internal bond strength, the tensile strength and the surface strength of a particleboard is correlated with its density the properties decrease by decreasing the density. This is one aspect that should be investigated within this project to develop a processing technique to size the hemp material in an optimal way for their later application in the particleboard production. By developing a more comforTable structure of the sized hemp material that is equal to the commonly used wood particles, better adhesion between the hemp material in a particleboard can be achieved and boards with lower densities but better mechanical-technological properties should be improved.

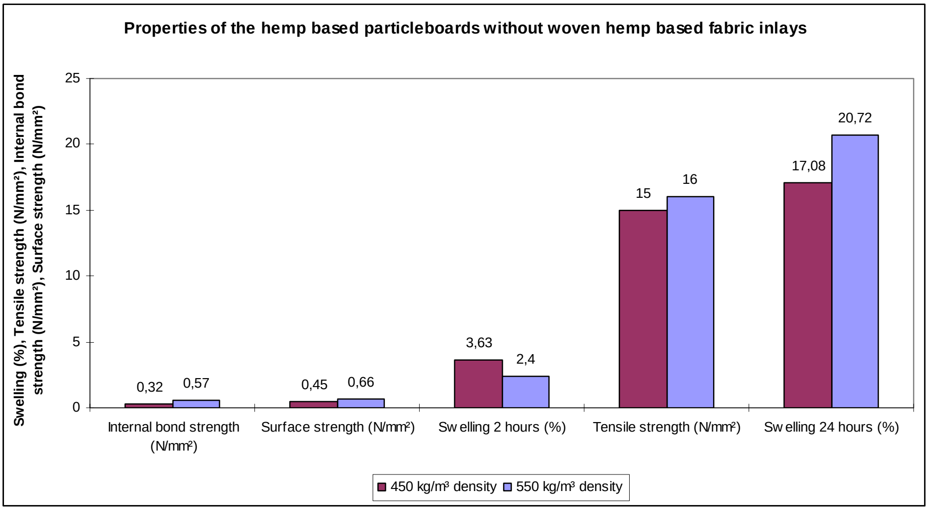

Figure 6: Results of the three-layered hemp based particleboards with reduced densities

Results of three-layered hemp based particleboards with reduced densities and hemp based woven fabric inlays

The results of the produced hemp based particleboards in laboratory scale under utilisation of hemp shives, hemp leafs and hemp based woven fabric inlays show that a woven inlays improves the mechanical-technological properties of the particleboards (see Figure). All properties, except the results of the swelling test after 24 hours in water and the surface strengths, fulfil the given DIN and European standards concerning the production of particleboards for indoor use. The internal bond strength (0.37 N/mm², 0.59 N/mm²) and the tensile strength (17 N/mm², 19 N/mm²) increased compared to the hemp based particleboards produced without hemp based woven fabric inlays (see Figure , 0.32 N/mm², 0.57 N/mm² and 15 N/mm², 16 N/mm²). On the other hand the utilisation of these hemp based woven fabric inlays lead to higher swelling results after 2 hours (3.91 %, 3.68 %) and 24 hours (18.21 %, 21.45 %) compared to the boards produced without these hemp based inlays (2 hours: 3.63 %, 2.60 %, 24 hours: 17.08 %, 20.72 %). As described in chapter 0 the structure of the hemp material is a very important parameter to achieve well mechanical-technological properties. Therefore the sizing and milling is a main goal in line with this project to optimise the properties of the hemp based particleboards and to enable the utilisation of complete hemp plants for the industrial production of lightweight three-layered particleboards.

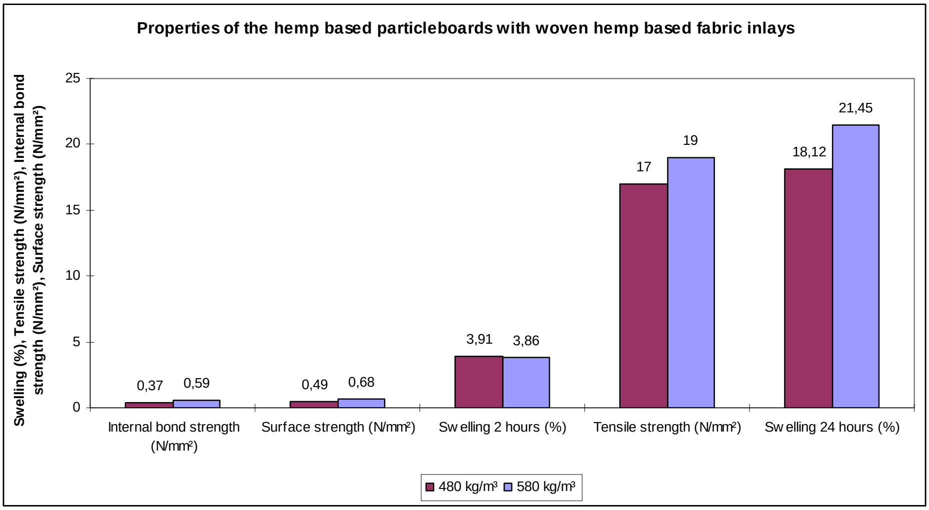

Figure 7: Results of the three-layered hemp based particleboards with hemp based woven fabric inlays in laboratory scale

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Investigations on the utilization of grand fir timber and beech timber from nature-orientated forest stands for the production of innovative particle- and fiberboards

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Introduction

Within the scope of this, investigations are made to analyse the application of grand fir timber for the production of high valuable particleboards. These studies are part of the super ordinate project "Research for sustainable forestry" from the "the German Federal Ministry of Research and Development", which provides utilization oriented investigations of the timbers *Fagus sylvatica* and *Abies grandis*. Beside the plain fabrication of grand fir timber the particles and fibres of the tree species should be combined with each other. The acquired synergy effects should be used for future productions of a new generation of derived timber products. The grand fir (*Abies grandis* (*DOUGLAS*) *Lindley*) of Northern America grows in Germany on a few thousand hectares and is, beside the Douglas fir, the Japanese larch and the Hybrid-Cottonwood, one of the four foreign forest species which has a pertinence on the German market. A lot of cultivation trials in the new and old German states have shown that the grand fir has an intense potential of growth and rank among the most height-capacity conifer species in West Europe. Furthermore it features a good ecological integration. The bright coloured timber has a constant texture and shows physical and mechanical qualities which are comparable with the fir (*Picea abies*) and the native silver fir (*Abies alba*). Regarding the machinability and the paste application properties, the grand fir shows excellent attributes. On the American market the grand fir will be applicable mainly in the pulp- and paper industry as well as a resource for the production of cases. So far there are barely bibliographical references for the utilization of grand fir timber for the production of derived timber products. Preliminary tests at the "Institute of Forest botany" of the University of Goettingen have shown that thermo-mechanical wood pulp and particles of grand fir timber can be used for the production of medium density fibreboards and accordingly particle boards. Thereby for the first time researches on three-shifted particle boards are accomplished in this degree dissertation. In face of the presently subordinated significance of the grand fir on National markets, the forestry and timber industry must be prepared for possible questions and problems regarding the attributes, usage and commercialization of the timber.

Natural area of circulation of *Abies grandis*

The natural area of circulation (Figure 1) of Abies grandis is North- America. There are two areas of growth. A costal area, which ranges from south-east British Columbia to the east of Vancouver Island, to the west of Washington, west-Oregon and north-east of California. Aside this area, there is an inland area, which ranges from the south of British Columbia to the east of Washington, central-

Idaho to the west of Montana and the north of Oregon (Merkblatt, 1984). As a result of the widespread areas, there are a lot of provenances (Stratmann, 1988).

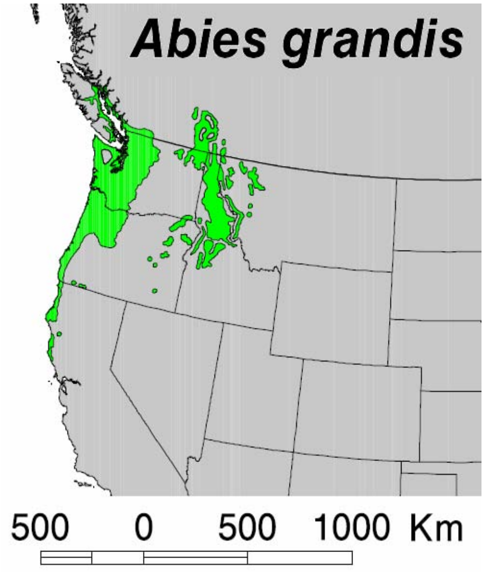

Figure 1: Natural area of circulation

In Germany there is about 12000 hectares *Abies grandis*. It is about states forest and it's composed of pure and mixed forest stands. Primarily there are forest stands in Lower saxony, Rhineland- Palatinate, Hesse and Baden- Württemberg. There from are some sample areas. The dimensions of forest stands in private forest are unknown.

Yield- parameters of *Abies grandis*

In References there are some references which show the fast growing properties of *Abies grandis* (Schumacher, 1967; Kramer, 1976). There values specified for medial height growth of 1.35 m per annum with a stock of 444m³ per hectare for a 40 years old stand (Schumacher, 1967). *Abies grandis* is culminating between 40 and 50 years (Riebel, 1994). One author described this tree as the most capable coniferous tree in west-Europe. Figure 2 shows of a small forest stand in Reinhausen, Germany. From there, the first material of *Abies grandis* for the first investigations was taken. The size of this stand is 0.3 hectares with an age of 22 years. The height growth is about 18 meters. So the medial high growth amount 0.82 meters in one year. The breast height diameter is 25 cm. So the breadth of annual rings is 1.14 cm. This should reveal the above-average yield- parameters of *Abies grandis* in relation to other conifers in west-Europe like *Picea abies* and *Pinus sylvestris* (Kramer, 1976).

Figure 2: Forest stand in Reinhausen, Germany

Physical and mechanical properties (solid wood) of *Abies grandis*

On consideration the physical and mechanical properties of solid wood, it becomes apparent that these values are comparable to those from *Picea abies* and *Abies alba* (Hapla, 2002; Niemz, 1993; Sell, 1989) except the density of the solid wood which are lower than those from *Picea abies* and *Abies alba*.

Usage- relevant properties of *Abies grandis*

For an economic processing of the timber a good machinability is an important factor. The usage- relevant properties of *Abies grandis* are the soft wood, the constant fiber- orientation, the uniform texture, the low density and the fact that it has no resin canals. It follows from the above that the wood has a low resistance against machining (Alden, 1997: Sachse, 1991). It is possible to dry the timber very fast without ripping and warping. Anymore the timber has good properties to keep paint and excellent gluing abilities (Knigge, 1960). So here we find best conditions for the production of derived timber products.

Previous possible uses of *Abies grandis*

So the outcomes of this are the previous possible uses of *Abies grandis* which are refering to the American market. The wood is used mainly in the pulp- and paper industry (Caesar, 1979; Foiles et al., 1990), furthermore for the production of cases, for construction timber and claddings. Further advantages are the light colored timber and the scentless after drying.
In face of the presently subordinated significance of the grand fir on national markets, the forestry and timber industry must be prepared for possible questions and problems regarding the attributes, usage and commercialization of the timber.

Aims of the project

The objectives in this project are the development of new techniques for the production of high valuable particle- and fiberboards from *Abies grandis*. It is a precondition to determine the abilities of beech timber and grand fir timber for the production of derived wood products. So it is possible to develop optimal parameters of process and recipe with different bonding agents for a derivation of a manufacturing technology. Furthermore the material interactions by combining beech and grand fir timber are under examination.

Collaboration with industry partner

The part of the University of Goettingen is basically the fundamental research. There, a lot of pilot surveys in laboratory- and pilot scale were accomplished. With the results of these trials it was possible to make some proposals to the industry partner for generating an expedient production plan. So the companies can realize

the industrial trials. In return the University gets raw data's and raw material like particles. So a scientifically editing of these industrial trials could be done for optimizing following enterprises.
Raw data´s were taken are from all sections of production by sampling and using the process control system. Furthermore *Abies grandis* particles in great quantities for continuing investigations in laboratory- and pilot scale were taken. The resourcing of experimental boards for continuing investigations is also an important element of editing these trials.
So it was possible to contribute the technical expertise in industrial trials at the particle board factory Gutersloh, Germany. The objectives in these trials were on the one hand to find out how the different sections of production (machines) react if an unknown tree with low density and low piled weight will use continuously. On the other hand it was important to see if the timber of the grand fir is only useable for an extension or furthermore applicable for the production of high- valued particle boards.
Table 1 shows the production plan for three-shifted particle boards from grand fir timber in the first trial. First a reference consisting common practice composition of particles were produced. In the first part of this trial boards from 100 % *Abies grandis* with densities from 350 kg/m³ to 550 kg/m³ were produced.

Table 1: Production plan

		Density kg/m³	upper layer %	middle layer %	grand fir %	beech in %	common practice com-position of particles %
reference	Version 1	550	34	66	0	0	100
Grand fir(Part 1)	Version 2	350	34	66	100	0	0
	Version 3	450	34	66	100	0	0
	Version 4	550	34	66	100	0	0
Grand fir/ beech	Version 5	650	34	66	50	50	0
(Teil 2)	Version 6	550	34	66	33,3	33,3	33,3
	Version 7	550	34	66	25	25	50

In the second part other particles in different proportions were admixed and the densities of the boards were diversified. After that the effects on the mechanical-technological properties of the boards were analyzed.
To get enough values, from every version five boards were assigned and separated out. In the following the boards were put into storage again for conditioning (Figures 3-5).

Figure 3: Cooler

Figure 4: experimental boards

Figure 5: Board bearing

The pictures 5 and 6 show the trial-wood. For this trial 70 t absolutely dry wood of grand fir were worked up. The sections have a length of 3 meters with a medial diameter of 18 cm. The medial moisture content was 118 %.

Picture 5: Unloading the trial-wood

Picture 6: Wood-Sections

While chipping the wood we determinate the wood- specific energy consumption. For this we need a weighted sample of the wood, here 15 t. This particle board factory uses a cutter block chipper. Before chipping the cutters were grounded, so we can determinate the cutter abrasion. While chipping it is important to load the treadmill without gaps during the readings.

Mechanical-technological properties of particleboards and medium density fibreboards

The appraisal factors for the quality of particleboards are generally the mechanical- technological properties like bending strength, transversal internal bond and swelling proportionately to the density and the moisture content of the boards. It must be pointed out that the properties of the boards are dependent on different factors. Among other things the quality of the boards is affected by binding agents, by nature and form of the particles and fibres respectively and of course by pressing parameters. By the variation of the decisive factors it is possible to arrange the properties of the boards. So they can achieve those requirements which are needed for certain areas of application. There are norms and directives that form the basis of assignments for the determination of quality attributes. In the following the most needed methods of testing are listed:

EN 322	Determination of moisture content
EN 323	Determination of density
EN 310	Determination of modulus of elasticity in bending and of bending strength
EN 311	Surface soundness of particleboards
EN 317	Determination of swelling in thickness after immersion in water
EN 319	Determination of tensile strength perpendicular to the plane of the board (transversal internal bond)
EN 120	Determination of formaldehyde content; perforator method

Results

In the following chapter there are some results of the mechanical- technological properties of the boards which are made of 100 % grand fir. Figure 7 represents the results of the determination of transversal internal bond and peeling strength of the boards. With a density of 550 kg/m³ the values of the boards are inside of those values which are required in EN 312-3. In comparison to the references the values are significant higher. This result will be more clearly on consideration the bending strength (Figure 8).

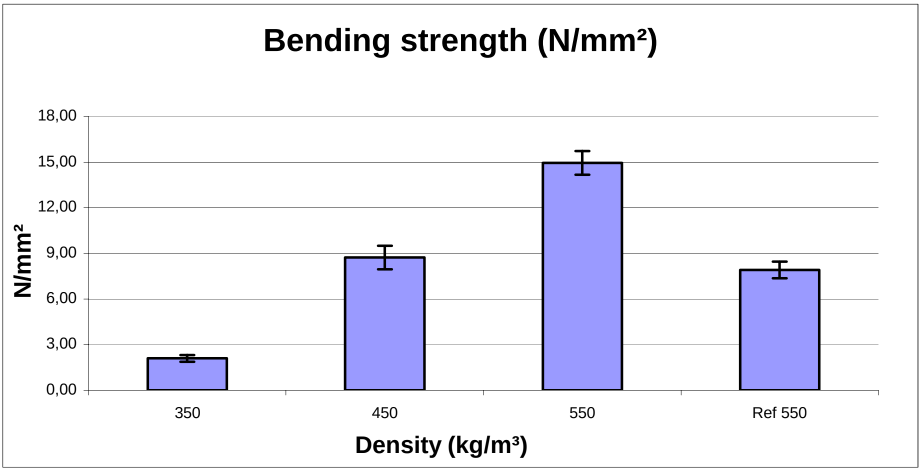

Figure 7: Peeling strength and transversal internal bond

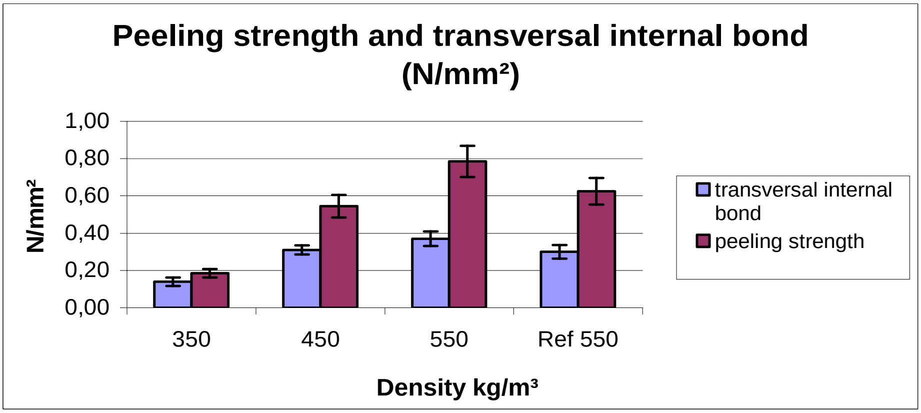

Figure 8: Bending strength

Here, the average value of the boards made of grand fir with 14.95 N/mm² is nearly two times higher than the corresponding reference. The cause of these strong differences can be mentioned by the usage of particles with high quality in the intermediate layer of the boards. The fiber orientation is mainly parallel to the layer. So the bending strengths are superior.

The values for swelling in thickness (Figure 9) after immersion in water for 2 and for 24 hours are not very significant. All values are between 15 % and 20 %. So thus they are higher than 15 % which are required. Normally this fault can be resolve by optimizing the paste.

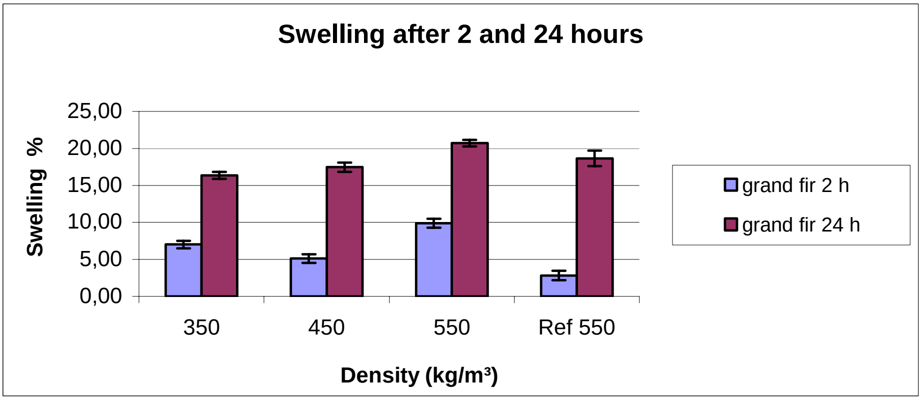

Figure 9: Swelling after 2 and 24 hours

Conclusion

This industrial trial was a very effective enterprise. During the production of the different series of boards there were no exceptional incidents which can be traced back to the specific properties of *Abies grandis*. A production of three shifted particleboards in industrial scale with *Abies grandis* is possible. In doing so all mechanical- technological properties are superior to the references which were made of common practice composition of particles. In comparison to the references the boards consisting *Abies grandis* have a bright colour. This is an expedient property for coating these boards with thin melamine papers.

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Protective treatment of wood in order to increase the safety of wooden vessels and port equipment

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Abstract

Wood samples of this research were Iranian wood species Oak (Qurercus castaneafolia), Hornbeam (Carpinus betulus) and Beech (Fagus orientalis). The dimensions of the samples were 20*7.5*2 cm treated by Creosote and Celcure using full cell process (Bethel) method. Retentions of Creosote were 161, 443.17, 383.43 kg/m3 and Celcure 2.92, 6.03, 6.11 kg/m3 respectively. Both control samples (untreated) and preservative treated samples were placed in seawater (Bandar Abbas and Boshehr in Persian Gulf), according to the recommendation of IRG/WP-4432 (1985). After 6, 8, 12, 24, 33 and 38 months exposure in seawater, the samples were evaluated according to IRG/WP 4432 (1985) and ASTM D-2481. As a result of this research, all the control samples (natural durability) of Oak, Hornbeam and Beech against marine borers in Bandar Abbas and Chabahar coasts were seriously attacked or less than 10 months. Oak, Hornbeam, and Beech samples, treated by Creosote and Celcure, were sound after more than 15 months exposure in seawater but Oak, Hornbeam, and Beech samples, treated by Celcure, were destroyed after 24 months exposure in Bandar Abbas and Boshehr seawater. Oak, Hornbeam and Beech samples, treated by Creosote, were destroyed after 38 months exposures in Bandar Abbas and Boshehr seawater. According to the field test result, Oak, Beech and Hornbeam wood treated with Creosote, is recommended for marine structure. The rate of activity of marine borers in Boosher coast is more than that of in Bandar Abbas coast.

Keyword: durability, Creosote, Celcure, Bethel, marine borers & wood

Introduction

South coasts of Iran have vital importance in exporting, importing, fishing and transportation of passengers. Wood is applied in marine structures and vessels (Figure 1a-c).

Figure 1a

Figure 1b

Figure 1a-c: Lange (boat) and wooden wharves (jetty)

Timbers of Teak (Tektona grandis), Keruing (Dipterocarpus alatus), Yellow Balau (Shorea laevis) and Chengal (Balanocarpus heimii) are applied in marine structure, which are imported from India and South East Asia (4). In recent years the application and replacement of domestic timbers in marine structures and wooden vessels has been started. This research has been done with the aim of investigation on treated and untreated durability of Oak, Hornbeam and beech wood species against marine borers in South coasts of Iran.

Materials and Methods

Wood samples of the research were Oak, Hornbeam and Beech. The dimensions of the samples were 20*7.5*2 Cm. Samples treated by Creosote and Celcure using Bethel method (Table 1) according to the recommendation of IRG/WP-4432 – 1985(1, 2, 3).

Table 1: Average retention of Creosote and Celcure

		Retention	
		Creosote	Celcure
1	Oak	161	2.92
2	Hornbeam	443.17	6.03
3	Beech	383.43	6.11

Samples were arranged, tied with 16 mm diameter nylon rope each containing 15 panels (Figure 2). They were exposed at about 1 meter below the surface of the seawater. The installation stations of the samples were Boshehr and Bandar Abbas coasts.

Figure 2: Making space by tying the rope between the samples

Evaluation of durability

Wood samples were evaluated, after 6, 8, 12, 24, 33 and 38 months exposure in seawater. Each of the samples was removed, carefully scraped to eliminate the surface of marine organisms to examine their durability. Then, they were inspected for surface deterioration and holes, indicating tunneling by marine borers (Figure 3a-c).

Figure 3a

Figure 3b

Figure 3a-c: Placing the samples in seawater and eliminating their surface

The basis of the evaluation was ASTM standard D 2481 - 89 and AWPA (1, 2) (Table 2).

Table 2: Rating scales developed by ASTM and AWPA

ASTM and AWPA Rating	Description
10	Sound, no-to- trace surface deterioration and no signs of tunneling
9	Light surface attack or suspicion of tunneling
7	Moderate surface attack or clearly defined areas of tunneling but board integrity, generally sound
4	Heavy attack with well-established area of tunneling but board integrity main tainted
0	Board destroyed, missing time

Results and Discussion

In Bandar Abbas coasts

Evaluation was done according to ASTM, all the untreated Oak samples after 12 months, Hornbeam and Beech samples after 8 months exposure in sea water, were completely destroyed by marine borers (Table 3 and Figure 4).

Table 3: Average evaluation of the untreated samples in Bandar Abbas coasts

Species	Rating after months		
	6	8	12
Oak	10	7	0
Hornbeam	4	0	-
Beech	4	0	-

No evaluation

Figure 4: Control samples of Oak, Hornbeam and Beech

All the samples treated by Celcure, after 24 months exposure in sea water, were completely destroyed by marine borers (Table 4 and Figure 5).

Table 4: Average grade of the samples treated by Celcure in Bandar Abbas coasts

Species	Rating after months		
	8	12	24
Oak	10	7	0
Hornbeam	10	4	0
Beech	10	9	0

Figure 5: Samples of Oak, Hornbeam and Beech treated by Celcure

All the samples treated by Creosote, Oak and Beech after 38 months, Hornbeam after 24 months exposure in sea water, were completely destroyed by marine borers (Table 5 and Figure 6).

Table 5: Average grade of the samples treated by Creosote in Bandar Abbas coasts

Species	Rating after months				
	9	12	18	24	38
Oak	10	9	8	5	0
Hornbeam	10	10	7	0	-
Beech	10	10	10	4	0

No evaluation

Figure 6: Samples of Oak, Hornbeam and Beech treated by Creosote

In Boshehr coasts

All the untreated Oak samples after 12 months, Hornbeam and Beech samples after 6 months exposure in sea water were completely destroyed by marine borers (Table 6 and Figure7).

Table 6: Average evaluation of the untreated samples in Boshehr coasts

Species	Rating after months		
	6	8	12
Oak	9	7	0
Hornbeam	0	-	-
Beech	0	-	-

No evaluation

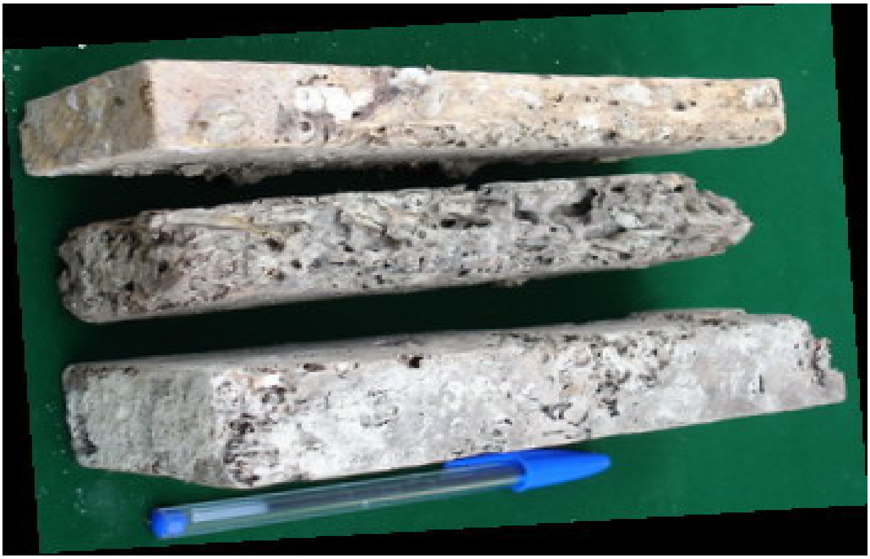

Figure 7: Control samples of Oak, Hornbeam and Beech

Oak, Hornbeam and Beech samples, treated with Celcure, were completely destroyed by marine borers after 18 months exposure in sea water (Table 7 and Figure 8).

Table 7: Average grade of the samples treated by Celcure in Boshehr coasts

Species	Rating after months		
	8	12	18
Oak	10	7	0
Hornbeam	10	8	0
Beech	10	5	0

Figure 8: Samples of Oak, Hornbeam and Beech treated by Celcure

Oak and Hornbeam samples, treated with Creosote, after 38 months and Beech samples after 29 months exposure in sea water, were completely

Table 8: Average grade of the samples treated by Creosote in Boshehr

Species	Rating after months				
	9	15	24	29	38
Oak	10	9	6.2	5	0
Hornbeam	10	10	8.2	7	0
Beech	10	10	5	0	-

No evaluation

Figure 9: Samples of Oak, Hornbeam and Beech treated by Creosote

Conclusion

Average natural durability of Oak, Hornbeam and Beech woods against marine borers in Bandar Abbas and Boshehr coasts is less than 9 months, and also they are not resistant against soft rot organisms. Oak, Hornbeam and Beech samples treated with Creosote were sound after more than 15 months exposure in seawater. Oak, Hornben and Beech samples treated with Celcure were sound after more than 10 months exposure in seawater. According to the field test result, Oak, Beech and Hornbeam wood treated with Creosote are recommended for marine structure. The rate of activity of marine borers in Boosher coast is more than that of in Bandar Abbas coast.

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Investigation on the anatomical, physical, and chemical characteristics of *Ziziphus spina-christi*, *Z. lotus, Z.mauritiana and Z.nummularia*

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IntroductionLacking of commercial forests of Iran case that the lignocelluloses resource should be developed. One of success conditions of development is identification of lignocelluloses resource. Because that crate the success management of develop and culture of natural resources.

In South of Iran Extensive Region, There Are Tropical and Sub-tropical Sensitive Ecosystems With Arid and Semi-arid Land. Ziziphus Sp. Of the Rhamnaceae Family Is Widely Distributed in the Southern Region of Iran and Considered As One of the Most Drought- Resistant Genius of the Country.

In This Investigation Was Attempted to Study Wood Properties of Four Species of This Genius. It Seems Necessary to Recognize the Best Utilization of These Woods That Are Potentially Available and Easy to Cultivate in Iran.

Ziziphus spina-christi	Christ's thorn
Z. lotus	African lotus
Z.*mauritiana*	Ber, Indian jujube
Z.*nummularia*	Camel thorn

The genus Ziziphus belongs to the buckthorn family (Rhamnaceae). It is a genus of about 100 species of deciduous or evergreen trees and shrubs distributed in the tropical and subtropical regions of the world (Johnston 1963).

A great majority of the rural population in arid regions meets their daily household requirements through biomass or biomass-based products such as food, fuel, fodder, fertilizer, building materials and medical herbs. Ziziphus meet many of these needs and they can be used for a variety of purposes in arid regions (Arndt 2001).

The Wood of the Ziziphus tree species is dense and compact. It is used for various purposes in the everyday life of the people including the production of tools, poles, toys and for turning. Z.mauritiana is an excellent fuel-wood tree and makes a good charcoal, with a heat content of 4900 kcal kg-1 (Khoshoo and Subrahmanyam 1985).

The large genus Ziziphus is divisible into three distinct anatomical groups, which closely correspond with the distribution pattern of the species, main distinguishing characters of the groups are ray width, parenchyma distribution and the type of vessel perforation plate (Schirarend 1991).

Materials and Methods

Samples were taken at 15-20 cm of stem bottom, 50 % and 75 % height of stem, from six trees each of *Z. spina-christi* and *Z. lotus*, and three trees each of *Z. mauritiana* and *Z. nummularia*.
In this investigation the anatomical, physical and chemical characteristics of wood were studied respectively on the basis of IAWA list of microscopic features, ASTM and TAPPI standard.
For anatomical properties in each height, three specimens were taken at near pith, near bark and between, pith and bark.
Anatomical characteristics were measured with 360 replications in each height. Physical characteristics were measured with 60 replications in each height. Chemical characteristics were measured with 4 replications.
The analysis of data among species was performed by two factor completely randomized design and Duncan's multiple range test for variable.

(L/d)= felting coefficient

(2P/C)*100= tear coefficient

(C/d)*100= flexibility coefficient

L = Fiber Length,
d = Fiber Diameter,

C = Fiber Lumen Diameter,
P= Fiber wall Thickness

Discussion of Results The results of this study revealed that, isn't significant difference in the most of characteristics among three heights of tree.

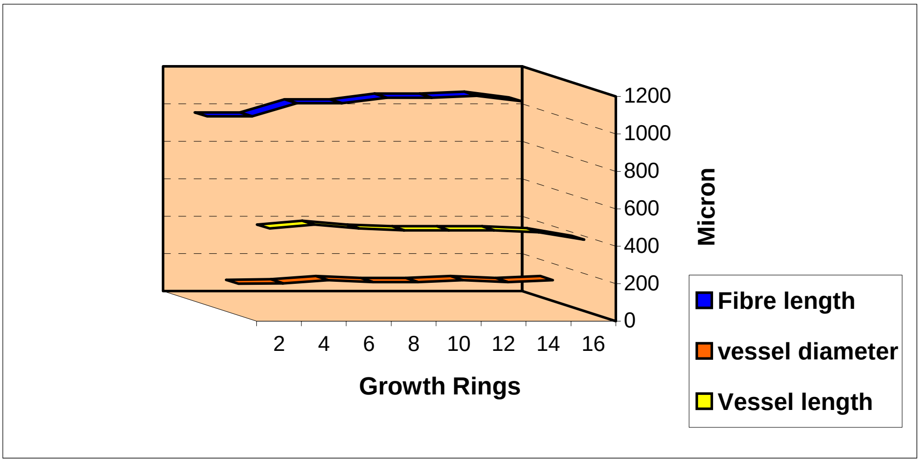

Figure 4:.The change of fibres length, vessels length and vessels diameter from pith to bark in Z.spina-christi

Table 1: To compare anatomic characteristics among four species by Duncan's test.

	Z.lotus	Z.spina-christi	Z.mauritiana	Z.nummularia
Vessel diameter (µm)	C) 89	AB) 109.72	B) 106.32	A) 114.79
Vessels per mm^2	A) 20	BC) 14	C) 13	B) 15
Rays per mm	A) 12	A) 13	B) 11	A) 13
Height ray (mm)	A) 390.72	A) 413.39	B) 336.78	B) 300.67
Width ray (µm)	B) 29.04	A) 34.05	B) 25.80	B) 26.36
Vessels length (mm)	A) 469	A) 463.5	B) 415.67	C) 341.33
Width ray (cell)	1	1-2	1-2	1
Intervessel pits size (µm)	8.2	8.5	8	7.5

Table 2: To compare fibres characteristics among four species by Duncan's test.

	Z.lotus	Z.spina-christi	Z.mauritiana	Z.nummularia
Fiber Length (µm)	B) 867	A) 971	B) 869	C) 726
Fiber Diameter (µm)	AB) 15.86	B) 15.36	A) 16.08	C) 14.36
Fiber Lumen Diameter (µm)	B) 6.74	C) 6.19	A) 7.52	B) 7.06
Fiber wall Thickness (µm)	A) 4.56	A) 4.59	B) 4.28	C) 3.65
Felting coefficient	B) 54.75	A) 62.78	B) 54.16	B) 50.60
Tear coefficient (%)	B) 136.78	A) 149.51	C) 114.4	D) 103.76
Flexibility coefficient (%)	B) 42.40	C) 39.82	A) 46.75	A) 48.05

Table 3: To compare physical characteristics among four species by Duncan's test.

	Z.lotus	Z.spina-christi	Z.mauritiana	Z.nummularia
Annual growt (cm)	0.04	0.3	0.99	0.78
Density (Mc=0)(gr/cm3)	A) 0.67	A) 0.70	B) 0.55	B) 0.57
Basic Density(gr/cm3)	A) 0.6	A) 0.62	B) 0.50	B) 0.52
Density (Mc=12) (gr/cm3)	A) 0.64	A) 0.66	B) 0.53	B) 0.55
Swelling (%)	B) 11.91	A) 14.21	B) 11.68	C) 9.42
Shrinkage (%)	B) 10.69	A) 12.44	CB) 9.34	C) 8.59
Porosity (%)	B) 55.08	C) 52.79	A) 62.76	A) 61.91

Illustrating of Woods *Ziziphus spina-christi*

In growth ring boundaries distinct there are 1-4 raw of marginal parenchyma. Wood is diffuse-porous. There is not distinct vessel arrangement, but there is often solitary vessel and sometimes 2-4 multiples vessels in radial direction. Perforation plates are simple. There are not scalariform Perforation plates not at all. Intervessel pits are alternate and its shape is often elliptical and sometimes polygonal. Mean Intervessel pits size is medium. Range of Intervessel pits size is 6-12 micron.

Vessel-ray pits with distinct borders; similar to Intervessel pits in size and shape throughout the ray cell. Mean tangential diameter of vessel lumina is 100-200 micron. Mean vessel length is 350-800 micron. There are 5-20 vessels per square millimeter. Vascular tracheids present in wood. Ground tissue fibres are fibres with simple to minutely bordered pits. Fibre wall thickness is thin-to thick-walled. Mean fibre lengths is 900-1600 micron.There are paratracheal axial parenchyma, that is often vasicentric and sometimes aliform. Parenchyma in marginal is variable width 1-4 cells at the margins of growth rings. There are fusiform parenchyma cells and seven (2-7) cells per parenchyma strand. Ray width is exclusively uniseriate and sometimes 2-3 cells in the middle of ray width. Ray cellular composition: body ray cells are procumbent with mostly 2-4 rows of upright and/or square marginal cells. There are special pit arrangements on ray cells as column (Figure4).
Ray per millimeter is =>12/mm. Prismatic crystals are in procumbent ray cells and in chambered upright and/or square ray cells.

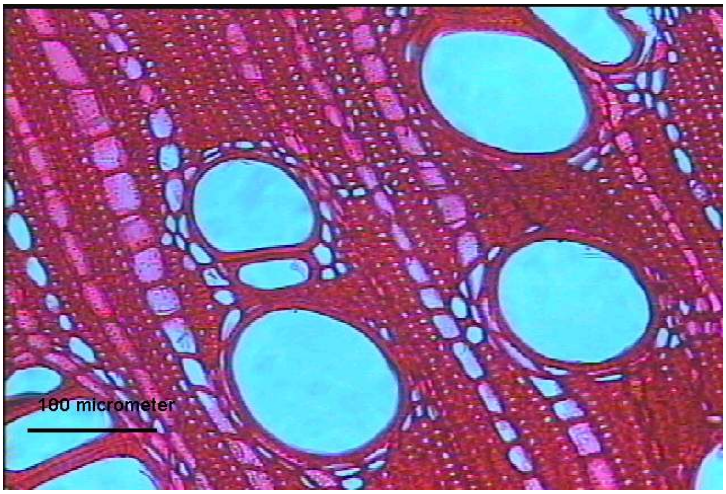

Figure 2: Z.spina-christi

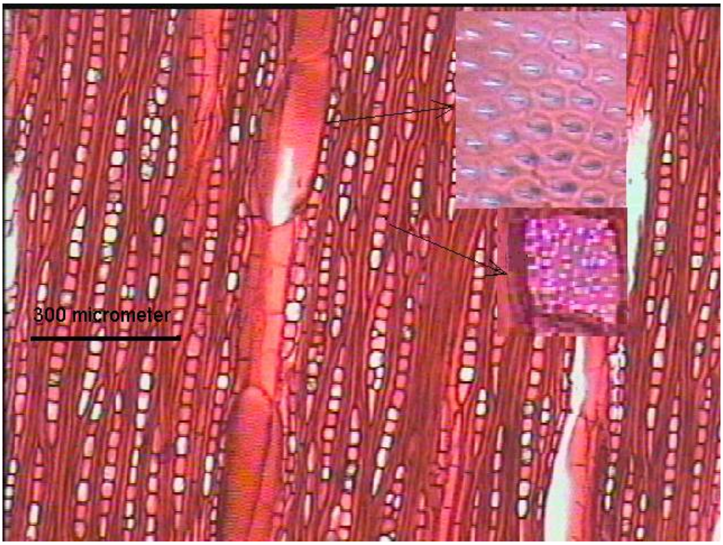

Figure 3: Z.spina-christi

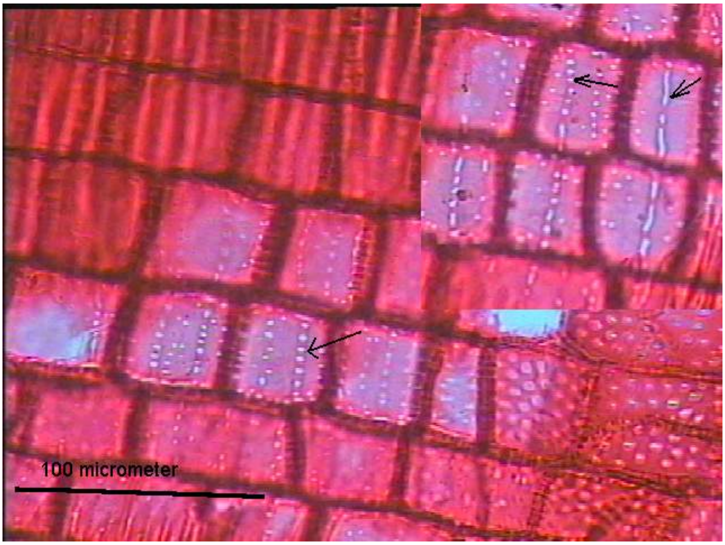

Figure 4: Z.spina-christi

Ziziphus lotus

In growth ring boundaries distinct there are 1-3 raw of marginal parenchyma. Wood is diffuse-porous. There is not distinct vessel arrangement, but there is often solitary vessel and sometimes 2-4 multiples vessels in radial direction. Perforation plates are simple. Intervessel pits are alternate and its shape is often polygonal. Mean Intervessel pits size is medium. Range of Intervessel pits size is 6-12 micron. There are vestured pits. Vessel-ray pits with distinct borders; similar to Intervessel pits in size and shape throughout the ray cell. Mean tangential diameter of vessel lumina is 50-100 micron. Mean vessel length is 350-800 micron. There are 5-20 vessels per square millimeter. Vascular tracheids present in wood. Ground tissue fibres are fibres with simple to minutely bordered pits. Fibre wall thickness is thin-to thick-walled. Mean fibre lengths is =<900 micron. There are paratracheal axial parenchyma, that is often vasicentric and sometimes aliform. Parenchyma in marginal is variable width 1-3 cells at the margins of growth rings. There are fusiform parenchyma cells and seven (2-5) cells per parenchyma strand. Ray width is exclusively uniseriate and there are seldom two cells. Ray cellular composition: rays with procumbent, square and upright cells mixed throughout the ray. There are special pit arrangements on ray cells as column. Ray per millimeter is =>12/mm. Prismatic crystals are in chambered square ray cells. This species is a shrub.

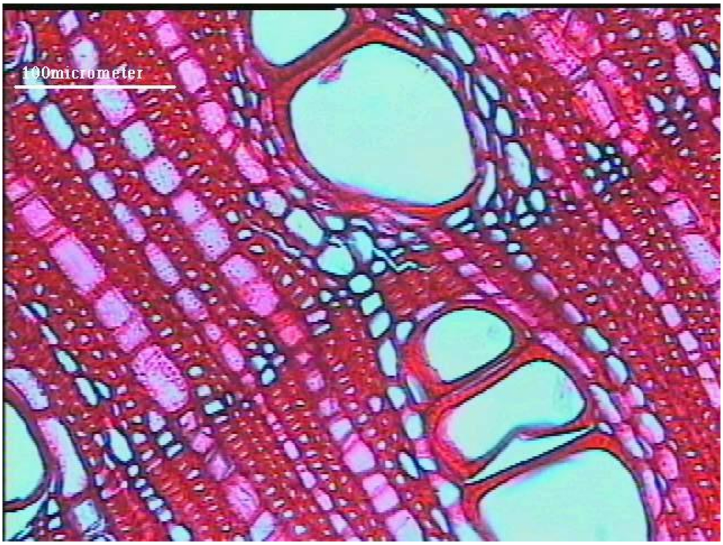

Figure 5: Z.lotus

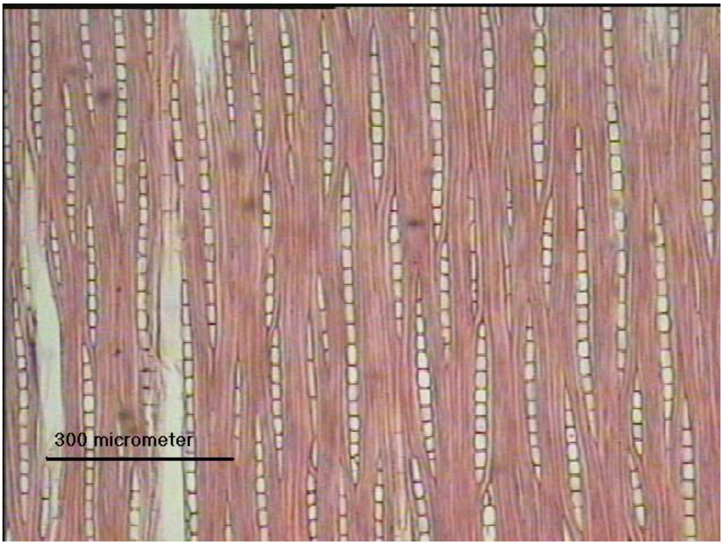

Figure 6: Z.lotus

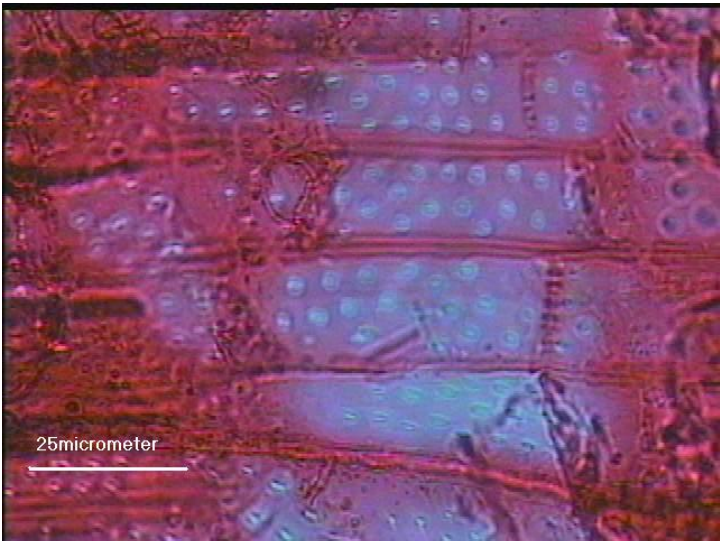

Figure 7: Z.lotus

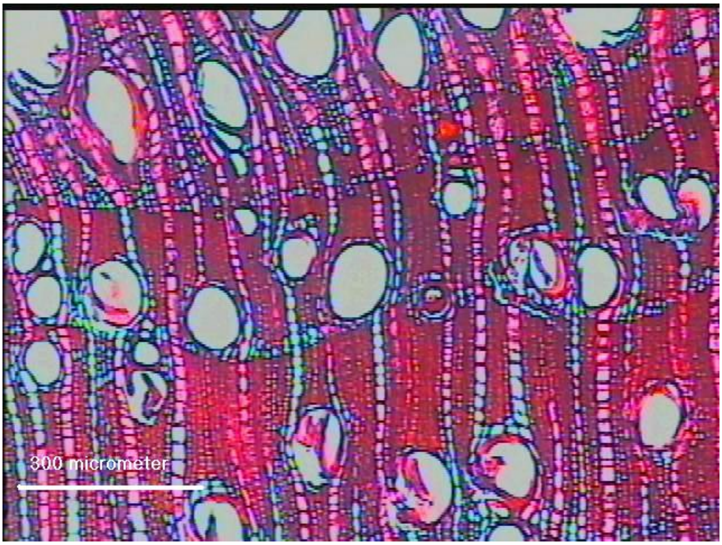

Figure 8: False growth ring in Z.lotus

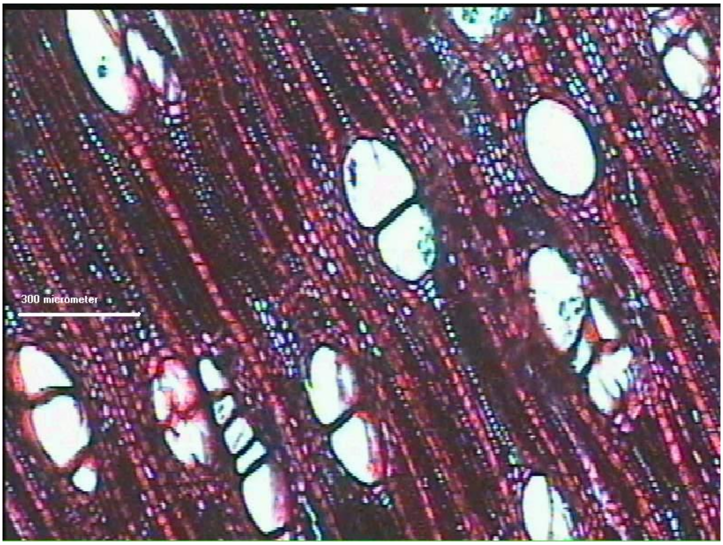

Figure 9: Z.mauritiana

Ziziphus mauritiana

In growth ring boundaries distinct there are 2-3 raw of marginal parenchyma cells. Wood is diffuse-porous, that seldom is semi-ring-porous. There is often solitary vessel and sometimes 2-5 multiples vessels in radial direction. Perforation plates are simple. Intervessel pits are alternate and its shape is polygonal. Mean Intervessel pits size is medium.

Range of Intervessel pits size is 6-12 micron. Vessel-ray pits with distinct borders; similar to Intervessel pits in size and shape throughout the ray cell. Mean tangential diameter of vessel lumina is 100-200 micron. Mean vessel length is 350-800 micron. There are 5-20 vessels per square millimeter. Vascular tracheids present in wood. Ground tissue fibres are fibres with simple to minutely boardered pits. Fibre wall thickness is thin-to thick-walled. Mean fibre lengths is =<900 micron.

There are paratracheal axial parenchyma confluent. And axial parenchyma in narrow bands or lines up to three cells wide. Parenchyma in marginal is variable width 2-3 cells at the margins of growth rings. There are two cells per parenchyma strand. Ray width is exclusively uniseriate and sometimes 2 cells in the middle of ray width. Ray cellular composition: body ray cells are procumbent with one row of upright and/or square marginal cells. Ray per millimeter is =>12/mm.

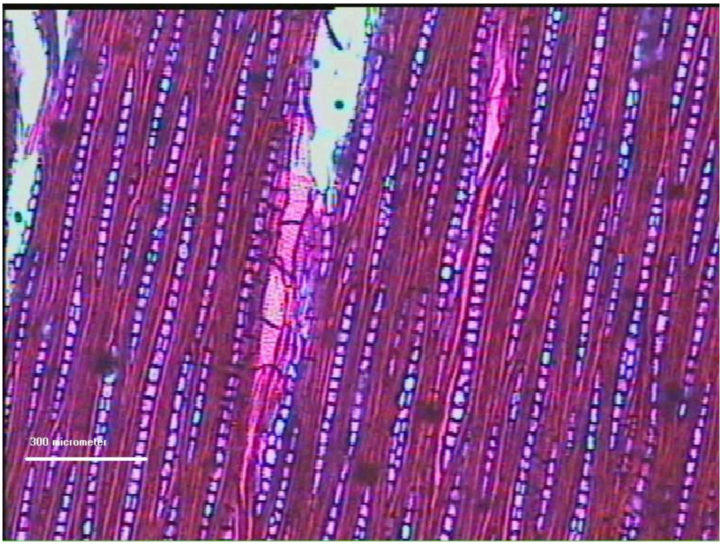

Figure 10: Z.mauritiana

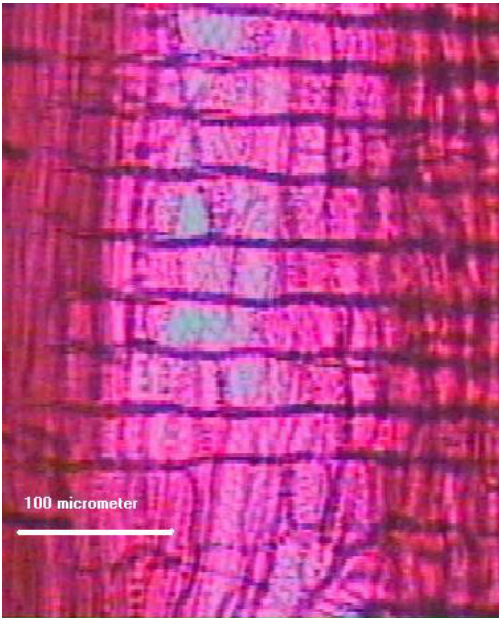

Figure 11: Z.mauritiana

Ziziohus nummularia

In growth ring boundaries distinct there are 1-3 raw of marginal parenchyma. Wood is diffuse-porous. There is not distinct vessel arrangement, but there is

often solitary vessel and sometimes 2-4 multiples vessels in radial direction. Perforation plates are simple. Intervessel pits are alternate and its shape is polygonal. Mean Intervessel pits size is medium. Range of Intervessel pits size is 5.5-11 micron.
Vessel-ray pits with distinct borders; similar to Intervessel pits in size and shape throughout the ray cell. Mean tangential diameter of vessel lumina is 100-200 micron. Mean vessel length is <=350 micron. There are 5-20 vessels per square millimeter. Vascular tracheids present in wood. Ground tissue fibres are fibres with simple to minutely boardered pits. Fibre wall thickness is thin-to thick-walled. Mean fibre lengths is =<900 micron. There are paratracheal axial parenchyma, that is often vasicentric. Parenchyma in marginal is variable width 1-3 cells at the margins of growth rings. There are two cells per parenchyma strand. Ray width is exclusively uniseriate and there are seldom two cells. Ray cellular composition: all ray cells are upright and/or square. Ray per millimeter is =>12/mm. This species is a shrub.

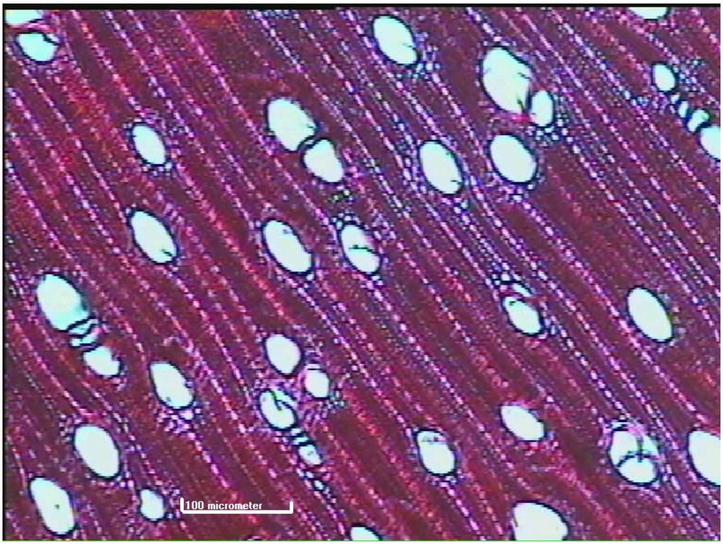

Figure 12: Z.nummularia

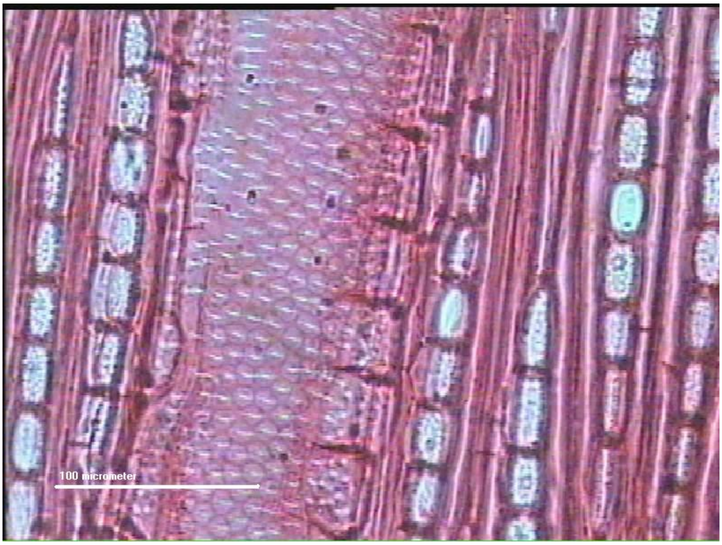

Figure 13: Z.nummularia

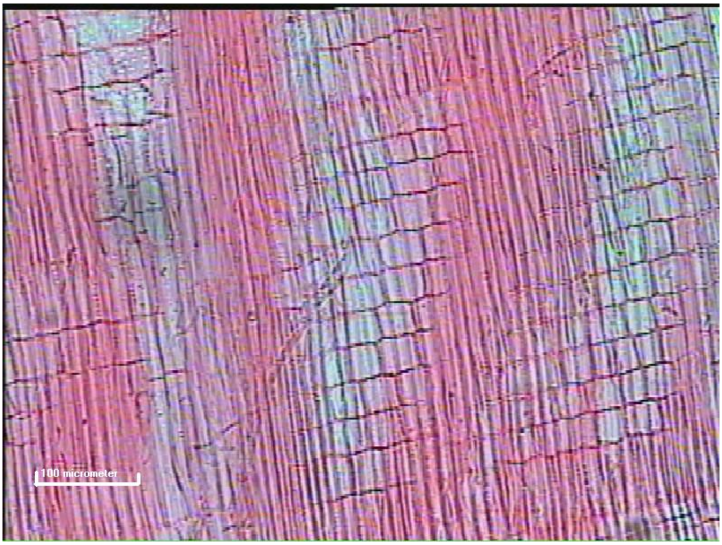

Figure 14: Z.nummularia

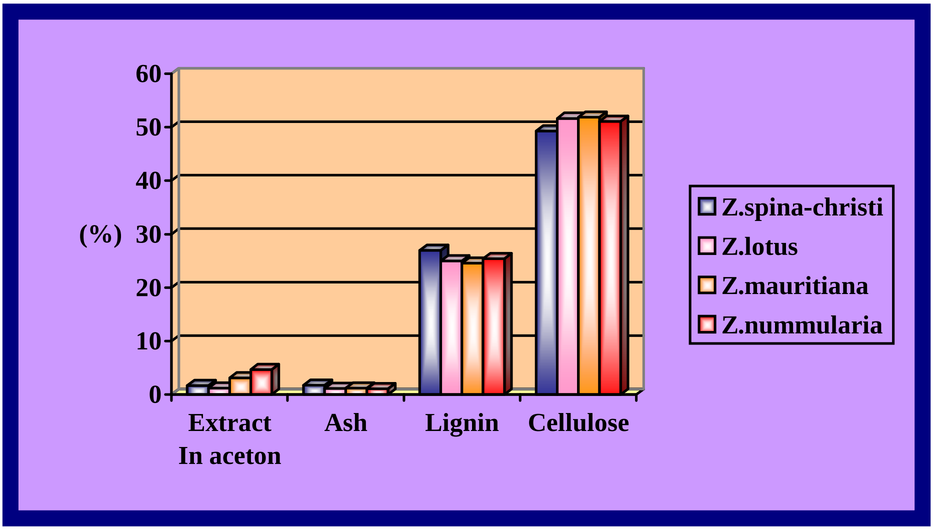

Figure 15: Chemical characteristics

Discussion

The results of this investigation compared with Schirarend's results (1991) and revealed that in these results, rays per millimeter, vessels per square millimeter and vessels diameter of four species, fibres length of *Z. mauritiana* and *Z. nummularia* are less than Schirarend's results. The vessels and fibres length of Z.lotus and ray height of Z.spina-christi are more than Schirarend's results. The compare among four species indicated that in *Z. spina-christi*. Rays width, fibres length, shrinkage, swelling, Felting coefficient, Tear coefficient are more than others, and Fiber Lumen Diameter and flexibility coefficient are less than others. In *Z. lotus* vessels per square millimeter are more than others, and vessels diameters are less than others. In *Z. mauritiana* Fibers Lumen Diameter are more than others, and rays per millimeter and Tear coefficient are less than others. In *Z. nummularia* vessels diameter are more than others, and fibres length, fibres diameter, vessels length, shrinkage and swelling are less than others.

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The effect of various moisture treatments on water use efficiency (WUE) in *Haloxylon* plant

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Abstract:

To investigate water use efficiency in Haloxylon plant (Haloxylon Spp.), a project was performed in Yazd control desert research station of Shahid Sadughi with longitude 54° 11' 9" and latitude 32° 4' 30", near to man made forest. The project was begun with making and installing 10 weighted lysimiters with dimension of 121 cm and depth of 170 cm. After preparation of lysimiters, the Haloxylon seedlings were planted in them and by one-year maintaining them, some conditions prepared to apply moisture treatments. Moisture treatments are included of pot capacity (control), one-third of pot capacity and draught stress that was applied complete randomize design in form of basis project with three repetitions. The required water to achieve considered moisture gave to the plants via lysimiters distribution weekly while irrigation in drought stress treatment was stopped after perfect establishing of seedlings. To minimize evaporation rate, the lysimiters surface was covered by fiberglass thin sheets and a lysimiters with no planting was considered to calculate the rate of evaporation. Total exited water from lysimiters (drainer + evaporation) was deducted from entered water into lysimiters (irrigation+raining) and was calculated as the consumed water (transpiration) by plants.

The required water to achieve considered moisture gave to the plants via lysimiters distribution weekly, while in drought stress treatment, irrigation was stopped after perfect establishing of seedlings. To minimize evaporation rate, the lysimiters surface was covered by fiberglass thin sheets and a lysimiter that was with no planting was considered to calculate the rate of evaporation. Total exited water from lysimiters (drainer + evaporation) was deducted from entered water into lysimiters (irrigation + raining) and was calculated as the consumed water (transpiration) by plants.

Moisture treatments were applied during two growth seasons and measured the drought weight of covering garland and drought root weight and water use efficiency (WUE) was calculated at the end of second year.

The results of performed studies indicated that water use rate has meaningful effect on drought weight increasing of air organs and drought root weight in statistical level of 0.1 % (α=0.001), but its effect was various on water use efficiency as if the water use efficiency is reduced by increasing of soil moisture rate.

Keywords: lysimiter Haloxylon, water use efficiency (WUE), root weight, shoot weight.

Introduction:

Although fighting against the flowing sands has long background, what today introduced as sand sTableilization by applying plant species has about 40 years background began by planting as Haloxylon (Haloxylon Spp.) and still continues (Ekhtesasi, 2003). More fields have sTableilized by planting the various species of this plant, as if now there exceeds 1.5 million hectares of Haloxylon forests in country (Amani & Arefi, 2003). Despite the useful effects of Haloxylon forests such as controlling wind speed and erosion (Ekhtesasi, 2003), rain storing, vegetative cover varying, increasing the rate of soil organic and mineral materials NPK, accelerating the soil formation processes (Azarnivand et al, 2003), increasing the symbion microorganisms (Rad & et al, 1998), existed carbon sedimentation in air (Amani & Arefi, 2003), etc. ecological requirements such as its humidity should be never forgotten. As the most important element, water controls the plant growth in addition to playing an effective role in the plants survival

Haloxylon is from chenopodeacea family, which is known as Haloxylon persicum and Haloxylon aphylum. These plants mostly grow on the sandy and clay solids of central Asian deserts, Middle Asia and Middle East (Qorqum, Qezelqum, Iran and Afghanistan). Haloxylon presicum scatters in west north of China, Near East deserts and northern Russia (Pyankov et al, 1999 quoted from Iljine, 1963 and Sokolov, 1977). Haloxylon tree growths well in the light and deep sandy soil and also it growths on the light sandy hills. It growths better on the sandy land, but its growth is less on the hard and clay land and is seen as shurb. (Rahbar, 1987 quoted from Hangafarin, 1972). The results of soil tissue studies performed by Javanshir and et al (1997) indicate that the species of Haloxylon persicum spread in soils with clay 1.2 to 25.6 % (often with 5 to 10 %) and sand 45 to 95 % and Haloxylon aphylum spread in soils with 1.1 to 8 % (often to 50 %) clay and 90 to 100 % sand. Pyankov et al (1999) quoted from Rotov (1969) and Netchaeva (1973) stated that growth area of both species is the hot sandy deserts and propounded it as a dominant vegetation, while they emphasis on Haloxylon aphylum resistance to clay soils, salt lands and cold for Haloxylon presicum. Quoted from Anon (1981), Rahbar has mentioned that the proper growth area for Haloxylon aphylum is desert light soils, lack of organic materials and nutrient elements and full of sulfate and chloride salts and the growth area for Haloxylon presicum is mentioned by him such as wind soft sand and hollow soils. Rad and et al (1998) have reported the electrical soil conductivity in Haloxylon natural forests located in Robatat area to 220.7 ds/m and soil pH from 8.1 to 8.6 and in under planting forest of Yazd-Ardekan field, also have reported the electrical soil conductivity to 18.7 ds/m and soil pH was among 7.9 to 8.2.), Gul and et al (2000) quoted from Khan and Aziz (1988) reported that Haloxylon can tolerate 400 mill molar Nacl in soil naturally. Haloxylon species are established and grow properly in the most severe environmental conditions of drought desert and in the areas in which summer temperature reaches to 50 c and in winter reaches about -25 °C and in the areas with annually raining 30-170 mm (Amani and Parvizi, 1996).

In both species the leaves form as filament branches and certainly make main photosynthesis organs in plant. Type of photosynthesis for branches has recognized as C4 (Pyankov et al, 1999, quoted from Voznesn Skaya and Gameley, 1986).

Water use efficiency (WUE) in plants is the main subject of recent researches of many scientists. Determination of effective factors on WUE is the aim of many performed studies and researches about plant requirement for water. Wittwer (1975) introduces water as second limit source to produce food after land. He claims that circumstance of desired usage of water by plants should be considered as a basic research.

Proper Using of water is an ambiguous subject because of including many meanings and cases. In spite of this, we can state its main definition as total drought material excited by each unit of using water.

The effective factors on WUE depend on its definition. (a) In a plant biomass, total attracted carbon dioxide is taken into account. (b) Total produced crops (on or under surface of soil) and/or (c) efficiency of crop seed.

Water use may be measured via transpiration rate (T); evapor transpiration rate (ET) or via total exited water from system.

Stanhill has measured proper water use in physiological and hydrological levels. In hydrological levels, he mentioned that WUE is related to the water proper usage and its good distribution in root and in physiological levels, it is related to water losses of crop toward atmosphere, efficiency or total produced drought material via crop. He prefers applying the word of transpiration rather WEU. While the water loss can be included of evaporation from soil surface and plant air part surface. Therefore, he applied the words of evapor transpiration and knew it a proper choice instead of WUE.

There are various methods in plants to optimize WUE that the sTableilizing method is the most important among them. C4 plants in comparing with C3 plants have better physiological advantages in high temperature and high light (Money, 1980). Some of tropical plants are containing the compound of C4 photosynthesis cycle and Kelvin cycle (C3). It seems that this compound is more useful than C3 manner to tolerant the hard conditions of much rays and high temperature (Pearson, 1982). Crasulase Acid meTableolism (CAM) of plants results in deduction of transpiration rate via pores in during day.

Other effective factors on WUE can be pointed out are included of specific position of leaf level or leaf area index (LAI) in plant, the ratio of radiation inner attraction level to leaf transpiration level and how foliages rotate in during a day (Nbel, 1980, Bolger and Matches, 1990 and Sinclair et al, 1984). The most important environmental effective factors on WUE are air moisture rate. Turner

(1986) has pointed out this matter that increasing of evaporation pressure reduction rate around space of leaf increases the transpiration without effect on photosynthesis results in WUE reduction. Also, temperature effects on WUE via effecting on evaporation pressure reduction, high temperatures result in WUE increment. Warmed leaf level due to the high radiation is resulted in vapor pressure slope to be quicken as if transpiration occurs regardless present of rational high moisture (Valterlarcher, 1995). Bieloria points to this subject that in the plants in cold climate or in C3 plants, by increasing the environment temperature, WUE is decreased and this is when that in some C4, also WUE is increased by increasing the temperature. Also wind caused to move vapor and temperature change and moisture displacement that is effective on evapor transpiration rate (Heydari Sharifabad, 2004).

Soil moisture content has direct effect on the plant growth; therefore, WUE decreases by reducing soil moisture. Each factor that effects of water movement in soil, it can limit accessing water for plant and effects on WUE, for example; soil permeable rate, soil solutions salts and soil temperature are the related effective factors, root growth rate and proper exploit from soil moisture by plant is effective for WUE increasing. Soil moisture reduction increases the resistance of pores by increasing ABA surfaces and potential reduction will increase leaf water and consequently, WUE is optimized. Internal and external concentration of CO_2 can have positive or negative effect on WUE via variation of photosynthesis conditions (Mirhosseini, 1994 and Alizadeh, 2004).

Water efficiency rate through plants can be found by measuring evapor transpiration. Different factors effect on evapor transpiration that makes its exact evaluation problematic. The method used in evapor transpiration estimation categorized in two main groups that are Direct Methods and Calculative Methods. In direct method, a small and controlled part of field with considered plant cover is separated and evapor transpiration is measured in a period directly. Various ecological and plant factors are used in calculative method and the considered plant cover evapor transpiration is estimated by their relation with evapor transpiration and equations previously calculated by direct method (Alizadeh, 2004, Sfari, 2003).

The most common direct method in determining evapor transpiration is by using bielan mass principle in a controlled volume of soil.

ΔS= Input Stream-Output Stream

Input and out put stream = Total water rate that enters or leaves certain volume of soil in a distinct period (like one hour, one week, or one month) and usually describes in terms of millimeter.

ΔS= moisture change in soil controlled volume in a distinct period that describe in terms of centimeter or millimeter.

Materials and methods

Project performance place:

The project was performed in desert control research station of Shahid Sadughi located in Yazd-Ardekan field with longitude 54° 11' 9" and latitude 32° 4' 30". Annual average rain of area is 70 mm, maximum speed of wind is 120 km/h, annual average of sunny hours is 3052, annual average number of cold days are 73 days, annual average of class A evaporation 4000 mm, annual average of rational moisture in the morning 85 %, annual average of rational moisture in the evening 38.5 %, annual average of temperature 18 °C, absolute minimum of annual temperature -13.5 °C, absolute maximum of annual temperature 45.5 °C and area climate was improved on the basis of Dumarten's method, has reported cold ultra drought (Rad and Dashtakeyan, 2001).

Lysimiter designing and manufacturing:

10 weight lysimiters with high 10 cm and diameter 122 cm were designed and manufactured. Type of lysimiters was galvanized iron with the proper frame were designed as if that be able to tolerate minimum 5000 kg soil weight. To study the soil moisture condition in various depths and possibility of access the plant root in the various depths of soil, some valves were prepared in 30, 60, 90 and 120 cm of lysimiters body. However, Haloxylon root growth specially from longitudinal may be more than considered rate in lystimiters designing, but because of applying young trees and also to investigate the plant reaction to lake of accessibility to the under earth moisture sources, the above mentioned values were recognized suiTable, while the high cost of lysimiters manufacturing and installing big weight lysimiters should not been ignored.

Bottom gradient of lysimiters considered 2 cm and was ended a pipe which was regarded to go out additional water or drainage. Lysimiters body was covered by glass-wool with about 5 cm thick to reduce thermal exchange. Lysimiters were placed on the platform in land which was designed for this purpose in front of under planting Haloxylon fields, as if the lysimiters level was equal to the around soil level and the possibility of putting measurement containers for external water was provided.

Filling lysimiters with soil:

Regarding to this matter that Haloxylon is established well on sandy soils and is under consideration as psamophyte (Rahbar, 1987) so attempts were done on applying a soil which has such feature, for this purpose the soil of sand hills in front of project performance location were applied after its equalization and measuring its appearance special weight.

Measured appearance special weight was 1.61 g/cm², which means in this situation, 2000 kg soil was considered for each lysimiters. At the first, 25 cm big sand was added at the bottom of lystimiters and 5cm washed sand was added over it to create the proper drainage.

Seedling planting in lystimiters:

By preparing the lystimiters and condition providing to plant seedling in them, 3 Haloxylon seedlings that have equal appearance features was planted in each lystimiters and in autumn of 2002. The planted seedlings were selected among thousands seed seedlings from general office of natural resources. The seedlings selection criterion was their appearance features that attempts were performed to select seedlings, which have equal features. Evidently after planting the seedlings, their irrigation was begun in rate of 200 liter.

Treatments application:

The planted seedlings were irrigated with 250 liter and monthly for one year. After being sure about seedlings establishment, two seedlings were removed and only one seedling was kept in each lysimiters. By complete establishment of seedlings in the new place and when they were one year old, the considered treatments such as pot capacity (control), one-third of pot capacity and drought stress treatment was applied complete randomiz in form of basis design with three repetitions. To prevent evaporation from soil surface and not add soil to lystimiters (due to severe storms of area), the lysimiters levels were covered completely by thin sheets fiberglass and foam. Another aim, which was considered in covering the lysimiters level, was evaporation reduction from soil surface. In Haloxylon forests because of a little moisture of soil surface, usually air rational moisture is not under effect of moisture due to evaporation from soil surface. It is natural that increasing of air rational moisture around air part is effective on transpiration rate.

Soil suction curve was drawn before applying treatments by sending the soil sample to the laboratory of soil and water research institute. Then by saturating the lysimiters soil and after getting out the gravity water, the soil moisture rate was measured with TDR and soil moisture rate in field capacity was viewed. By direct sampling and putting in oven and soil moisture measurement via weight, also the exactness of subject was increased. By considering the soil volume of each lysimiters and type of applying soil, each lysimiters has capacity to store 170 liter water and if exceeds from its capacity, it is exited as drainage. In such conditions, soil had moisture equal to 13.5 volume percent that this moisture was controlled via TDR and was included of lysimiters weight moisture measurement, soil weight measurement, direct measuring controlled via TDR. Irrigation was done weekly and water used rate by plant was compensated at end of week. Two growth seasons was considered for treatments application duration.

Measuring factors:

1) To measure the weight of shoot: air parts of trees were cut at the end of second growth season (late November) and their drought weight were calculated by putting them in oven in temperature of 75 °C for 24 hours (Alizadeh, 2004, Mirhossini, 1994).
2) To measure the weight of root: after cutting the air part, the thick and hairy roots were separated by sieving and then washing the soil. Drought weight of root was obtained by putting the separated roots in oven in temperature of 75 °C for 24 hours (Alizadeh, 2004).
The obtained data were compared with each other in form of a statistical analyzing and also averages were compared with each other via Dankan's method.
3) Water use efficiency: As definition, water use efficiency in included of the produced drought material rate per each unit of used water by plant that is calculated as the following: WUE=D/W
Where WUE is water use efficiency, D is the mass of produced drought material and W is water mass used by plant. To measure WUE, after obtaining the drought weight of various parts of plant (root, stem and leaf) and by knowing the water rate used by plant during plant growth period and then by placing them in the mentioned formula, water use efficiency was calculated for each treatments. Various treatments average numbers were applied.

Results

Soil physical and chemical properties: by filling lysimiters via methods that were pointed in material and method chapter, total profile (0-120cm) of soil was sampled and its some physical and chemical properties were determined according to the standard methods of soil and water research institute in laboratory of Yazd agricultural and natural resources researches center and soil and water research institute (Table 1 and 2).

Table 1: Some physical properties of applied soil in lysimiters

Saturation Percent (sp)	Type of texture	Clay (%)	Silt (%)	Sand (%)	Porosity (%)	Special mass (g/cm3)	Depth
24.8	Sandy	3.7	3.3	93	38.7	1.61	0-120

Table 2: Some chemical properties of applied soil in lysimiters

AttracTable potassium (ppm)	AttracTable phosphorous (ppm)	Total Azote (%)	Organic carbon (%)	Neutral material (%)	Soil reaction (Ph)	Conductivity (ds/ m)	Depth
78.5	0.77	0.005	0.06	35.8	8.1	4.36	0-120

Soil suction curve: obtained results from performed studies indicated that the applied in potential -0.3 load or agricultural capacity has moisture equal to 13.5 volume percent and in potential -15 load has moisture about 6.75 volume percent. After gravity water was exited and reached to agricultural capacity via TDR the above results were confirmed. Figure 1 indicates the applied soil moisture properties that are function of a sandy soil.
Water balance sheet: because all lysimiters levels were covered to reduce evaporation rate, deference of used water rate and raining with exited water from lysimiters and loosed water from lysimiters without plant was regarded as consumed water by plants. Table 3 indicates the rate of evaporated water in during two agricultural seasons.

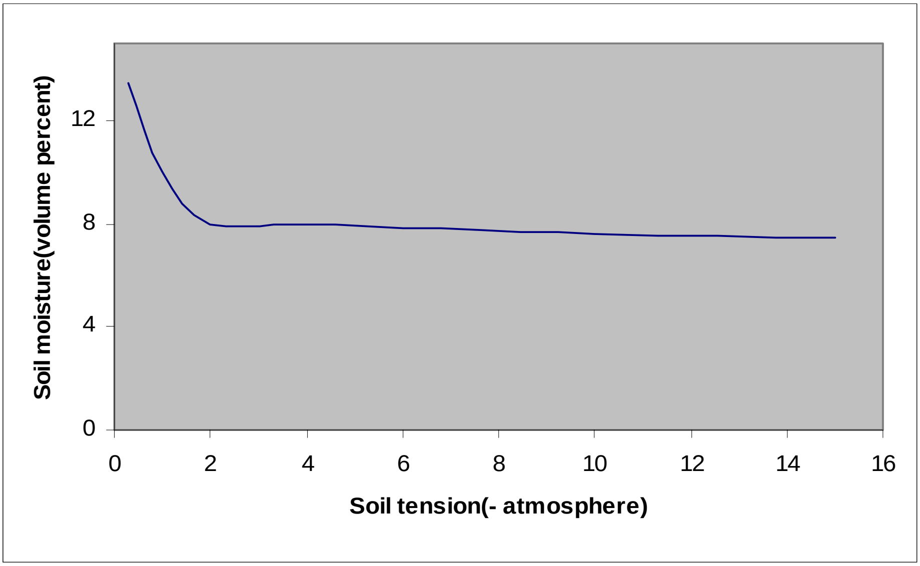

Figure 1: Effect of moisture treatments on drought root weight

Drought weight of root: by getting out the root from soil and drying and balancing it, it has clear that there were meaningful deference between various treatments in statistical level 0.1 % (α = 0.001) (Table 4). The most root weight was related to pot capacity treatment with 858.8 g and its least was related to drought stress with 235.6 g. The rate of root drought weight in one-third pot capacity treatment was measured equal to 553.4g (Figure 2).

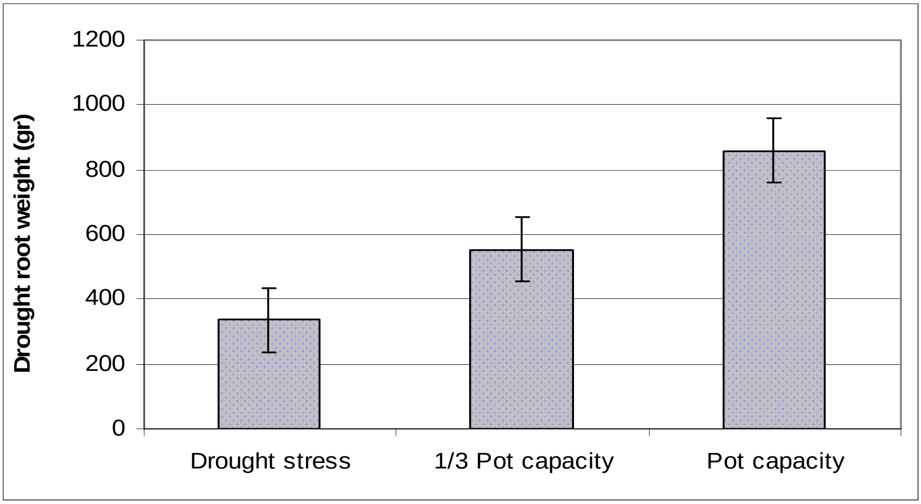

Figure 2: Effects of moisture treatments on drought root weight

Drought weight of air organ: by measuring the drought weight of air organ, each present tree in various treatments was determined that have the meaningful difference in statistical level 0.1 % (α = 0.001) (Table 5). The most drought material in air part was related to the pot capacity treatment with 825.1g and its least was related to drought stress with 236.2 g. Rate of drought material in one-third pot capacity was measured equal to 471.7 g (Figure 3).

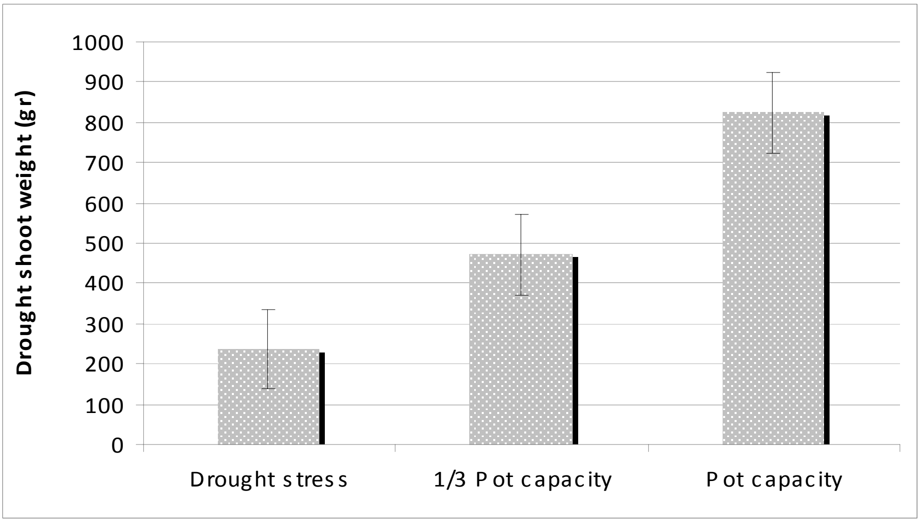

Figure 3: Effect of moisture treatments on drought weight of shoot

Water use efficiency: by obtaining the rate of root and air organ drought weight, the water use efficiency was calculated per rate of produced drought material to consumed water rate in each moisture treatments (Table 6 and 7). The numbers of mentioned Tables are indicated that with increasing the rate of soil moisture, water use efficiency has decreased. In other word, when soil was around of pot capacity by loosing water more via transpiration, although it has resulted in production of more drought materials, but water use efficiency was reduced. As if per each kg of produced drought materials, 574.5 liter water has consumed. This number is 333.3 liter about one-third of pot capacity and it is 182.5 liter for drought stress spited of that all repetitions were dried at the end of first application treatment year.

Table 3: Average used water in various treatments on during test per each tree (liter)

Drought stress	One third of capacity	Pot capacity	Treatment Agricultural year
104.3	154	475	2004
-	188	492	2005
104.3	342	967	total

Table 4: Analyzing data variance related to drought root weight

P	Mean squares	Square sum	Freedom degree	Variation sources
Ns	3870.84	7741.68	2	Repitition
***	207222.11	41444.23	2	Treatment
	1438.17	5752.67	4	Fautl
		427938.58	8	Total

Meaningful in level: *** in statistical level 0.01% ns (non significant deference) cv = 6.51%

Table 5: Analyzing data variance related to drought weight of air organ

P	Mean squares	Square sum	Square sum	Variation sources
Ns	5453.89	109077.78	2	Variation source
***	263581.45	527162.89	2	Treatment
	2530.11	10240.41	4	Fautl
		548311.07	8	Total

Meaningful of level: *** in statistical level 0.01% ns (non significant deference) cv = 9.90%

Table 6: weight of drought produced materials in the various treatments

Drought stress	One third of capacity pot	Pot capacity	Treatment /organ type
236.23	471.45	825.15	Shoot
335.59	553.39	858.83	Root
571.82	1024.84	1683.98	Total

Table 7: Water use efficiency (WUE) in the various treatments

Drought stress	One third of capacity pot	Pot capacity
5.48	3.0	1.74

Conclusion

The obtained results from this research indicated that the rate of produced drought material per each unit of usage water (rate of transpiration or water use efficiency) has decreased with increasing of soil moisture. In many sources this matter has pointed that although water use efficiency has depended on plant type and climate conditions and can improve the plant by changing type of plant, but the most rate of material in a special plant when its accessibility to water should be in desired level and plant transpiration should be perfect. In other word, transpiration rate reduction results in reduction of cell swelling then will reduce photosynthesis and finally it decreases production of drought material.

Soil moisture increment to pot capacity has resulted in water use efficiency reduction. The principal deference between the mentioned treatment with one-third of pot capacity and drought stress (1.74, 3, 5.48 g/liter respectively) states this fact that Haloxylon as a sTable plant against drought stress can increase the water use efficiency by preventing of water loose via closing pores, evaporation level reduction, sun light attraction reduction, water storing, to protect the cellular turgescence, osmotic adjustment and to reduce branches in comparison to root. Alizadeh (2004) indicated that C4 plants are able to produce 3-5 g drought material per each kilogram of water.

Unexpected increasing in water use efficiency in drought stress treatment is a phenomenon, which can be related to the photosynthesis cycle variation of plant. Perhaps, when a plant has faced to severe drought stress it uses a little moisture of soil by changing its photosynthesis cycle and has conflicted with applied stress. Photosynthesis cycle variation from C3 and C4 to CAM is a phenomenon under drought stress that has reported by some researchers (Heydari Sharifabad, quoted from Hartsock and Noble, 1976 and Zaygo, 1999).

Although water use efficiency is remarkable by drought stress plants, their gradually drying indicates that plant is depended on the soil moisture. When a plant was dead, the soil moisture was less than 3.2 volume percent. In such conditions the soil moisture in one-third of pot capacity was less than withered point its means that it was 4.5 volume percent and plants could remain life with these conditions. Zhang kebin (1989) has stated this point that growth of Haloxylon trees was depended on rate of soil moisture in Mikoen area of china that usually should be more than 2 weight percent. Rad and et al (2005) have reported that desired growth of Haloxylon in Yazd-Ardekan field is obtained when the soil moisture is about 3.1 weight percent.

Haloxylon trees balanced growth when is obtained that soil moisture is in a threshold limit. This exceeds threshold of soil moisture (field capacity) for this plant could not effect on water use efficiency increscent. While root growth ease and its accessibility to water also has provided desired conditions for the plant by considering to the sandy tissue of soil.

Although the total drought produced material (root and shoot) are the most important to measure WUE, but each rate can be under effect of various factors such as their accessibility to water. By measuring the effect on transpiration rate on the drought material that was produced by root and air organ it is determined that the air organ is under effect by soil moisture more than air organ and it has increased remarkably with increasing of transpiration rate (R2=0.915), although the correlation coefficient of transpiration rate is also high with root production (R2=0.905). To justify the subject cab state than by reducing plant accessibility to water, the root production is increased to provide required water (Figure 4). The meaningful difference that was observed between moisture treatments in production of drought material of air organ and root (α=0.01) indicates this subject that separate from growth quality (diameter and high of air part), with increasing of transpiration rate, the drought produced material has increased, how many transpiration has happened per produced drought materials is the issue referred before.

Although the ratio shoot to root is a genetic phenomena, influenced by circumstance conditions completely distinct. High ratio of root to branch can be more effective in compatibility plant to drought conditions.

Obtained results of this research indicates that this relation is decreased by increasing drought stress, that is by supplying conditions to more plant transpirations, shoot ratio to root and also produced drought materials increase and finally, results in this ratio deduction in pot capacity treatment compared to other treatments.

Quoted from Walter (1967), Rahbar (1979) reports that annual production rate of air Haloxylon organs in Gharaghoum desert areas is 1/17 tons/h which its existence depends on underground waters, while underground organs in mentioned conditions exceed 2/11 tons/h. That is root ratio to air organ is about 1/8 in above-mentioned conditions. Obtained ratio in experimental conditions and in pot capacity moisture treatments, one-third of pot capacity and drought stress are respectively 1/04, 1/17, and 1/42 that has a diverse relationship with transpiration rate increase. Naturally, the rate of drought material in surface unite depends on plant density and age.

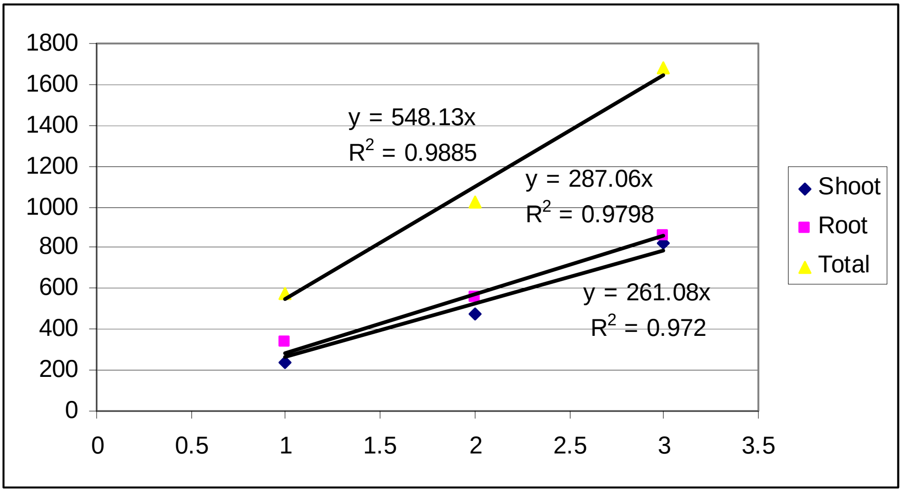

Figure 4: Drought weight correlation of air organs, roots, total air organs and root transpiration rate

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Resistance of Teak, Yellow Balau, Chengal and Keruing woods against marine borers attacks in Bandar Abbas (Persian Gulf) coasts

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Abstract

Four hardwood species including Teak (*Tectona grandis*), Keruing (*Dipterocarpus alatus*), Yellow Balau (*Shorea laevis*) and Chengal (*Balanocarpus heimii*) that are used in marine structure were treated by Creosote using Ruping method. The dimensions of samples were 20 x 7.5 x 2 cm and the retention were 188, 186, 331 and 40 kg/m^3 respectively. Both preservative treated and untreated samples of above species and also Beech (*Fagus orientalis*) and Oak (*Quercus castaneafolia*), were placed in seawater (Bandar abbas in Persian Gulf) according to IRG/WP-4432 (1985). After 6, 9, 21, 28, 48 and 168 months, samples were inspected according with recommendation of IRG/WP-4432 (1985) and ASTM D-2481.

Key word: marine borers, wood, treatment, Creosote, Celcure, durability

Introduction

In Iran, the common timber for Hull planking of wooden vessels is Teak wood that is imported from Myanmar (Burma) and India. Yellow Balau, Chengal and Keruing are using for other parts of wooden vessels such as keel and beams. Traditional Hull protection of vessels is coating the Hull planking above waterline with a combination of lime and lipid. It is renewed monthly in warm seasons. Otherwise the Hull planking timber will be destroyed completely in less than one year. This research has been done with the aim of investigating on treated and untreated durability of Teak, Balau, Keruing and Chengal wood species against marine borers in Bandar abbas (Persian Gulf) coasts of Iran.

Figure 1: Hull planking of wooden vessel by Teak wood

Figure 2: Removing lime and lipid combination from Hull planking

Materials and Methods

Preparation of test materials

According to recommendation of IRG/WP 4432 (1985), Samples 25mm x 75mm x 200 mm size heartwood of Teak (*Tectona grandis*) from Myanmar, Balau (*Shorea laevis*), Chengal (*Balanocarpus heimii*) and Keruing (*Dipterocarpus alatus*) from Malaysia that are used in wooden vessels construction, treated with Creosote using empty-cell method.
Treated samples of above species with control samples (no treated) of them and also Beech (*Fagus orientalis*) and Oak (*Quercus castaneafolia*) were arranged as "coil" by tying them with 10 mm diameter nylon threaded and these were exposed at about 1 meter below low tied level in Bandar abbas jetty.

Evaluation of test material

After 6, 9, 21, 28, 48 and 168 months exposing in seawater, wood samples dislodged and evaluated. In order to examine the test material, each of the supporting frames was removed from the water and the panels carefully scraped to remove the surface of the marine organism (Figure 3). During this process any coupons that had lost all strength or were missing were recorded .The remaining samples were carefully examined. Each sample was carefully inspected for surface deterioration and entrance holes indicating tunneling by marine borers. The surface was also carefully probed for areas with loss in strength that is indicative of tunneling. As a result of this inspection, each test sample was assigned a rating that is recommended by AWPA and ASTM standard D 2481-01 (Table 1).

Table 1: Rating scales developed by ASTM and AWPA

ASTM and AWPA Rating	Description
10	Sound, no-to-trace surface deterioration and no signs of tunneling.
9	Light surface attack or suspicion of tunneling
7	Moderate surface attack or clearly defined areas of tunneling, but board integrity generally sound.
4	Heavy attack with well-established area of tunneling, but board integrity maintained.
0	Board destroyed, missing at time.

Figure 3: Treated samples' frame was removed from the seawater and carefully scraped

Results and Discussion

Details of ASTM result of 168 months evaluation are shown in Table 2. According to these results, all the untreated Beech samples after 6 months (Figure 4) and untreated Oak samples after 9 months installing were completely destroyed. Because of assurance of marine borers present, in every inspection time, a set of new one of non-durable control sample was placed. After 6 months of installing, all of else samples were sound. Average degree of attack of untreated Teak and Balau samples after 9 months exposing were 7 and 5.5 and after 21 months, all the Teak samples were completely destroyed (Figure 5).

Figure 4: Heavy attack of untreated Teak sample

Among untreated samples after 28 months installation just Chengal were sound (Figure 6). The rest samples of other species after that completely destroyed. Although treated samples of all kinds of timbers after 21months exposure were sound with no damage of marine borers but the sample's surface had moderate soft rot (Table 3). After 168 months, treated Teak and Balau degrade to 7 (Figure 7) and 5.5 (Figure 8) respectively and treated Chengal (Figure 9) and Keruing (Figure 10) were sound.

Figure 5: Beech control samples degrade to 0 after 6 months

Figure 6: Untreated Chengal after 28 in seawater

Table 2: Index of samples' attack in Bandar Abbas coasts

Species	Rating after months										
	Untreated					Treated					
	6	9	21	28	46	6	9	21	28	48	168
Teak	10	7	0			10	10	10	10	10	7
Balau	10	5.5	2	0		10	10	10	7	5	4
Chengal	10	10	10	10	10	10	10	10	10	10	10
Keruing	10	-	2	0		10	10	10	10	10	10
Oak	10	0									
Beech	0										

Figure 7: Treated samples of Teak after 168 months exposing in seawater

Figure 8: Treated samples of Balau after 168 months exposing in seawater

Figure 9: Treated samples of Chengal after 168 months exposing in seawater

Figure 10: Treated samples of Keruing after 168 months exposing in seawater

Conclusion

- Natural durability of Teak and yellow Balau woods against marine borers in south coasts of Iran is less than one year and also they are not resistant against soft rot organism.
- Chengal wood is durable against marine borers attack in Bandar abbas coast (Persian Gulf).
- Creosote treated of Teak samples after more than 4 years exposing in Seawater were sound and after 168 months were attacked by marine borers.
- According to the field of Teak wood uses, for marine structure treated teak wood is recommended
- In launch (wooden vessel) structure, Yellow Balau and Chengal are used as KEEL, according to the results of this research, Chengal is better than Yellow Balau.

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Iran and its natural resources features

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Geographical and land characteristics

The Islamic Republic of Iran comprises a land area of 1.64 million km^2. It lies in the northern part of the temperate zone, between latitudes 25˚00' and 39°47' north and longitudes 44˚02' and 63˚02' east. The average altitude is over 1200 m. Iran is bordered by Turkmenistan, the Caspian (over 900 km of coastline), Azerbaijan, and Armenia in the north, Afghanistan and Pakistan in the east, the Sea of Oman and the Persian Gulf in the south (1850 km of coastline), and Iraq and Turkey in the west. The country features three main climatic zones:
Arid and semi-arid regions of the interior and far south, which are characterized by long, warm and dry periods, lasting sometimes over seven months, cover nearly 90 % of the country. The annual precipitation rate in such regions varies between 30 and 250 mm.
Mediterranean climate (mainly in the western Zagros mountains, the high plateau of Azerbaijan, and the Alborz moiuntains), characterized by warm, dry summers and cool, damp winters, with annual rainfall between 250 mm and 600 mm, and covering about 5 % of the land surface.
Humid and semi-humid regions (mainly in the Caspian, but also in west Azerbaijan and the southwest Zagros), with an annual precipitation rate of 600 mm to 2000 mm, also covering about 5 % of the land surface.
The six main watersheds are: Caspian; Persian Gulf and Sea of Oman, Uroomiyeh; Markazi (Central); Hamoun (eastern); and Sarakhs (northeastern). The total annual volume of precipitation in these main basins (28-year average, 1969-1997) is estimated at 408 thousand million m3.
The relief and climatic variations have given rise to five biomes namely:
Irano-Touranian (ITP): Arid and semi-arid plains and desert. Irano-Touranian (ITM): Arid and semi-arid mountains. Zagrosian (Z): Semi-arid Zagros mountains. Hyrcanian (H): Semi-humid and humid Arasbaran and Hyrcanian mountains and Caspian plain. Khalijo-Ommanian (KO): Dry southern coastal plains with high humidity.

Flora and fauna

Most of Iran is located in the Palaearctic realm and is considered the center of origin of many genetic resources of the world, including many of the original strains of commercially valuable plant species such as wheat, or medicinal and aromatic species. The southwest has some Afro-tropical features, while the southeast has some species from the Indo-Malayan sub-tropical realm.
Iranian habitats support some 8,200 species of plants (a conservative estimate), almost 1,900 of which are endemic. There are 12.4 million hectares of woodland,

and some 8,900 hectares of *Avicennia* mangroves along the Persian Gulf coast. Field studies confirm the presence of over 500 species of birds and 160 species of mammals.

The wetlands of Iran are globally significant. Large populations of migratory birds winter at these wetlands or use them on their way to and from wintering areas in Africa or the Indian Sub-continent. The marshes of the south Caspian lowlands in Iran's northwest are particularly important for over 20 species of ducks and geese while the mud flats of the Persian Gulf coast are of critical importance for shore birds, gulls and terns. A variety of marine mammals is observed in the southern waters of Iran.

Aquatic living resources

In Iran, the availability of water sources, such as rivers, springs and lakes, determines the scope, location and the sustainability of all human activities. Iran, with two of the world's most arid deserts, Dasht-e-Kavir and Dasht-e-Lut covering nearly one third of the country, is one of the most arid regions of the world.

Marine living resources play an important role in the food security of the country. Many of the aquatic resources are exclusive to the region, and therefore are of great importance in the context of biological diversity. Seafood protein comprises the largest proportion of protein consumption in the world. In Iran, fish consumption has increased in the last two decades, but it is still below the average global consumption, at about one third of international rates. The marine environment of Iran comprises two distinct water bodies, namely, the Caspian to the north, and the Persian Gulf and the Sea of Oman to the south.

The Caspian

The Caspian, the largest lake in the world, is located in the northern part of Iran. The area of the Caspian is about 422,000 km² with 6397 km coastline, of which more than 900 km is on the Iranian side. About 128 large and small rivers flow into the Caspian from Iran. The four largest are Sefidrood, Shalman, Shafarood, and Tonekabon. The highest salinity level, 12.7 parts per thousand (about one third of ocean salinity) is reached during the summer. The average water temperature in the coastal regions throughout the year ranges from 15.9 °C to 17 °C. Water temperature difference between the coldest area (in the northern parts of the Caspian) and the warmest area (in the south) is 4 °C during winter and 16 °C during summer.

Commercial fish: There are over 120 species of fish the southern Caspian, which are commercially divided into sturgeons and bony fishes. The bony fishes are

further divided into kilka (small fish of the family Clupeidae) and other species. The main commercial species are as follows:
Sturgeons: Beluga *Huso hus*o, Russian sturgeon *Acipenser guldenstadt*i, Iranian sturgeon *A. persicu*s, and Sevruga *A. stellatu*s. Iranian caviar, a famous and exclusive product worldwide, is produced by these species.
Kilkas: *Clupeonella delicatula, C. engrauliformis, C. grimm*i.
Other bony fishes are: Kutum *Rutilus frisii kutu*m, Mullets *Mugil auratus* and *M. salien*s, Carp *Cuprinus carpi*o, Bream *Abramis bram*a, Pike-perch *Lucioperca* lucioperca, Roach *Rutilus rutilus* and Salmon *Salmo trutta caspiu*s.

Southern waters

Two important water bodies are located along the southern borders of Iran. The Persian Gulf has an area of 232,850 km^2, which stretches 930 km from the Arvandrood River to the Sea of Oman Sea, with an average width of 288 km. The maximum water depth reaches 280 m with an average of 38 m. The Persian Gulf is one of the warmest areas in Asia. The highest and the lowest water temperatures recorded are 40 °C and 13.8 °C. Although the salinity of the Persian Gulf is alleviated through its connection to the open sea, it is still more saline than the open sea and ranges among 37 to 50 parts per thousand.
The Sea of Oman is surrounded by Iran in the north, the Indian Ocean in the east, and Oman in the southeast. The water temperature is lower than in the Persian Gulf, because of the water depth and its connection to the open sea. The highest and lowest surface water temperatures recorded are 23 °C and 19.8 °C respectively.
Different species of marine mammals are observed in the southern waters of Iran, including blue whale *Sibbaldus musculu*s, fin whale *Balaenoptera physalu*s, sperm whale *Physeter catodo*n, humpback whale *Megaptera musculu*s, common dolphin *Delphinus delphi*s, and black finless porpoise *Neomeris phocaenoide*s, and dugong *Dugong dugo*n.

Rivers

Iran has more than 3,450 rivers (including seasonal rivers). Within the six main watersheds there are 37 major river basins. The most important (with their average annual flow) are: Karoun River (Persian Gulf) 14,619 million m^3; Dez (Persian Gulf) 8,825 million m^3; Sefidrood (Caspian) 6,491 million m^3; Aras (Caspian) 2,317 million m^3; Zayandehrood (Markazi) 1,473 million m^3; Atrak (Sarakhs) 877 million m^3; Hirmand (Hamoun) 142 million m^3; the inflow to Lake Uroomiyeh (from all rivers) is 5,971 million m^3. These figures show clearly that the head of the Persian Gulf and the Caspian receive the highest flows, while the other four watersheds receive relatively low inflow. Rivers are natural habitats for aquatic species, small animals, water birds and a specialized flora.

Coastal regions

Coastal regions have important economic values. Many infrastructure facilities, such as harbors and power plants are constructed in these regions. A large variety of plant and animal species is observed in the coastal ecosystems. Mangrove forests are unique coastal wetlands, important fish as habitats. Marine turtles, many on the endangered list, live in these ecosystems. The following marine turtles have been observed in Iranian waters: Green Turtle *Chelonia myda*s, Leatherback Turtle *Dermochelys coriace*a, Olive Ridley Turtle *Lepidochelys olivace*a, Loggerhead Turtle *Caretta carett*a, Hawksbill Turtle *Eretmochelys imbricat*a, and Black Turtle *Chelonia aqaziz* (recently reported for the first time).

Forests and rangelands

Forests

Today forest areas cover some 12.4 million hectares (about 7.5 % of the area of the country) It has been estimated that this figure was about 18 million ha. 40 years ago. The forests of Iran can be classified in five zones as follows:

Caspian broadleaf deciduous forests consist of a rather narrow green belt in the north of Iran with a current area of about 1.9 million hectares, whilst it was some 3.4 million hectares 45 years ago. The yield of these forests has been reduced from 300 tons/ha. to 100-110 tons/ha. during the last four decades.

Arasbaran broadleaf deciduous forests are in the northwest of Iran, with many endemic species, very degraded, with only 60,000 hectares of the original 500,000 remaining.

Zagros broadleaf deciduous forest consists mainly of oak forest in the west of the country. This forest has an area of 5.5 million hectares and currently produces 8 tons/hectare biomass compared to 12 million hectares and 125 tons/hectare five decades ago.

Irano-Touranian evergreen juniper forests; almost all high-mountain environments of the country outside the deciduous forest areas, were covered by the Persian Juniper *Juniperus polycarpu*s. The area of these juniper forests was estimated at around 3.4 million hectares 50 years ago with a biomass of 30 tons/hectare. Currently the most optimistic figures are 500,000 hectares, with a biomass of 5 tons/hectare. In addition there are currently 2.5 million hectares of other evergreen forest.

Semi-savanna thorn forests, with an area of about two million hectares, cover narrow bands in the west of the country and a wider belt in the south along the Persian Gulf and the Sea of Oman. The biomass of these forests is currently estimated at 2 t/ha. Unfortunately no data are available on the former area and biomass of these forests.

Rangelands

Rangelands comprise some 54.8 % of the total land area of the country, covering more than 90 million hectares. They play the most important role in soil protection. The condition of 16 % of the rangelands is excellent, whereas 66% are in favorable to medium condition and 18 % are in poor and degraded form. They can be classified in three types:
Summer rangelands: Production per hectare 580 kg of dry biomass. Mainly in humid and semi-humid zones of the Caspian and high plateau of Azerbaijan. Area: 14 million hectares.
Winter rangelands: Production per hectare 184 kg of dry biomass. Mainly in the Mediterranean and semi-arid zones in western Zagros and Alborz mountains. Area: 60 million hectares.
Arid rangelands: Production per hectare 52.5 kg of dry biomass. Mainly around central arid zones. Area: 16 million hectares.

Wetlands

Wetlands occupy the transitional zone between permanently wet and generally dry environments, sharing characteristics of both aquatic and terrestrial environments but not belonging exclusively to either. Under the Ramsar Convention (adopted at the Iranian city of Ramsar on the Caspian coast in 1971), wetlands are defined as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters". The Convention also provides that they "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands". Therefore, wetlands are everywhere, and it is probably simplest to think of the Convention as having an interest in the management of all water ecosystems (whether permanent or temporary, natural or artificial) which are not deep marine waters. Iran has designated 20 sites, covering about 0.7 % of the country for the Ramsar "List of wetlands of international importance.

The national protected area system

The protected area and reserve system provides the core areas for biodiversity conservation. This reserve system is not sufficient in itself for long-term conservation, and must be harmonized with conservation efforts in other areas and land-uses. In Iran, areas protected by the Department of Environment cover 8.2 million hectares (about 5 % of the land area, Annex 1). The Department of Environment's goal is to increase this proportion to 10% of the national land area. Limited tourism and research occurs in these areas. Details of the four categories of protected area managed by the Department of Environment are given below.
In addition the Forests and Rangelands Organization of the Ministry of Jehad-e-Sazandegi manages 131 reserves with a total area of over 111,000 ha. Of these, 19 are Natural Forest Parks, 91 are Forest Reserves, and 21 are Natural Parks. Furthermore, the other ministries also manage a number of protected areas.

National Parks (11 sites)

These represent some of the most outstanding examples of nation's geological, ecological, historical, archaeological and scenic features. Management includes minimum manipulations necessary for ecological conservation. National Parks and National Nature Monuments serve dual functions of conservation and ecotourism, and are typically selected as outstanding examples of biodiversity/ecology, and geological/scenic resources that are of national and global importance. In recognition of their dual function, some park infrastructure is constructed, but under strict conservation and architectural control. The total area is 1.3 million hectares covering 0.79 % of the national land surface.
From both ecological and economic perspectives, the most important national parks are Golestan and Uroomiyeh. Both enjoy a wider range of ecosystems than the other parks of Iran, and have potential for increased tourism. Golestan is located in the northeast of Iran along the Caspian, and is characterized by temperate to humid deciduous and hardwood forests, while Uroomiyeh, one of the largest deep saline lakes in the world, is located in the province of Western Azarbaijan.

Wildlife Refuges (25 Sites)

There are 25 wildlife refuges, which currently cover about 1.9 million hectares, 1.16 % of the national land area. These habitats are protected for their native wildlife. Hunting, fishing and capturing of wildlife are prohibited. These areas contain public-use areas in which farming and grazing are permitted.

Protected Areas (47 sites)

Protected areas support representative ecosystems with nationally significant wildlife, but do not justify the intensity of management of a fully-fledged national park. These are areas with single or multiple use objectives, with a total area of 5.3 million hectares, 3.23 % of the national land area. They may cater for ecological, scientific, economical, educational, cultural and recreational interests. Human settlements are often present, and it is proposed to esTablelish integrated management plans governing the present human settlement, grazing and agriculture.
Five rivers, namely Chalus (Caspian watershed), Karaj, Lar, Sardab and Jajeroud (all in the Central watershed) are also protected by DoE.

National Nature Monuments (5 sites)

These are small areas, with unusual phenomena of scientific, geological, historical and/or natural history interest. Management includes maintaining certain species or special features.

Biosphere Reserves (9 sites)

Biosphere Reserves are areas of terrestrial and coastal/marine ecosystems, or a combination thereof, which are internationally recognized within the framework of UNESCO/MAB (Man and Biosphere) program. Biosphere Reserves should preserve and generate natural and cultural values, through management that is scientifically correct, culturally creative and operationally sustainable. All Biosphere Reserves enjoy protection under one of the national protected area categories listed above. The Islamic Republic of Iran has 9 sites with 1.9 million ha area.

Tourism and Recreation

Iran, benefiting from different ecosystems, has good tourist potential. The climatic variations combined with natural ecosystems and landscapes create unique natural scenery. Outdoor recreation activities are popular and widespread among Iranians. In spite of the development of modern life and urbanization, many people prefer to seek fresh air and nature at the weekend. But outdoor recreation has not yet been included in management policies, and there is no comprehensive management plan on this subject. As a result, destruction of nature and natural scenery occurs in the suburbs of large cities, because of a lack of public awareness. There has been very limited public education for nature utilization and people are not familiar with the values of the biodiversity. Illegal construction of houses and villas in naturally sensitive areas has also exerted pressure on ecosystems.

Despite continuous efforts to attract tourists over the last 60 years, successive governments have not been successful. Eco-tourism is one of the developing sectors in global economy. Tourists can enjoy Iran's rich biological diversity, including the forests and the Caspian in the north, the deserts of the central regions, mangrove forests in the south, as well as the coral reefs and exotic fish in the Persian Gulf. The income earned by ecotourism can be partially spent on preservation of ecosystems.

The issue of tourism was mentioned in the first (1989-1994) and second (1994-1999) Five-Year National Socio-Economic Development Plans, but in recent years, the budget allocated to tourism was not fully spent. Generally, it can be concluded that tourism has not been successful in these five-year plans. Some of the reasons for this failure are as follows:

The role of the private sector in this industry is not well defined.

Tourism is not looked upon as an industry among decision-making government bodies.

Lack of international advertisement.

Lack of well-trained human resources.

The efforts of the government are directed towards ways of promoting tourism without sacrificing cultural and environmental values.

Iran and Palearctic terrestrial ecoregions

The **Palearctic** or **Palaearctic** is one of the eight ecozones dividing the Earth surface.

Physically, the Palearctic is the largest ecozone. It includes the terrestrial ecoregions of Europe, Asia north of the Himalaya foothills, northern Africa, and the northern and central parts of the Arabian Peninsula.

Central Asia and the Iranian plateau are home to dry steppe grasslands and desert basins, with montane forests, woodlands, and grasslands in the region's high mountains and plateaux. In southern Asia the boundary of the Palearctic is largely altitudinal. The middle altitude foothills of the Himalaya between about 2000-2500 m form the boundary between the Palearctic and Indomalaya ecoregions, and further east in eastern Asia, high mountain ranges form tongues of Palearctic flora and fauna in northern Myanmar and southern China. Isolated small outposts (sky islands) occur as far south as central Myanmar (on Mt. Victoria, 3050 m), northernmost Vietnam (on Fan Si Pan, 3140 m) and the high mountains of Taiwan.

Palearctic Temperate broadleaf and mixed forests edit	
Caspian Hyrcanian mixed forests	Azerbaijan, Iran
Zagros Mountains forest steppe	Iran

Palearctic Temperate coniferous forests edit	
Elburz Range forest steppe	Iran

Palearctic Temperate grasslands, savannas, and shrublands edit	
Eastern Anatolian montane steppe	Armenia, Iran, Turkey
Middle East steppe	Iraq, Syria

Palearctic Flooded grasslands and savannas edit	
Tigris-Euphrates alluvial salt marsh	Iraq, Iran

Palearctic Montane grasslands and shrublands edit	
Kopet Dag woodlands and forest steppe	Iran, Turkmenistan
Kuhrud-Kohbanan Mountains forest steppe	Iran

Palearctic Deserts and xeric shrublands edit	
Azerbaijan shrub desert and steppe	Azerbaijan, Georgia, Iran
Badkhiz-Karabil semi-desert	Afghanistan, Iran, Tajikistan, Turkmenistan, Uzbekistan
Central Persian desert basins	Afghanistan, Iran
Kopet Dag semi-desert	Iran, Turkmenistan
Rigestan-North Pakistan sandy desert	Afghanistan, Iran, Pakistan
South Iran Nubo-Sindian desert and semi-desert	Iran, Iraq, Pakistan

Elburz Mountains:

Major mountain range in northern Iran, 560 miles (900 km) long. The range, most broadly defined, extends in an arc eastward from the frontier with Turkmenistan southwest of the Caspian Sea to the Khorasan region of northeastern Iran, southeast of the Caspian Sea, where the range merges into the Aladagh, the more southerly of the two principal ranges there. More commonly, however, the westernmost part of the range is called the Talish (Talysh, Talesh, or Tavalesh) Range, or the Bogrov Dagh; the Elburz Range, in its strictest sense, forms part of the central stretch of the chain, which also includes Iran's two highest peaks, Mount Damavand and Mount Alam. The Elburz mountain system traverses virtually all of the northernmost portions of Iran from east to west.

The Elburz chain is not as truly alpine (i.e. resembling the European Alps) in its structure as is often suggested. On the one hand, continental conditions regarding sedimentation are reflected by thick Devonian sandstones (formed 345,000,000 to 395,000,000 years ago) and by Jurassic (136,000,000 to 190,000,000-year-old) shales containing coal seams. On the other hand, marine conditions are reflected by Permo-Carboniferous (225,000,000- to 345,000,000-year-old) strata that are composed mainly of limestones, as well as by very thick beds of green volcanic tuffs and lavas. Orogenic (mountain-building) phases of importance date from the younger Tertiary (Miocene and Pliocene epochs) Period (between 2,500,000 and 26,000,000 years ago). Over large areas they produced only a loose folding; but in the Central Elburz a number of folds were formed into blocks thrust mainly southward but in places northward, with cores made of aleozoic rocks. Structurally and topographically, the Elburz system is less clearly defined on the southern than on the Caspian (northern) side of the chain, since various off-branching elements interconnect it on the southern side with the adjoining Iranian Plateau.

The Western Elburz Range runs south-southeastward for 125 miles (200 km). Varying in width from 15 to 20 miles (24 to 32 km), it consists of a single asymmetric ridge, the long slope facing the Caspian. Few of its peaks approach or exceed 10,000 feet (3,000 m) in height. There is a low pass west of Astara, near the Turkmenistan frontier, 5,000 feet (1,500 m) above sea level. The Safid River, formed by the junction of the Qezel Owzan (Qisil Uzun) and Shahrud rivers, is the only river to cross the whole width of the chain: its gorge, giving access to the low pass of Qazvin, offers the best passage through the mountain chain, although by no means an easy one, between the Gilan region on the shores of the Caspian and the inland plateau to the south.

The Central Elburz is 250 miles (400 km) long. East of the longitude of Tehran, which lies to the south of the range, it reaches a width of 75 miles (120 km). Located among the longitudinal valleys and ridges of the range are some important centres of settlement, with the towns of Deylaman, Razan, Kojur, and Namar located on the Caspian side and Emamshahr (formerly Shahrud), Lar, Damavand, and Firuzkuh on the southern side. There are likewise many gorges, by which the rivers find their way down one or another of the slopes. Only two passes allow a relatively easy crossing in a single ascent—these are the Kandevan Pass, between the Karaj and the Chalus rivers, and the Gaduk Pass, between the Hableh and the Tala rivers. The main divide runs generally south of the highest crest, which—with the exception of the towering and isolated cone of the extinct volcano Mount Damavand (18,386 feet [5,604 m])—culminates in the glaciated massif of Takht-e Soleyman, which rises to more than 15,750 feet (4,800 m).

The Eastern, or Shahkuh, Elburz runs about 185 miles (300 km) in a northeasterly direction. Since two ranges branch off on its southern side and no compensatory elements appear on the northern side, its width dwindles to less than 30 miles (48 km). With the exception of the Shahkuh Range proper (which reaches an elevation of 12,359 feet [3,767 m]), the chain decreases in height toward the east. Longitudinal valleys are found less and less frequently east of the Shahkuh. There are several passes at low elevations.

The Caspian and the inland, or southern, slopes of the Elburz differ markedly from each other in climatic and vegetational aspects. The Caspian slope has a distinctly humid climate, thanks to northerly air movements, enriched with moisture from the sea, which collide with the steep faces of the mountains to cause precipitation. This precipitation amounts to more than 40 inches (1,000 mm) annually in the lowlands of the Gilan region and is even more plentiful at higher elevations. Although it decreases toward the east, it still suffices to nourish a humid forest for the whole length of the chain on the Caspian side, where the soils are mostly of the brown-forest type. The natural vegetation of this slope grows in distinct zones: the luxuriant Hyrcanian forest on the lowest levels; a beech forest in the middle zone; and a magnificent oak forest from the elevation of 5,500 feet (1,700 m) up to the levels where gaps in the divide allow the moist air to overflow into the inland basins. In some sheltered valleys there are extensive stands of wild cypress; sheltered valleys adjacent to the Safid River constitute the only olive-growing areas of note in Iran.

The southern slope of the Elburz, by direct contrast, shares the arid character of the Iranian Plateau. Annual precipitation varies between 11 and 20 inches (280 and 500 mm) and is very irregular. The soils are mostly of the type associated with steppe (treeless, grassy, or shrubby) vegetation. The slope has become even more steppe-like ever since the almost complete destruction of its original dry forest of junipers.

The Hyrcanian tigers for which the Caspian forests were famous are now very rare; but other wild cats, such as the leopard and the lynx, are still numerous in the Elburz. The bear, the wild boar, red and roe deer, the mouflon (wild mountain sheep), and the ibex are also present. Eagles and pheasants are noTable among birds.

While large areas of the Elburz Mountains are almost uninhabited—some being occupied
only by nomads and others having been depleted by Turkmen raids in the 19th century—there are still several well-settled districts, including Deylaman, Alamut, Talaqan, and Larijan (at the foot of Mount Damavand). The landscape of the Caspian slopes is characterized by forest clearings with shingle-roofed loghouse villages and by lush fields and pastures. The landscape of the inland slopes is of the oasis type. Extensive grain cultivation occurs on both slopes, and cattle raising occurs on the Caspian side. Alpine pastures, seasonally dotted with flocks of sheep, cover an extensive zone yet higher. The land-distribution pattern prevailing in the Elburz includes a high proportion of peasant ownership. The holdings often are much-fragmented.

Many of the traditional ways of livelihood of the mountaineers, including charcoal burning (now prohibited because of devastation of the forests), the transportation of goods (especially of rice and of charcoal for Tehran) by pack animals, and the working of hundreds of small coal mines, have been displaced by the 20th-century modernization of Iran.

Apart from the main line of the trans-Iranian railroad, which links Tehran with Bandar-e Torkeman via the Gaduk Pass, there are several asphalted roads across parts of the Elburz. From west to east, these run between Ardebil and Astara, between Qazvin and Rasht, between Tehran and Chalus, between Tehran and Amol (via Damavand); between Tehran and Babol (via Firuzkuh), and between Emamshahr and Gorgan (via Kotal-e Zardaneh Pass).

The wild (natural or original) forests of the Elburz Mountains cover more than 8,000,000 ac (3,000,000 ha), of which some 3,000,000 ac can be exploited commercially for timber and other wood. There are also a few modern coal mines, as well as some deposits of iron and other ores. But most important is the water of the rivers, which is used for irrigation, for generating hydroelectric energy, and for supplying the fast-growing Tehran. Spectacular dams have been built. These include the Safid Rud Dam, used for the irrigation of the Safid Rud Delta; the Karaj Dam and the Jajrud Dam, used mainly for supplying water to Tehran and partly for irrigation; and a series of dams on other rivers of the Mazandaran ostan also used for irrigation.

Elburz range forest steppe

+ WHERE
northern Iran

+ BIOME
Temperate Coniferous Forests

+ SIZE
24,400 square miles (63,300 square kilometers) -- about the size of West Virginia

+ CONSERVATION STATUS
Critical/Endangered

Located in northern Iran along the southern and eastern slopes of the Elburz Mountain range, this ecoregion is characterized by an arid climate with cold winters and low annual precipitation. Juniper forest once dominated the ecoregion but has largely retreated to less accessible, higher altitudes on the mountain slopes.

Eagles, gazelle, leopard, wild sheep, wolves and an impressive variety of birds can still be found in relative abundance in the eastern reaches of the ecoregion.

Location and General Description

The Elburz Range Forest Steppe ecoregion occupies the southern and eastern slopes of the Elburz Mountain range in northern Iran. The mountains extend approximately 1,000 km (600 miles) in an arc from Astara (at the edge of the Azarbaijan region) along the southwestern and southern coasts of the Caspian Sea and into the northeast reaches of the country as far as Jajarm.

The ecoregion is bounded to the north by the Caspian Hyrcanian Mixed Forest ecoregion that occupies the northern and western slopes of the Elburz range and the southern Caspian coastal plain. To the northwest, it runs into the Talish-Azerbaijan Mountains, and to the south, it faces Iran's central plateau. To the east, it runs nearly to the border with Turkmenistan and then extends southeast for a distance of about 250 km (160 miles); it then hooks back again in to the northwest for approximately another 140 km (90 miles).

Elevation generally ranges from 2,000 m to 4,000 m, with some peaks exceeding 5,000 m; Mount Damavand, a dormant volcano, is the highest peak at 5,671 m. The mountains are composed of limestones, shales, sandstones and tuffs, including 3,000m tuff beds on the southern slopes. Metamorphic and pre-eruptive rocks are widespread, with schists, marbles, amphybolite and granitic rocks in the central Elburz (UNEP, 1989a).

Facing Iran's arid central plateau region, the ecoregion receives only 150 to 300 mm of precipitation annually (Anderson 1999*)*, mostly in the winter. The mean annual temperature ranges from 15-18 degrees C, with extreme winter temperatures. Juniper (*Juniperus polycarpos)* forest once covered the southern slopes of the Elburz Mountains, as evidenced by numerous remnants, and could be found up to altitudes of 1,900 m to 2,000 m (Zohary, 1973). There is also evidence that the juniper forest steppe in Iran once occupied not only larger extents of the Elburz-Khurasan mountains but also much of the territory to the south, including some of the higher ranges and peaks in the Central Plateau (Zohary, 1973).

The typical shrub story in the juniper steppe forests of this area may include pistachio (*Pistacia atlantica)*, cotoneaster (*Cotoneaster racemiflora*), *Crataegus* spp., maple (*Acer turcomanicum*), almond (*Amygdalus* spp.), and other species. The groundcover commonly includes communities of *Artemisietea herbae-albae iranica* or the tragacanthic (thorn-cushion) *Astragaletea iranica.*

In more recent times, however, the vegetation has been heavily disturbed, and juniper forest tends to be restricted to the higher altitudes of the southern slopes. The lower slopes now reportedly support a zone of *Pistacia atlantica,* while *Artemisia*, *Cousinia*, and other genera are now more common in the degraded areas (Breckle 1983).

Biodiversity Features

The montane steppe supports a large population of wild sheep (Ovis ammon), and goitered gazelle (Gazella subgutturosa) are found on the plains in the southeast. These and other prey species sustain leopard (Panthera pardus), jungle cat (Felis chaus), wolf (Canis lupus), jackal (Canis aureus) and red fox (Vulpes vulpes). Other species include brown bear (Ursus arctos), stone marten (Martes foina), wild boar (Sus scrofa), red deer (Cervus elaphus) and roe deer (Capreolus capreolus) (UNEP, 1989a; UNEP, 1989b). The antlers of Cervus elaphus have long been sought by trophy hunters and for the creation of knife and dagger handles; Cervus elaphus is also valued for its venison (Humphreys & Karom, 1995).

The lesser spotted eagle (*Aquila pomarina*) and the golden eagle *(A. chrysaetos*) breed in the forested hills and mountain areas in this ecoregion (Humphreys & Kahrom, 1995). At least 151 species of avifauna have been recorded in the Golestan Biosphere Reserve, including most noTablely the honey buzzard (*Pernis aviporus*), goshawk (*Accipiter gentilis*), black vulture (*Aegypius monachus*), bimaculated lark (*Melanocorypha bimaculata*) and Caspian snowcock (*Tetraogallus caspius*). The site is also one of the few breeding areas in Iran for little bustard (*Tetrax tetrax*) and woodpecker (*Dryocopus martius*) (UNEP, 1989b). Certain taxa of lizards occur on the southern slopes of the Elburz Mountain range where winter and spring precipitation exceeds 200 mm annually; these include *Laudakia caucasia, Trapelus ruderatus*, and others (Anderson, 1999).

Current Status

This area has suffered a significant reduction in natural vegetation. Juniperus polycarpos forest, which once covered the southern slopes of the Elburz Mountains, exists now largely in scattered remnants and at higher altitudes in relatively inaccessible areas (Zohary, 1973). Although J. polycarpos is resistant to drought, heat and cold, it is a slow-growing tree and therefore juniper forests are difficult to re-esTablelish once cut.

The loss of vegetation on the sloped areas commonly results in soil erosion and an overall reduction in vegetation coverage, as well as in changes to the vegetation composition. Thorny shrubs, dwarf-shrubs and thorn-cushions increasingly dominate plant communities as species that can better withstand grazing and pruning gain a selection advantage (Frey & Probst, 1986).

The Golestan National Park and the adjacent Ghorkhod Protected Area, both designated as a Biosphere Reserve in 1976, lie on the mountainous divide between the Caspian and the arid interior region, at the easternmost tip of the Elburz Range. Covering an area of about 125,895 ha, the reserve ranges in altitude from 380 m to 2,410 m and is home to many mammals, avifauna and reptiles (UNEP, 1989).

Types and Severity of Threats

Overharvesting of fuelwood and overgrazing are among the primary factors behind the degradation of the natural vegetation and the soils in this ecoregion (Frey & Probst, 1986).

Justification of Ecoregion Delineation

This ecoregion boundary was determined using Zohary's (1973) geobotanical map of the Middle East and corresponds to the *Juniperus polycarpos* steppe forest remnants within the Iranian steppe forest climax zone.

Caspian Hyrcanian mixed forests

+WHERE
Central Asia: Northern Iran into southern Azerbaijan

+BIOME
Temperate Broadleaf and Mixed Forests

+SIZE
21,300 square miles (55,100 square kilometers) -- about twice the size of Maryland

+CONSERVATION STATUS
Critical/Endangered

Gorgan, Iran

If you were to travel along the northern stretches of Iran and just into Azerbaijan, you'd discover a region of lush forests covering the hillsides and coastal plain along the southern shores of the Caspian Sea. Climb up these hillsides and you'll discover a jungle-like habitat of oak beech, hornbeam, ash, English elm, and maple trees entangled with many climbers and low shrubs, and inhabited by an assortment of animals, including both red and row deer.

Special Features

The Caspian Hyrcanian Mixed Forests experience abundant rainfall and snowmelt that runs off the north slope of the Elburz and Talish mountains. These lush forests sweep down to the coastal plain south of the Caspian Sea, where they eventully yield to coastal lagoons, swamps, and salt marshes. The climate in this zone is temperate, with wet summers and mild winters much like those of the Atlantic coast of Europe.

Wild Side

Pheasants nest within the thick groundcover under the leafy trees. Wetlands along the coast of the Caspian Sea provide wintering habitat and migration rest areas for birds that include Dalmatian pelicans, pygmy comorants, white-headed ducks, and imperial eagles. Pelicans, herons, flamingos, swans, and other migratory birds also frequent the southern coast of the Caspian Sea. This ecoregion is also important as a wintering area for the slender-billed curlew, considered the most threatened bird species in the western Palearctic. The snorts and stamping of wild boars can be heard within the dense thickets and reed beds of the coastal marsh. Otters, water voles, and pine martens silently creep about the riverine areas, as golden jackals and wildcats roam this ecoregion, searching for prey.

Cause for Concern

Gray poplar, Caucasian wingnut, and Caucasian alder trees once lined the river banks within the coastal plain, but most of the lowland forest of this ecoregion has been cleared for agriculture or urban development. Invasive plants such as the spiny maquis have taken over in areas of secondary growth, especially in areas of selective tree felling. Coastal habitats have been drained and turned into agricultural fields. Only a few patches of native forests and wetlands remain

Zagros Mountains

The **Zagros Mountains** make up Iraq's and Iran largest mountain range. They have a total length of 1500 km from western Iran, specifically the Kurdistan region on the border with Iraq to the southern parts of the Persian Gulf. The range ends at the Straits of Hormuz. The highest point in the Zagros range is Mt. Dena at 5098 m/16998 feet.

Formed by collision of the Eurasian and Arabian tectonic plates, the range extends for hundreds of kilometers. Stresses induced in the Earth's crust by the collision caused extensive folding of the preexisting layered sedimentary rocks. Subsequent erosion removed softer rocks, such as mudstone (rock formed by consolidated mud) and siltstone (a slightly coarser-grained mudstone) while leaving harder rocks, such as limestone (calcium-rich rock consisting of the remains of marine organisms) and dolomite (rocks similar to limestone containing calcium and magnesium). This differential erosion formed the linear ridges of the Zagros Mountains. The depositional environment and tectonic history of the rocks were conducive to the formation and trapping of petroleum, and the Zagros region is an important part of Persian Gulf production.

Salt domes and salt glaciers are a common feature of the Zagros Mountains. Salt domes are an important target for oil exploration, as the impermeable salt frequently traps petroleum beneath other rock layers. Since the northern part of

Zagros encompasses much of the historic Kurdish regions of Middle East, it has also been referred to as *Kurdish Mountains* or *Kurdistan Mountains*.

Type and age of rock

The mountains are divided into many parallel sub-ranges (up to 10, or 250 km wide), and have the same age and orogenesis as the Alps. Iran's main oilfields lie in the western central foothills of the Zagros mountain range. The highest point of the range is Zard Kuh (4548 meters). The southern ranges of the Fars Province have only somewhat lower summits of up to 4000 m. They contain some limestone rocks showing abundant fossils. Special surveyor expeditions sometimes come across fossil snails of 2 kilograms at altitudes of 3000 metres. It is now hard to imagine that these high summits were indeed part of the deep ocean some 50 million years ago. The second highest peak is named Dena.

The Kuhrud Mountains form one of the parallel ranges at a distance of approx. 300 km to the east. The area between these two impressive mountain chains is home to a dense human population that lives in the intermediate valleys which are quite high in altitude with a temperate climate. Their rivers, which eventually reach salt lakes, create fertile environments for agriculture and commerce.

Zagros in history

Signs of early agriculture date back as far as 9000 BC to the foothils of the Zagros Mountains, in cities later named Anshan and Susa. Jarmo is one archaelogical site in this area. Shanidar, where the skeletal remains of Neanderthals have been found, is another.

Some of the earliest evidence of wine production has been discovered in the Zagros Mountains; both the settlements of Hajji Firuz and Godin Tepe have given evidence of wine storage dating between 3500 and 5400 BC.

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Compatibility experiment of 14 black poplar varieties (*Populus nigra*) for introducing of superior varieties in Kurdistan (Iran), (First 5 years)

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Abstract

In this trial 14 black Poplar varieties were studied in the border land of Sanandaj during 2001-2005. Planting of cuttings were accomplished in early March of 2001 and transplanting of saplings and planting of them were conducted in late March of 2002with space of 3*3 meters based on randomized complete block design (RCBD) with 3 replications.

Results showed that first and second years after planting were" relative establishing phase "of saplings and mentioned years showed a very low portion of the total diameter breast height (D), tree height (H) and cumulative wood volume (CWV) growths in latest year (respectiveley 11 % , 32 % and 0.4 %). Total mean of D, H and CWV in end of trial was 11.7 cm, 7.71 m and 0.0473 m^3 respectively.

Analysis of variance showed significant differences at $p \leq 0.01$ among Poplar varieties for all studied traits. This provides a very suitable background for selection of superior varieties. Dancanns test ($p \leq 0.01$) for Poplar varieties showed that varieties of *P.n. 56.75, P.n.62.140, P.n. 56.52 and P.n. 63.135* respectively with diameter breast height 15.43, 13.62, 12.60 and 12.35 cm, tree height 9.02 , 8.26, 8.82 and 7.87 m, CWV for each tree in end of experiment 0.0858, 0.0635, 0.0594 and 0.05252 m^3 per tree, average year volume (AV) growth with 0.02145, 0.01586, 0.01484 and 0.01313 m^3/y for each tree and mean of AV per hectare of 23.83, 17.62, 16.49 and 14.59 $m^3/y/ha$ were superior varieties among studied varieties in first stage.

Superior varieties have had crown diameter (CD) about 1.41-1.96 m, general juiciness of medium-good, mainly safe from a contamination by pests view point and mostly straight trunks with 1-2 main branches. The wood yield of superior varieties was about 1.13-2 times as much as total varieties mean and 1.5-2.5 times as much as 2 standard varieties (*P.n.Saghez* and *P.n.*Grizah) mean.

Kind and so mostly order of superior varieties in the 2, 3, 4 and 5th year of trial was similar. If this point be same in the second phase of experiment (2006-2010), it will be an important result from view point of to decrease of time for introduction of Poplar variety in the Comparative Popleteum (from10 to 5 years).

Key words: Compatibility, Black Poplar (*Populus nigra*), Wood Volume Comparative, Popleteum

Introduction

Extension of wood production by "wood farming" is a very important and suiTable way to grant of increaser demands for wood. Because of limitation of natural forest resources and increaser extension of wood industries, wood technologies and commercial view to wood, recently indeed wood farming is necessary. This requirement in Iran, alike other countries of the world, is an important demand and for answer to this evaluating of proper potentials of different parts of country from view point of wood production is necessary. Kurdistan is located in the west of Iran and in order to relive a suitable ecological conditions such as over than 14 billion m^3 annual rainfall, considerable permanent rivers and riversides and river lands susceptible for wood farming particularly traditional deep seated experiences of Poplars and Willows planting (now there are about 14000 ha and 20000 ha under planting of Poplars and Willows land varieties respectively) with about over than 150000 m^3 annual Poplar wood production, is a one of the most important areas of Iran from view point of wood production. Thus added on present areas under planting of Poplars, it can be developed to 1.5-2.5 multiple in Kurdistan. Furthermore if Poplar land varieties substitute by improved varieties, present wood production will increase at least two times.

Recently two important difficulties, related with wood production in Iran and Kurdistan, are containing of:

1 - decreasing trend of areas of poplar planting, because of higher gain of other crops such as Alfalfa (*Medicago sativa*), Corn (*Zea mays*), Potato (*Solanum Tubersum)* etc., higher governmental supporting of these crops in comparison with Poplar from view point of buy security and other aspects, earlier gaining, lower natural risks such as drought stress and others difficulties, farmers prefer to substitute the Poplar farm by mentioned crops. Decrease ratio of Poplar under planting is varying in different areas in Iran. In west provinces as main areas of Poplar farming it is about 20 % in Kermanshah, Hamedan and Kurdistan provinces (report of Gharb Paper Industries Company, 2001) to 40 % in Zanjan province (Assadi and Bagheri, 1999).

2 - using of traditional methods of farming (dense planting, disinclination to using of fertilizers, etc.) and particularly using of traditional and unimproved varieties with maximum annual wood production about 10-12 m^3 per year per hectare.

To resolve of portion of mentioned problems, a national programming of breeding of Poplar in Iran is necessary so that to be resulted in release of a number of suiTable, resistant to biotic and non biotic stresses, with high wood production, compatible varieties.

Primary experiments similar to collection of territorial Poplar germplasm, evaluating of them and selecting of proper high production genotypes and breeding for suiTable characteristics and introducing of them besides of introduction of exotic superior Poplar varieties and survey of their wood production and compatibilities to different areas, have accomplished in many countries of world (Modir Rahmati, 1997; Shiji, 1998 and Weisgerber, 1989). In the superior countries from view point of Poplar farming such as the United States of America, Germany, Italy, turkey and recently China etc. such these efforts have been resulted to release many improved high wood production varieties. Compatibility Survey of 245 endemic and exotic varieties of Poplar in Germany during 1951-1971 resulted to selecting and introducing of 25 high wood production and compatible varieties (Frohlich, 1973). In Turkey Compatibility studies of endemic and exotic varieties of Poplars belong to *nigra* and *euramericana* have accomplished and superior varieties have introduced to planting (Basimevi, 1988). Also A study of 236 varieties of Poplar in south east of Turkey resulted in introducing of 31 superior varieties with 47 % and 28 % supplementary growth for diameter and height growth respectively (Toplu, 1999). In China growth and compatibility of many varieties have been evaluated and a number of superior varieties have been introduced (Shiji, 1998).

Poplarresearches in Iran has begun since about 1960 with introduction a number of exotic varieties belong to *Aigeiros* Duby. and *Leuce* Duby. sections. Compatibility studies of introduced varieties in different part of country has been major effort of Poplar research program as yet. In study of 45 endemic and exotic varieties of Poplars in the Alborz research station (Tehran) at primary stage of compatibility survey (selection nursery) 27 varieties have selected (Modir Rahmati, 1997) and after compatibility survey (10 years) a number of superior varieties with 20-30 m^3 per year per hectare wood production and resistant to contamination by pests such as *Populus nigra 42.78*, *P.n. betulifolia* and *P.n. 47.3* have introduced (Ghasemi, 1999). Compatibility study of 20 varieties of black Poplar in west Azerbijan during 10 years by Salari (1999) resulted to introducing of 3 superior varieties in clouding P.n. 62.154, P.n. 56.75 and P.n. 62.172 with 27.5, 25.7 and 16.39 m^3 per year per hectare wood yield respectively. Results of Compatibility experiment of 18 varieties in Kermanshah province showed that *P.n. 62.171* and *P.n. 63.135* with 27.32 and 25.79 m^3 per year per hectare wood yield were superior varieties (Hemati and Modir Rahmati, 2002). Same study has accomplished in the southern Khorasan (Bojnourd) and results showed that species belonging to *deltoids*, *nigra* and *euramericana* have had high wood yield respectively (Bozorgmehr et al., 2001).

The objective of the present work was to recognizing and introducing of higher wood production and compatible varieties of 14 Poplar varieties (selected from20 black Poplar varieties that studied in selection nursery) in Compatibility Popleteum of Sanandaj, Kurdistan of Iran.

Material and Methods

The experiment was performed with 14 black Poplar varieties (Table 1) in Sanandaj, Kurdistan of Iran during 2001-2005 in borderlands of Geshlagh River with conditions as - mentioned in Table 2.

Table1: Black Poplar varieties

Abbreviations	Variety Name
P.n.56.72	*Populus nigra 56.72*
P.n.M	*Populus nigra M(disguised)*
P.n.56.32	*Populus nigra 56.32*
P.n.63.135	*Populus nigra 63.135*
P.n.56.75	*Populus nigra 56.75*
P.n.betulifolia	*Populus nigra betulifolia*
P.n.62.149	*Populus nigra 62.149*
P.n.42.53	*Populus nigra 42.53*
P.n.56.52	*Populus nigra 56.52*
P.n.62.154	*Populus nigra 62.154*
P.n.62.140	*Populus nigra 62.140*
P.n.62.171	*Populus nigra 62.171*
P.n.Saghez	*Populus nigra Saghez**
P.n.Grizah	*Populus nigra Grizah**

*-Standard (check) varieties

Table2: Conditions of research location

Subject	Quantity
Annual Average rainfall	462.4 mm
Annual Average evaporation	1340.69 mm
Mean of Max. temperature	15° C
Mean of Min. temperature	11.3° C
Mean of Opt. temperature	13.4° C
Absolute Max. temperature	44° C
Absolute Min. temperature	-31° C
Mean of frost days per year	105.9 days
Depth of frost	105 cm
Mean of sunny hours in day	7.8 hrs
Max. speed of wind (in April)	10.2 knots
Soil texture	Loam-Clay
pH	8.2
Irrigation cycle	10 days

Planting of cuttings were accomplished in early March of 2001 and transplanting of saplings and planting of them were conducted in late March of 2002 with space of 3*3 meters, based on randomized complete block design (RCBD) with 3 replications.

Each plot was contained 25 saplings that were palnted as 5*5 (9 saplings as main and 16 as buffer).
In each year some protection operations such as irrigation and weed control were conducted similar and simultaneous for all plots and replications and some of morphological and qualitative traits were measured in appropriate time.

Results and Discussion

Results of the total mean of studied traits of Poplar varieties in each year separately is shown in Table3.Analysis of variance of the collected data and the means comparison of studied traits for each trait and year have conducted by using of multiple ranges test of Dancann at $p \leq 0.01$ and their results are shown in Tables4 and 5 respectively.
As shown in Table 3, the first and second years after planting (2001 and 2002) in growth process of Poplar varieties were "relative establishing stage". Two mentioned years a low portion of total diameter breast height (D), tree height (H) and articularly cumulative wood volume (CWV) growths of Poplar varieties in studied period. The portion of the first and second years of total diameter breast height, tree height and particularly cumulative wood volume growths were about 11%, 32% and 0.4% respectively.

Table 3: Total mean of studied traits of Poplar varieties in years

trait	unit	2001	2002	2003	2004	2005
diameter breast height (D)	cm	0.87	1.25	4.41	7.88	11.7
tree height (H)	m	1.6	2.47	4.29	6.49	7.71
cumulative wood volume (CWV)	m^3	0.000064	0.000194	0.003997	0.01868	0.047281
crown diameter(CD)	m					1.70

This point especially for cumulative wood volume growth is considerable that total cumulative wood volume growth in these 2 years was less than 1% (Figure1).
In this stage, saplings were employed to extension of root systems and some height growth, adaptation to physical, chemical and biological conditions of soil. Furthermore in this stage because of smallness of saplings, high presence of weeds would caused the competing with young saplings and decreasing of growth and wood production.
After this, there was began a true growth stage from third and especially fourth year of planting (2003 and 2004). Growth on time (years) curve (Figure1) in the second or growth stage of Poplar varieties life, approximately is linear but finally similar to all kind of Growth curves will find a sigmoid shape. This will study in second phase (2006-2010) of present experiment.

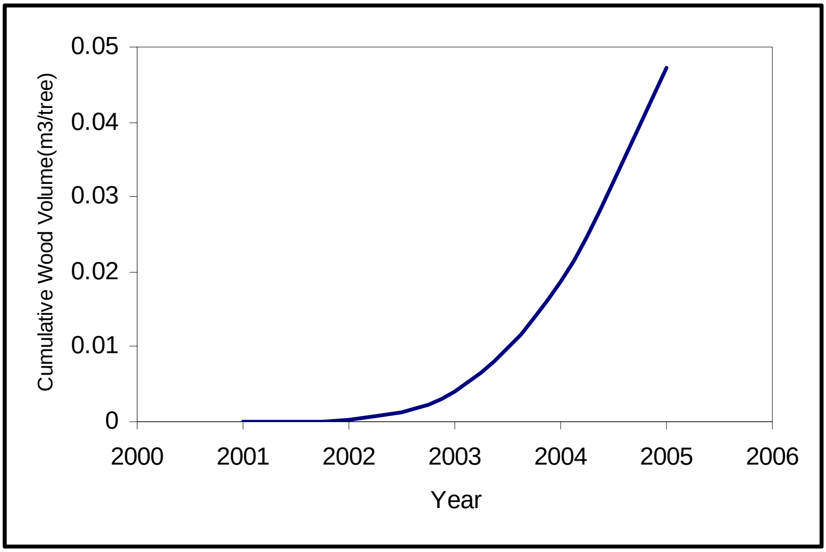

Figure 1: Cumulative wood volume of Poplar varieties

Analysis of variance of studied traits of Poplar varieties in each year showed significant differences among Poplar varieties for studied traits at p≤0.01. This high genetic

Table 4: Analysis of variance for studied traits of Poplar varieties in years

SV.	D.F.	2001[1]			2002			2003			2004			2005			
		MS			MS			MS			MS			MS			
		D	H	CWV	D	H	CWV	D	H	CWV	D	H	CWV	D	H	CD	CWV
Blocks	2				1.349**	0.7424**	1×10^{-7}**	8.038**	2.8748**	10^{-5}**×4.4	39.352**	12.473**	0.001394**	56.829**	16.133**	1.3622**	0.00607**
Varieties	13	3.541**	1.807**	1×10^{-7}**	7.5569**	7.1201**	1×10^{-6}**	48.12**	22.084**	10^{-4}**×2.56	115.146**	30.142**	0.003226**	224.797**	146.777**	2.0544**	0.031129**
Error	333	0.067	0.119	3×10^{-9}	0.1603	01319	1.36×10^{-8}	1.579	0.3867	7.2×10^{-6}	3.326	0.681	8.67×10^{-5}	5.906	1.273	0.0641	0.000457

**significant at p≤0.01

In 2001, data was analysed by completely randomized design with 14 varieties and 27 replications (saplings)
Variability can provide very suiTable backgrounds for breeding studies and selection of favorite genotypes. Approximately in all reported studies related to compatibility experiments in Iran, existence of significant differences have been accounted (Modir Rahmati, 1997; Ghasemi, 1999; Salari, 1999; Hemati and Modir Rahmati, 2002 and Bozorgmehr et al., 2002). The great portion of this high genetic variation among Poplar varieties, in deed is results of dioecious and high heterozygosity of Poplars.
Comparison of means of studied traits for each trait and year have conducted dy using of multiple ranges test of Dancann at p≤0.01 and classification of Poplar varieties have accomplished. Since cumulative wood volume (CWV) trait, in deed is a result and dependent variable that related to many other quantitative and qualitative traits especially to diameter breast height (D) and tree height (H) directly and so, selection of superior Poplar varieties is performing based this economic trait, following we more focused on this trait in our discussion.
Results of mean comparison for cumulative wood volume (CWV) in years showed that kind, order and wood production of superior Poplar varieties in each year were as below:

The first year (2001) - The varieties of ***P.n. 56.32*, *P.n.M, P.n. 56.72* and *P.n. 42*.53** with cumulative wood volume means and rank as 0.000149(a), 0.000126(ab), 0.000091(bc) and 0.000079(cd) m^3/sapling respectively (the total cumulative wood volume mean of Poplar varieties was 0.000064 m^3/sapling).
The second year (2002) - The varieties of ***P.n. 56.75*, *P.n. 62.140, P.n. 56.52* and *P.n. 56.32*** with cumulative wood volume means and rank as 0.0003(a), 0.000296(a), 0.000264(ab) and 0.000256(ab) m^3/tree respectively (the total cumulative wood volume mean of Poplar varieties was 0.000194 m^3/tree).
The third year (2003) - The varieties of ***P.n. 56.52*, *P.n. 56.75, P.n. 62.140* and *P.n. 63.135*** with cumulative wood volume means and rank as 0.00646(a), 0.00628(ab), 0.00588 (abc) and 0.00435(bcd) m^3/tree respectively (the total cumulative wood volume mean of Poplar varieties was 0.003997 m^3/tree).
The fourth year (2004) - The varieties of ***P.n. 56.75* , *P.n. 56.52, P.n. 62.140* and *P.n. betulifolia*** with cumulative wood volume means and rank as 0.03645(a), 0.02808(b), 0.02705(b) and 0.02106(bc) m^3/tree respectively (the total cumulative wood volume mean of Poplar varieties was 0.01868 m^3/tree) .
The fifth year (2005) - The varieties of ***P.n. 56.75*, *P.n. 62.140, P.n. 56.52* and *P.n. 63.135*** with cumulative wood volume means and rank as 0.08579(a), 0.06346(b), 0.05938(bc) and 0.05252(bcd) m^3/tree respectively (the total cumulative wood volume mean of Poplar varieties was 0.04728 m^3/tree) .
We can gather two important points from above mentioned objects that are:

- The first is that until end of 2005 (The fifth year of experiment) the varieties of ***P.n. 56.75*, *P.n. 62.140,* *P.n. 56.52*** **and** ***P.n. 63.135*** were superior, more compatible and higher varieties from view point of wood production in present experiment.
- The second is that kind and order of superior varieties in the third, fourth and fifth year of this trial was a like. If this phenomenon (relative similarity of kind and order of superior varieties) occur in the second phase of experiment (2006-2010), it will be an important result of this study because of in that case, execution time of compatibility experiments (comparative popleteum) can be decrease from 10 to 5 years. Decrease of comparative studies time without decrease of research delicacy will cause to economize of time and outlay in the future Poplars breeding and introducing works.

Mean of crown diameter (CD) of superior Poplar varieties in this experiment (1.68 meters) was closely similar to total varieties crown diameter means (1.70 meters).

Although the trait of widespread of crown will cause the better use of sunlight, space,stable tree skeleton and higher mass production (trunk, branches, leaves etc.) but in the Kurdistan and other same areas it isn't a desirable trait, because it will be cause breakage of Poplar branches at snowing time. Furthermore spread crown trees occupy greater lands and space instead of strong and straight trunk, produce strong branches.

With consideration of the importance of wood production in each year, results of annual and average wood volume of Poplar varieties are shown in Table 6. Based on this four superior Poplar varieties including varieties of ***P.n. 56.75*, *P.n. 62.140,* *P.n. 56.52*** **and** ***P.n. 63.135*** with 23.83, 17.62, 16.49 and 14.59 m^3 per year per hectare wood yield respectively were produced 1.13-2 times as much total wood yield mean of varieties (12.91 m^3 per year per hectare) and 1.5-2.5 times as much mean of two standard varieties of experiment (*P.n.Saghez* and *P.n.Grizah*).As shown in results (Table 6) ,the procedure of wood production in years was ascendant procedure that the greatest annual change in wood volume production was belong to third to second year of planting. Perspicuously, height and diameter and cumulative wood volume growth will rise increasingly in futures years of planting but the commercial and economic growth and wood production a period of till 15 years after planting. Unfortunately, this time in Iran and Kurdistan is about 20-30 years.

Table 5: Mean comparison of studied traits (Dancanns test, p≤0.01)

Variety	2001			2002			2003			2004			2005			
	D	H	CWV	D	H	CWV	D	H	CWV	D	H	CWV	D	H	CWV	CD
P.n.56.72	1.033 ab	1.839 bc	0.00009 bc	1.227 bcde	2.463 bcd	0.00019 abc	3.985 C	3.93 e	0.00327 d	7.13 cd	6.381 bcd	0.01636 cde	10.96 cd	7.78 Cd	0.04373 cdef	1.92 bc
P.n.M	1.115 a	2.177 a	0.00013 ab	1.427 abc	2.652 ab	0.00026 ab	4.115 C	4.11 de	0.00311 d	6.392 d	5.242 f	0.00976 e	9.754 d	6.28 g	0.02831 g	2.10 ab
P.n.56.32	1.107 a	2.084 ab	0.00015 a	1.4 abc	2.603 abc	0.00026 ab	4.133 C	3.897 e	0.00364 d	7.410 cd	6.444 bcd	0.01788 cd	11.63 cd	7.65 Cde	0.04814 bcdef	1.59 de
P.n.63.135	0.8926 bcde	1.860 bc	0.00007 cd	1.204 bcde	2.473 bcd	0.00018 abc	4.415 Bc	4.577 abcd	0.00435 bcd	7.893 cd	6.536 bc	0.01782 cd	12.35 bc	7.87 Cd	0.05252 bcd	1.96 bc
P.n.56.75	0.9518 abcd	1.782 cd	0.00008 cd	1.593 a	2.648 ab	0.0003 a	5.4 Ab	5.25 a	0.00628 ab	10.91 a	7.618 a	0.03645 a	15.43 a	9.02 a	0.08579 a	1.66 d
P.n.betulifolia	0.7407 def	1.514 ef	0.000042 cde	0.923 e	2.253 d	0.000094 c	4.607 Abc	4.363 bcde	0.004037 cd	8.459 bc	7.238 a	0.02106 bc	12.29 bc	7.96 bcd	0.04906 bcde	2.17 a
P.n.62.149	0.9778 abc	1.537 de	0.000063 cde	1.312 abcd	2.51 abcd	0.000204 abc	4.085 C	4.048 e	0.003416 d	7.084 cd	5.856 def	0.01411 cde	11.17 cd	7.98 bcd	0.04636 bcdef	1.25 f
P.n.42.53	0.9481 abcd	1.843 bc	0.000079 cd	1.308 abcd	2.449 bcd	0.00019 abc	4.023 C	3.957 e	0.002797 d	6.962 cd	5.632 ef	0.01182 de	10.58 cd	6.66 fg	0.03165 efg	1.69 d
P.n.56.52	0.7852 cdef	1.518 ef	0.00005 cde	1.52 ab	2.774 a	0.00026 ab	5.574 a	4.705 abc	0.00646 a	9.530 b	7.245 a	0.02808 b	12.6 bc	8.82 ab	0.05938 bc	1.69 d
P.n.62.154	0.6889 ef	1.369 ef	0.00003 de	1.046 de	2.237 d	0.00011 c	4.044 c	4.199 de	0.00304 d	7.122 cd	5.936 cde	0.01387 cde	11.24 cd	7.26 def	0.0397 defg	1.39 f

P.n.62.140	0.8444 bcde	1.360 ef	0.000044 cde	1.485 ab	2.582 abc	0.000296 a	5.141 ab	4.787 ab	0.005883 abc	9.359 b	7.3 a	0.02705 b	13.62 b	8.26 abc	0.06346 b	1.41 ef
P.n.62.171	0.7556 def	1.244 f	0.00003 de	1.126 cde	2.367 bcd	0.00015 bc	4.037 c	4.255 cde	0.00291 d	7.281 cd	6.54 bc	0.01433 cde	10.78 cd	7.12 defg	0.03356 efg	1.39 f
P.n.Saghez	0.7074 ef	1.382 ef	0.00003 de	0.9 e	2.314 cd	0.0001 c	3.992 c	3.975 e	0.00329 d	6.763 d	5.813 def	0.01312 de	9.75 d	6.83 efg	0.03091 fg	1.79 cd
P.n.Grizah	0.6296 f	0.931 g	0.00002 e	0.964 e	2.324 cd	0.000102 c	4.126 c	4.195 de	0.00341 d	7.852 cd	7.009 ab	0.01889 cd	11.46 cd	8.40 abc	0.04785 bcdef	1.71 d

Means with similar letters have not significant differences at $p \leq 0.01$

Table 6: Annual and average wood yield of Poplar varieties

Variety	2001		2002		2003		2004		2005		[3]Average AWV of tree(M^3/year)	Average AWV (M^3/ha/y)	rank
	AWV[1]	%[2]	AWV	%	AWV	%	AWV	%	AWV	%			
P.n.56.72	0.000092	0.21	0.000104	0.24	0.003078	7.04	0.013084	29.92	0.027377	62.6	0.010934	12.15	9
P.n.M	0.0001262	0.45	0.0001277	0.45	0.002853	10.08	0.006654	23.5	0.018547	65.52	0.007077	7.86	14
P.n.56.32	0.0001485	0.31	0.0001155	0.24	0.003375	7.01	0.014243	29.59	0.030255	62.85	0.012034	13.37	6
P.n.63.135	0.0000702	0.13	0.0001108	0.21	0.004168	7.94	0.013467	25.64	0.0347	66.07	0.013129	14.59	4
P.n.56.75	0.0000782	0.09	0.0002215	0.26	0.00598	6.97	0.030168	35.16	0.04935	57.52	0.0214485	23.83	1

5	8	12	3	10	2	11	13	7	
13.63	12.88	8.79	16.49	11.03	17.62	9.32	8.58	10.63	12.91
0.0122645	0.0115908	0.007912	0.014844	0.009930	0.015864	0.008388	0.007727	0.011962	0.011622
57.06	69.6	62.65	52.71	65.08	57.38	57.3	57.57	60.52	61.3
0.02799	0.032255	0.019829	0.031297	0.02585	0.03641	0.019226	0.017794	0.028958	0.02856
34.71	23.06	28.51	36.41	27.26	33.35	34.04	31.8	32.36	30.38
0.017026	0.010692	0.009023	0.02162	0.010827	0.021165	0.011423	0.009829	0.015482	0.01462
8.04	6.93	8.23	10.44	7.38	8.8	8.22	10.31	6.91	8.16
0.003943	0.003212	0.002603	0.006196	0.00293	0.005586	0.002757	0.003186	0.003307	0.0038
0.1	0.3	0.36	0.36	0.21	0.4	0.35	0.23	0.18	0.28
0.000052	0.0001406	0.0001147	0.0002161	0.0000852	0.0002524	0.0001174	0.000071	0.000085	0.00013
0.09	0.14	0.25	0.08	0.07	0.07	0.09	0.1	0.03	0.15
0.0000422	0.0000631	0.000079	0.0000484	0.0000288	0.000044	0.000032	0.0000302	0.0000164	0.00006
P.n.betulifolia	*P.n.62.149*	*P.n.42.53*	*P.n.56.52*	*P.n.62.154*	*P.n.62.140*	*P.n.62.171*	*P.n.Saghez*	*P.n.Grizah*	Mean

[1]- AWV: Annual Wood Volume [2] -%: Proportion from 5thl wood volume

[3]-Estimated values are based on division of CWV on 4 years (first year as sapling production year hasn't included)

Added to wood yield potential of poplar varieties, it is important that varieties have been shown a positive aspects of some qualitative traits. Results of studied qualitative traits are shown in Table 7.

Table 7: Studied qualitative traits

Variety	General Juiciness (%)				Contamination by Pests (%)		Trunks Status (%)				Trunks Branches numbers (%)		
	weak	middle	good	excellent	safe	low damaged	Perfect straight	straight	middle	tilted	1	2	3
P.n.56.72	-	7.5	85	7.5	100	-	54	23	4	19	69	31	-
P.n.M	-	11.5	73	15.5	100	-	31	46	15	8	61.5	38.5	-
P.n.56.32	-	30	70	-	95	5	30	20	10	40	50	50	-
P.n.63.135	-	15	85	-	100	-	66	19	-	15	81.5	18.5	-
P.n.56.75	-	18.5	81.5	-	96	4	30	33	-	37	41	48	11
P.n.betulifolia	-	41	59	-	100	-	85	7.5	7.5	-	96	4	-
P.n.62.149	-	27	73	-	100	-	42	27	8	23	58	38	4
P.n.42.53	-	27	73	-	100	-	58	27	8	7	92	8	-
P.n.56.52	-	37	63	-	100	-	55	30	8	7	63	29.5	7.5
P.n.62.154	-	46	54	-	100	-	38	31	-	31	54	46	-
P.n.62.140	-	37	59	4	100	-	-	37	15	48	26	59	15
P.n.62.171	-	52	44	4	96	4	23.5	18.5	7	41	29.5	48	22.5
P.n.Saghez	-	22	74	4	100	-	18.5	22	18.5	41	41	41	18
P.n.Grizah	-	18.5	77.5	4	100	-	48	30	4	18	70	22	8
Mean	-	27.9	69.4	2.7	99	1	42.3	26.5	7.4	23.8	59.6	34.1	6.3

In addition all of varieties in this study have showed desirable condition for studied general characteristics such as general juiciness, contamination by pests, trunk status and branching of trunk.

Introduced superior Poplar varieties in this experiment (***P.n. 56.75*, *P.n. 62.140,* *P.n. 56.52* and *P.n. 63.135***), from view point of general juiciness and contamination by pests were shoed good conditions but specially ***P.n. 56.75*, *P.n. 62.140, P.n. 56.52*** superior varieties need to a deal breeding for straight and mono branching trunks. Planting of straight trunks with cylindric height growth such as *Populus nigra* varieties is to be proposed to the Kurdistan province and other similar areas with a considerable suiTable river lands and deep valley and particular conditions for Poplar planting. Indeed selection of ***P.n. 63.135*** as a superior variety (although its wood production was less) was conducted for good trunk quality associated with relative high wood production.

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A number of photos from experiment – Sanandaj, Kurdiatan, Iran (2004-2005)

Essential Oil of *Pimpinella* species in Iran

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Abstract

The genus Pimpinella L. (family: Apiaceae/Umbelliferae) comprises of 150 species distributed in Asia, Europe and Africa. Over 16 species are distributed in Europe, and 23 species are found wild in different regions of Iran. In one of our research projects determination of essential oils content and composition of different parts of ten Iranian Pimpinella species were investigated. These species were P. affinis, P. anisum, P. anthriscoides, P. aurea, P. barbata, P. eriocarpa, P. kotschyana, P. puberula, P. tragioides and P. tragium.

The plant materials of Pimpinella species were collected from their natural habitats in different regions of Iran. Essential oils were isolated by hydro-distillation from the stem plus the leaf, aerial parts, flowering shoot, inflorescence, fresh and dried seeds individually and were analyzed by GC and GC/MS. The oil yields were calculated based on dry weight of plant materials (w/w).

The major constituents of these oils were different. Limonene, pregeijerene and trans-α-bergamotene were major constituents in P. affinis, P. puberula and P. tragioides oils. The major constituent in oil of P. anisum was trans-anethole. β-Bisabolene and Viridiflorol were the major constituents in P. aurea oil. The major constituents in P. barbata oil were limonene and methyl eugenol. Limonene, elemicine and pregeijerene were the main compounds in P. eriocarpa oil. β-caryophyllene and β-pinene and germacrene D were the main compounds in P. kotschyana and P. tragium oils, respectively.

The antimicrobial activity of the essential oils P. barbata, P. kotschyana and P. puberula was determined by disk diffusion method against Gram positive bacteria (Bacillus subtilis, Bacillus cereus, Micrococcus luteus and Staphylococcus aureus) and Gram negative bacteria (Yersinia entrocolitica, Klebsiella pneumonia and Escherichia coli) and yeast (Candida albicans). Results indicated that essential oil of P. kotschyana had significant antibacterial activity related to biologically active components and can be substituted with synthetic antibiotics which its microbial resistance has increased. Gram positive bacteria were more susceptible to antimicrobial activity of P. puberula oil. Essential oil of P. barbata showed no significant antimicrobial activity.

Key words: Umbelliferae, Pimpinella, essential oil, trans-anethole, Limonene, pregeijerene, trans-α-bergamotene, β-caryophyllene

Introduction

The genus Pimpinella belongs to Umbelliferae family. The dominant features of this family are the umbellate inflorescence, the smaller flower size, and the specialized fruit, consisting of two one-seeded mericarps suspended from a common stalk and the carpophore. According to the following characteristics, the genus Pimpinella is divided into two sections:

1. Section Anisum Ludwing DC.: Ovary and fruit hairy; plants annual and biennial; both medicinal and agricultural plants belong to this section; for example, P. anisum L.
2. Section Tragoselinum Mill. DC.: Ovary and fruit bare; plants perennial; both medicinal and agricultural plants belong to this section; for example, p. major L. Huds., P. peregrine L., P. saxifrage L.

The genus pimpinella mainly distributed in Asia, Europe and Africa. A few species can also be found in south America and one in the western part of North America. From a medical and agricultural point of view, only few species are economically significant. Species which are more distributed in the world include (Jodral 2004):

1- P. alpina
2- P. anisum L.
3- P. brachycarpa (Kom.)
4- P. candollena Wight
5- *P. caudata* (Franch)Wolff.
6-*P. coriacea* (Franch) de Boiss.
7- *P. diversifolia* DC.
8- P. epibracteata Bak.
9- *P. magna* L.*(P. major* L.)
10- *P. nigra* Willd
11- *P. peregrine* L.
12- P. rhomboids Diels.
13- P. saxifrage
14- P. serbica Benth.
15- *P. thellugiana* Wolff.

1- *P. affinis* Ledeb.
2- *P. anisactis* Rech.F.
3- *P. anisum* L.
4- *P. anthriscoides* Boiss.
5- *P. aurea* DC.
6- *P. avicenniae* Mozaff.
7- *P. barbata* (DC.) Boiss.
8- *P. deverroides* (Boiss.) Boiss.
9- *P. dichotona* (Boiss. et Hausskn.)
10- *P. eriocarpa Banks* & *Soland*
11- *P. gedrosiaca* Bornm.
12- *P. khayamii* Mozaff.
13- *P. khorasanica* Engstrand.
14- *P. kotschyana* Boiss.
15- *P. olivieri* Boiss.
16- *P. olivierioides* Boiss.
17- *P. pastinacifolia* (Boiss.) Wolff.
18- *P. peucedanifolia Fisch.*
19- *P. puberula.* (DC.) Boiss.
20- *P. rhodantha* Boiss.
21- *P. saxifrage* L.
22- *P. tragioides* (Boiss.) Benth. et Hook.
23- *P. tragium* Vill.

The genus of *Pimpinella* presents 23 species which are found wild in different regions of Iran; two of the more distributed species are *P. aurea* and *P. tragim*. These species are: (Mozaffarian, 1996).

The main compounds of essential oil from different parts of *Pimpinella* species in the literature are shown in Table 1.

Table 1: Previous studies on the oils of Pimpinella species

Pimpinella species	Plant Part	Main components	Reference
P. achilleifolia	AP	p-cymene(52.2%), limonene (9.3%), α-phellandrene (8.8%) and δ-2-carene (9.2%)	(Lohani, 1985)
P. anisetum	Fr	(E)-anethole (77.1%), methyl chavicol (22.4%)	(Baser,1999)
P. anisetum	P	(E)-anethole (55.2%), methyl chavicol (41.9%)	(Baser,1999)
P. anisum	Fr	(E)-anethole (94.1%)	(Kubeczka, 1986)
P. anisum	P	(E)-anethole (29.4%), germacrene D (14.8%), pseudoisoeugenyl 2-methylbutyrate (13.1%) and β-bisabolene (11.8%)	(Kubeczka, 1986)
P. anisum	R	β-bisabolene (52.5%) and pregeijerene (12.8%)	(Kubeczka, 1986)
P. aromatica	AP	methyl chavicol (91.1%) and (E)-anethole (7.2%)	(Baser, 1996)
P. aromatica	Fr	Methyl chavicol (82.6%)	(Mekhtieva, 1991)
P. aurea	AP	(E)-α-bergamotene (72.8%)	(Assadian, 2005)
P. aurea,	Fr+ AP	β-caryophyllene, β-bisabolene, trans-β-bergamotene and aurean.	(Tableanca, 2005)
P. aurea,	R	Phenylpropanoids	(Tableanca, 2005)
P. barbata	AP	methyl eugenol (34.0%) and elemicin (6.9%), limonene (26.6%), sabinene (6.7%) and perillaldehyde (5.2%).	(Fakhari and Sonboli, 2006).
P. corymbosa	Fr+ AP	β-caryophyllene, β-bisabolene, trans-β-bergamotene and aurean.	(Tableanca, 2005)
P. corymbosa	R	Phenylpropanoids	(Tableanca, 2005)
P. cumbrae	Fr	α-bisabolol (39%) and δ-3-carene (16%)	(Velasco-Negueruela,2002)
P. cumbrae	L	α-bisabolol (53%) and δ-3-carene (11%)	(Velasco-Negueruela,2002)
P. cumbrae	SL	α-bisabolol (39%) and isokessane (10%)	(Velasco-Negueruela,2002)
P. junoniae	AP	zingiberene (20.6%), α-pinene (17.9%), (E)-β-farnesene (9.3%), ar-curcumene (7.4%), β-phellandrene (7.0%), β-bisabolene (6.1%) and epoxypseudoisoeugenyl 2-methylbutyrate (6.0%)	(Velasco-Negueruela, 2003)
P. major	R	epoxy-pseudoisoeugenyltiglate(56.5%), pregeijerene (10.4%)	(Kubeczka, 1986)
P. major	R	trans-epoxyseudoisoeugenyltiglate(19.5%-37.3%), δ-elemene (12.1%), pregeijerene (9.8%), octanal (7.9%) and germacrene C (7.8%), germacrone (15.2%) and γ-elemene (9.8%)	(Bohn, 1989)
P. peregrina	R	epoxy-pseudoisoeugenyl-2-methylbutyrate (29.7%), β-sesquiphellandrene (19.8%), epoxy-pseudoisoeugenyl 2-methylpropionate (11.8%), pregeijerene (11.0%) and β-bisabolene (10.0%)	(Kubeczka, 1986)
P. peregrina	Fr+ AP	B-caryophyllene, B-bisabolene, trans-'B-bergamotene and aurean.	(Tableanca, 2005)
P. peregrina	R	Phenylpropanoids	(Tableanca, 2005)
P. puberula	Fr+ AP	limonene and methyl eugenol	(Tableanca, 2005)

P. saxifrage	AP	β-caryophyllene (16% and 9.8%), germacrene D (8.9% and 5.9%), camphene (6.4% and 5.3%)	(Cornu, 2001)
P. saxifrage		epoxy-pseudoisoeugenyl-2-methylbutyrate (46.2%), pregeijerene (9.2%), germacrene B (5.4%)	(Kubeczka, 1986)
P. serbica	S	β-caryophyllene (47.1%)	(Ivanic, 1883)
P. squamosa	P	(E)-anethole (54.5%)	(Mekhtieva, 1998)
P. squamosa	Fr	(E)-anethole (29.5%)	(Mekhtieva, 1998)
P. tirupatiensis	R	β-bisabolene (99.2%), δ-3-carene (8.9%), cis-carveol (6.7%), elemol (5.8%), δ-cadinol (4.4%), methyl geranate (4.3%) and γ-nonalactone (3.4%)	(Bakshu, 2002)

SL= stem plus the leaf AP= Arial parts P= whole plant S= seed IF= inflorescence Fr= fruit L=leaf R= root

Experimental

Plant materials were collected from different regions of Iran at flowering stage and seed stage (Table 2). The fresh plants were dried at room temperature. The herbarium specimens have been deposited in the Herbarium of Research Institute of Forests and Rangelands (TARI).

Table 2: Habitate of *Pimpinella* species in Iran

No.	Species	Habitation	Altitude (meters)	Provinces
1	*P. affinis*	Khojir	1500-1800	the north-east of Tehran province
	″	Chaloos	1900	the north of Tehran province
	″	Noshahr	80	Mazandaran province
2	*P. anisum*	Shiraz	-	Fars province
	″	Esfahan	-	Esfahan province
3	*P. anthriscoides*	Ilam	-	Ilam province
	″	Uromieh	-	Azerbaijan
4	*P. aurea*	Fasham	2200	the north-west of Tehran province
5	*P. barbata*	Ramhormoz	170	Khuzestan province
	″	Ilam, Dehloran	500	Ilam province
6	*P. eriocarpa*	Khojir	1500	the north-east of Tehran province
7	*P. kotschyana*	Lavasanat	1700	Tehran province
8	*P. puberula*	Ramhormoz	170	Khuzestan provinces
	″	Mashad	-	Khorasan provinces
9	*P. tragioides*	Chaloos road	2100	the north of Tehran province
10	*P. tragium*	polour	2300	(Northeast of Tehran province

The dried parts of the plants were crushed to small particles. At each time about 80-100g samples of plant materials were used. Dried aerial parts [AP], the stem plus the leaf [SL] (were collected during vegetative stage), inflorescences [IF] and Unriped [US], Ripped [RS] and dried seeds [S] (collected during flowering stage) were hydro distilled for three hours in a Clevenger type apparatus to produce the oil. Three distillations were performed for each oil then mixed for analysis. The sample oils were dried over anhydrous sodium sulfate and stored in sealed vials at 4 °C temperature before analysis.

GC analysis

The oils of Pimpinella were analyzed using Shimadzu GC-9A gas chromatograph equipped with a DB-5 fused silica column (30 m x 0.25 mm, film thickness 0.25 μm, J and W scientific corporation). Oven temperature was held at 40 °C for 5 min and then programmed to 260 °C at a rate of 4 °C/min. Injector and detector (FID) temperature were 270 °C; helium was used as carrier gas with a linear velocity of 32 cm/s. Percentages were calculated by area normalization method without the use of response factor correction. The retention indices were calculated for all compounds using a homologous series of n-alkanes.

GC-MS analysis

GC/MS analyses were carried out on a Varian 3400 GC/MS system equipped with a DB-5 fused silica column (30 m x 0.25 mm, film thickness 0.25 μm, J and W scientific corporation); oven temperature program was 50 °-260 °C at a rate of 4 °C/min. Transfer line temperature 270 °C, carrier gas helium with a linear velocity of 31.5 cm/s, split ratio 1/60, ionization energy 70 ev, scan time 1 sec, mass range 40-300 amu.

Identification of compounds

The constituents were identified by comparison of their mass spectra with those in a computer library (LIBR-TR and Wiley-5 lib.) or with authentic compounds. The identifications were confirmed by comparison of their retention indices either with those of authentic compounds or with data in the literature (Adams, 1995)

Antibacterial analysis

The antimicrobial activities of *Pimpinella barbata, P. puberula and P. kotschyana* oil were determined against Gram negative bacteria, Gram positive bacteria and one yeast. Microorganisms were obtained from microbial collection of the Biotechnology Department in Iran Research Organization of Science and Technology[1]. The microorganisms included *Bacillus cereus* (PTCC 1247), *Bacillus subtilis* (PTCC 1023), *Micrococcus luteus* (PTCC 1169), *Staphylococcus aureus* (PTCC 1431), Yersinia *enterocolitica* (PTCC 1151), *Pseudomonas aeruginosa* (PTCC 1430),

Escherichia coli (PTCC 1399), *Klebsiella pneumonia* (PTCC 1053), *Klebsiella oxytoca* (PTCC 1402), *Serratia marcescens* (PTCC 1187) and *Candida albicans* (5027).
The antibacterial investigations were performed using disk diffusion method (European Pharmacopoeia, 2001). The bacteria were cultivated on Triptic Soy Agar medium (Merck, Germany). The bacteria were suspended in Triptic Soy broth medium (Merck, Germany) with reference to the value 1 McFarland scale. 0.5 ml of standardized inoculate were placed on the surface of media. Oils were diluted by ethanol (1:5). Sterile paper disks (diameter 6 mm prepared from Whatman number 42) were impregnated with 20 µl of diluted essential oil were placed on the surface of each inoculated plates and incubated for 24 h at 37 ºC. Carbenicillin (100 µg), tetracycline (30 µg), gentamycin (10 µg) and vancomycin (30 µg) disks were used to compare antibacterial activity of essential oils. Zone of inhibition was measured after 24 h incubation.

Results

1- Pimpinella affinis Ledeb.

P. affinis (with the synonym names of: *P. reuteriana* Boiss., *P. griffithiana* Boiss., *P. ambigua* W.D. Koch ex Wolff, *P. multiradiata* (Boiss.) Korov., *P. korovinii* R. Kamelin) presents in different regions of Iran, Iraq, Syria and Israel. It is biennial aromatic plant, with 20-110 cm length, white umbel inflorescence and ellipsoid fruits (Mozafarian 1996, Rechinger 1972).
Plant materials were collected from Khojir (the north-east of Tehran province), Chaloos (the north of Tehran province) and Noshahr (Mazandaran province). Essential oil yield of different parts of *P. affinis* is shown in Table 3.

Table 3: Percentage (w/w) of essential oil from different parts of *Pimpinella affinis*

Samples	Stem/leaf	Inflorescence	Seed
Khojir	0.04	1.98	5.33
Chaloos	0.37	1.74	4.05
Noshahr	0.26	0.86	2.49

Eight constituents in Stem/leaf [SL] oil, eight constituents in inflorescence [IF] oil and nine constituents in seed [S] oil of the Khojir sample were identified. Ten constituents in [SL] oil, thirteen constituents in [IF] oil and ten constituents in [S] oil of Chaloos sample were identified. Six constituents in [SL] oil, fifteen constituents in [IF] oil and six constituents in [S] oil of Noshahr sample were identified. The main compounds are shown in Table 4. (Askari, 2006)

Table 4: Percentage of the major constituents essential oil from different parts of *Pimpinella affinis*

Major Compounds	RI*	Khojir			Chaloos			Noshahr		
		SL	IF	S	SL	IF	S	SL	IF	S
Limonene	102.9	1.4	47.9	90.5	0.8	37.8	70.8	-	-	-
pregeijerene	1278	69.9	37.6	-	72.8	49.1	-	-	-	-
Caryophyllene oxide	1577	9.1	-	-	-	-	-	-	-	-
methyl eugenol	1395	-	2.3	2.2	-	-	9.7	-	-	-
trans-α-bergamotene	1433	-	-	-	-	-	-	94.3	84.9	95.5
(E)-nerolidol acetate	1714	-	-	-	-	-	9.1	-	-	-

SL= stem/leaf IF= inflorescence S=Seed

* Retention indices calculated on DB-5 column

Pimpinella anisum L. (Anis)

P. anisum (with the synonym names of: *P. glaucescens* Boiss., *Ptychotis barbata* DC. Prodr.) presents in different regions of south and center of Europe, Anatoliy, Iran, south, west and east of Russia, Syria and Egypt. From a pharmacological and economic point of view, the most valuable species is *P. anisum.* It is cultivated in Argentina, Chile, China, France, India, Japan, Mexico, Spain and the United States. It is also cultivated in Azerbaijan, Esfahan, Fars and Tehran provinces of Iran. It is an annual plant of up to 50 cm length, with white flowers and aromatic fruits, covered with fine, short, addressed hairs. *P. anisum* is similar to *Illicium verum* Hooker (Mozafarian, 1996; Jodral, 2004).

Plant materials were collected from Shiraz (Fars province) and Esfahan (Esfahan province). Essential oils of *P. anisum* seed is shown in Table 5.

Table 5: Percentage (w/w) of essential oil of *Pimpinella anisum* seeds

Samples	Seeds
Shiraz	3.0
Esfahan	3.3

Eleven constituents were identified in seeds of both habitats. The main compounds are shown in Table 6 (Askari, 1998). The total amount of extracTable substances or global yield of *P. anisum* seed for the supercritical fluid extraction process varied from 3.13-10.67 % (mass). The major compounds identified and quantified in the extracts were anethol (~90 %), γ-himachalene (2-4 %), p-anisaldehyde (<1 %), methylchavicol (0.9-1.5 %), cis-pseudoisoeugenyl 2-methylbutyrate (~3 %) and trans-pseudoisoeugenyl 2-methyl-butyrate (~1.3 %) (Rodrigues, 2003).

Anethole is responsible for the characteristic odor and flavor of Anis.

Table 6: Percentage of the major constituents essential oil of *Pimpinella anisum* seed

Major Compounds	RI*	Sample Shiraz	Esfahan
(E)-anethole	1270	89.0	91.7
γ-gurjunene	1476	3.3	1.9
Eugenyl-acetate	1802	1.43	2.0

* Retention indices calculated on DB-5 column

Pimpinella anthriscoides Boiss.

P. anthriscoides (with the synonym names of: *P. cervariaefolia* Freyn & Sint.*, Sium lancifolium* M.B. *var. elangatum* Parsa) is present in different regions of Anatolia, Lebanon, Syria, Iraq, Afghanistan, Armenia and Iran. It is Perennial, erect, with 30-90 cm length, white inflorescence, ovoid-oblong bare fruits (Mozafarian 1996, Rechinger 1972).
Plant materials were collected from Ilam (Ilam province) and Uromieh (west Azerbaijan province). Essential oil yield of P. anthriscoides different parts is shown in Table 7.

Table 7: Percentage (w/w) of Essential oil from different parts of Pimpinella anthriscoides

Sample	Stems/leaves	Inflorescences	Seeds
Ilam	trace	0.05	0.11
Uromieh	-	-	trace

The oils were not identified.

Pimpinella aurea DC.

Two species of the more distributed genus of *Pimpinella* in Iran are *P. aurea* and *P. tragium. P. aurea* (with the synonym names of: *P. ramosisima* DC., *P. flava* C.A. Mey., *Reutera cervariaefolia* Boiss., *R. flava* (C.A.Mey.) Boiss., *R.aurea* (DC.) Boiss. presents in different regions of Anatolia orientalis, Iran, Torcomanica, Armenia, Georgia.
P. aurea is a variable species. Some individuals are very rich branched. It is Perennial erect with 100 cm length, yellow inflorescence and subglobosus fruits (Mozafarian, 1996; Rechinger, 1972).
Plant materials were collected from Fasham (north-west of Tehran province). Essential oil yield of *P. aurea* different parts is shown in Table 8.

Table 8: Percentage (w/w) of essential oil from different parts of *Pimpinella aurea*

Sample	Stem/leaf	Inflorescence	Seed
Fasham	0.4	1.5	2.0

Thirty-two constituents in stem plus the leaf oil, eighteen constituents in flower oil and eight constituents in seed oil were identified. Main compounds have shown in Table 9 (Askari, 2005). (E)-α-bergamotene (72.8 %) was the main compounds in arial parts of *P. aurea* oil (Assadian, 2005).

Table 9: Percentage of the major constituents essential oil of *Pimpinella aurea* different parts

Major Compounds	RI*	Stems/leaves	Inflorescences	Seeds
α-Pinene	930	11.5	1.6	-
Limonene and 1,8-Cineol	1020	21.4	8.9	-
Estragol	1170	1.3	5.1	-
Germacrene D	1470	4.9	-	2.9
β-Bisabolene	1502	4.2	29.5	50.8
Kessane	1517	10.5	0.4	-
Caryophyllene oxide	1565	2.5	6.6	1.0
Viridiflorol	1601	12.8	32.5	37.0

* Retention indices calculated on DB-5 column

Pimpinella barbata (DC.) Boiss.

P. barbata (Synonym: Ptychotis barbata DC. and *Pimpinella glaucescens Boiss.*) spread widely through Iraq, Iran and Australia. It grows in waste land, dry open hillside and steppe up to 1600 m. It is annual and erect aromatic plant with about 40 cm length, umbellate numerous, white inflorescence and ovoid fruits. *P. barbata* is recognized easily by the leaf-lobes which are linear-filiform in all leaves (Mozaffarian, 1996; Rechinger, 1972).
Plant materials were collected from Ramhormoz (Khuzestan province) and Ilam (Ilam province). Essential oils from the whole aerial parts (at vegetative stage), stem/leaf, inflorescence (at flowering stage), unripe and ripped seeds (at seeding stages) were extracted individually by hydro-distillation. Essential oils yield of P. barbata different parts is shown in Table 10.

Table 10: Percentage (w/w) of essential oil from different parts of *Pimpinella barbata*

Sample	Aerial parts	Stem/ leaf	Flowering Shoot	Inflorescence	Unripe seed	Ripped seed
Ramhormoz	0.67	0.42	0.45	1.29	2.05	1.71
Ilam	-	-	1.1	-	-	-

There were 16, 22, 17, 28, 22 and 12 constituents (93.5%-99.8%) in the aerial parts, stem/ leaf, flowering shoot, inflorescence, unripe seed and ripped seed oils of *P. barbata*. The main compounds are shown in Table 11.

Table 11: Percentage of The major constituents identified in the oils of *Pimpinella barbata*

Compounds	RI*	Aerial parts	Stem/ leaf	Flowering Shoot	Inflorescence	Unripe seed	Ripped seed
limonene	1028	14.9	24.3	33.3	46.9	45.3	63.6
pregeijerene	1285	32.7	8.6	6.0	1.4	2.6	1.0
methyl eugenol	1401	5.7	8.7	14.8	6.9	18.7	7.8
γ-muurolene	1478	16.4	28.2	18.6	18.2	0.7	-
elemicine	1554	1.1	4.2	6.2	4.3	7.5	13.8
foeniculin	1675	2.9	3.3	3.3	3.1	16.1	5.2

* Retention indices calculated on DB-5 column

Fakhari and Sonboli reported that the aerial parts of *P. barbata* were collected at full-flowering stage from Shiraz, (Fars province, Iran). 32 compounds have been identified in the oil accounting 97.0 % of the total oil methyl eugenol (34.0 %) and elemicin (6.9 %) were the two main constituents of *P. barbata* oil. The main compouds of monoterpene fraction were limonene (26.6 %), sabinene (6.7 %) and perillaldehyde (5.2 %) (Fakhari and Sonboli, 2006).
The antimicrobial activity of the essential oils was determined by disk diffusion method against Gram positive bacteria (*Bacillus subtilis, Bacillus cereus, Micrococcus luteus* and *Staphylococcus aureus*) and Gram negative bacteria (Y*ersinia entrocolitica, Klebsiella pneumonia* and *Escherichia coli)* and yeast (*Candida albicans*). Results showed no significant antimicrobial activity in essential oil of *P. barbata.*

Pimpinella eriocarpa Banks & Soland

P. eriocarpa (with the synonym names of: *P. tenius* Sieber ex Schultes, *P. moabitica* Post.) is distributed in south and west of Iran (1). It is present in different regions of Anatolia austro-orientalis, Palestina, Syria, Iraq and Iran. It is annual, erect, 20-110 cm length, pubescence, white petals, ovoid fruits (Mozafarian, 1996; Rechinger, 1972).
Plant materials were collected from Khojir (Northeast of Tehran province). Essential oils yield of different parts of P. eriocarpa is shown in Table 12.

Table 12: Percentage (w/w) of essential oil from different parts of *Pimpinella eriocarpa*

Sample	Aerial parts	Seed
Khojir	1.3	5.7

Fifteen constituents in the aerial parts oil and eight constituents in seed oil were identified. The main compounds are shown in Table 13 (Askari, 2005)

Table 13: Percentage of the major constituents in Essential oil of *Pimpinella eriocarpa*

Compounds	RI*	Arial part	Seed
limonene	1023	17.6	49.3
pregeijerene	1288	59.9	2.1
elemicine	1552	12.5	44.5

* Retention indices calculated on DB-5 column

Pimpinella kotschyana Boiss.

P. kotschyana Boiss. (with the synonym names of: *P. apiifolia* Boiss., *P. corymbosa* Boiss. var. *kotschyana* Boiss), spreads widely through Anatoly, Iran (north-west, west and center) and north of Iraq. It grows in dry slopes, steppes and dry open woodland in 1000-2200 m above sea level. It is Monocarpia plant, with about 60 cm length, umbellate numerous, white inflorescence and ovoid aromatic fruits (Mozafarian, 1996; Rechinger, 1972).
The essential oils were isolated by hydro-distillation from different parts of *P. kotschyana*: stem plus the leaf, aerial parts, inflorescence and unripe, ripped seed and dried seeds individually.
Plant materials were collected from Lavasanat in Tehran province. Essential oil yield of different parts of *P. kotschyana* is shown in Table 14.

Table 14: Percentage (w/w) of essential oil from different parts of *Pimpinella kotschyana*

Aerial parts	Stems/leaves	Inflorescence	Unripe seed	Ripped seed	Dried seed
0.31	0.05	0.65	7.10	5.16	5.32

Sixteen constituents in the inflorescence oil, thirteen constituents in unripe seed oil, seventeen constituents in ripped seed oil and sixteen constituents in dried seed oil were identified. The main compounds have shown in Table 15.
The analysis of antibacterial activity of essential oil was determined by disk diffusion method against Gram positive bacteria (Bacillus subtilis, Bacillus cereus, Micrococcus luteus and Staphylococcus aureus) and Gram negative bacteria (Yersinia enterocolitica, Klebsiella oxytoca, Klebsiella pneumoniae, Serratia marcescens, Escherichia coli and Pseudomonas aeruginosa). Results showed no significant differences between Gram positive and Gram negative bacteria in their susceptibility. The inhibitory effect on the tested microorganisms could be related to β-caryophyllene, germacrene D, and longipinanol that are major ingredients of oils. The higher antimicrobial activity in seed II can be related

to the presence of limonene which was observed only in this stage. Results indicated that essential oil had significant antibacterial activity related to biologically active components and can be substituted of synthetic antibiotics which microbial resistance has increased.

Table 15: Percentage of The major constituents in essential oil of *Pimpinella kotschyana* different parts

Compounds	RI*	Inflorescence	Unripe seed	Ripped seed	Dried seed
β-pinene	976	4.8	3.3	3.0	1.6
limonene	1028	-	-	7.8	-
β-caryophyllene	1418	40.5	49.9	40.6	40.8
germacrene d	1482	29.9	11.7	11.3	12.4
longipinanol	1567	7.2	18.0	17.6	19.3
bicyclogermacrene	1497	1.0	-	4.0	5.4

* Retention indices calculated on DB-5 column

Pimpinella puberula (DC.) Boiss.

P. puberula (with the synonym names of: *P. petraea* Nab, *P. cretica,* Poir. *ptychotis puberula* DC.) spreads widely through Anatolia austro-orientalis, Jordan, Iraq, Iran (North, West, North-East, and South-East), Turcomania, Afghanistan and Pakistan. It grows in deserts and steppes, stony slopes and river beds. It is annual and erect plant, with about 65 cm length, umbellate numerous, white inflorescence and globes-ovoid fruits (Mozaffarian, 1996; Rechinger, 1972).
Plant materials were collected from Ramhormoz (Khuzestan provinces) and Mashad (Khorasan provinces). Essential oils yield of *P. puberula* different parts is shown in Table 16.

Table 16: Percentage (w/w) of essential oil from different parts of *Pimpinella puberula*

Samples	Aerial parts	Stem/leaf	Inflorescence	Unripe seed	Ripped seed
Ramhormoz	0.49	0.31	3.81	6.01	1.80
Mashad	0.96	0.87	3.59	6.94	4.96

In the aerial parts, stem/leaf, inflorescence inflorescence, unripe and ripped seed oils *P. puberula* from Ramhormoz samples 10, 14, 10, 7 and 8 constituents and Mashad sample oils 9, 8, 10, 6 and 6 constituents were identified, respectively. The main compounds are shown in Table 17.

Table17: Percentage of the major constituents identified in the oils of *Pimpinella Puberula* (DC.) Boiss.

Compounds	RI*	Ramhormoz					Mashad				
		AP	SL	IF	US	RS	AP	SL	IF	US	RS
limonene	1028	21.7	46.6	58.9	78.8	82.4	25.3	33.8	60.8	74.1	80.6
geijerene	1141	10.4	8.5	1.0	-	0.5	11.7	7.2	3.0	0.7	0.4
pregeijerene	1285	55.4	14.6	1.4	1.3	1.0	45.8	38.8	18.1	3.5	1.5
methyl eugenol	1401	-	6.4	4.6	1.0	-	5.4	12.0	10.5	16.3	13.1
elemicine	1554	1.0	14.0	27.3	13.4	7.0	-	-	-	-	-

AP= aerial parts SL= stems plus the leaves IF= inflorescence US=Unripe seed RS=Ripped seed
* Retention indices calculated on DB-5 column

Plant tissue of *Pimpinella aurea*, *P. corymbosa*, *P. peregrina* and *P. puberula* were collected from Turkey. 140 different compounds were identified in fruits, aerial parts without fruits and root oils of them. The oils of fruits and aerial parts *P. puberula* profile consisted of monoterpenes in high concentration with limonene and methyl eugenol (Tableanca, 2005).
The antimicrobial activity of the essential oils was determined by disk diffusion method against Gram positive bacteria (*Bacillus subtilis, Bacillus cereus, Micrococcus luteus* and *Staphylococcus aureus*) and Gram negative bacteria (Y*ersinia entrocolitica, Klebsiella oxytoca, Serratia marcescens, Escherichia coli and Pseudomonas aeruginosa)* and yeast (*Candida albicans*). Results showed significant difference between Gram positive and Gram negative bacteria in their susceptibility. Gram positive bacteria were more susceptible to antimicrobial activity of *P. puberula* oil. In addition, the antimicrobial activity of samples which were collected from Ramhormoz was more than Mashad.

P. tragioides (Boiss.) Benth. et Hook.

P. tragioides (Boiss.) Benth et Hook (with the synonym names of: *Reutera tragioides* Boiss.) is one of the endemic plants of Iran that distributed in west, northwest and center of Iran. It is perennial plant, with 30-65 cm length, numerous umbels, yellow inflorescence and ellipsoid fruit (Mozaffarian, 1996; Rechinger, 1972).
Plant materials were collected from Chaloos road (the north of Tehran province). Essential oils yields of *P. tragioides* different parts are shown in Table 18.

Table 18: Percentage (w/w) of essential oil from different parts of *Pimpinella tragioides*

Samples	Stems/leaves	Inflorescences	Seeds
Chaloos	0.15	0.79	2.49

Thirteen constituents in the stem plus the leaf oil, thirteen constituents in the inflorescence oil and fifteen constituents in the seed oil were identified. The main compounds are shown in Table 19.

Table19: Percentage of The major constituents identified in the oils of *Pimpinella tragioides*

Compound	RI*	Stem/Leaf	Inflorescence	Seeds
pregeijerene	1288	-	-	87.0
trans-α-bergamotene	1427	77.1	70.3	-
isoacorone	1806	-	15.1	-
nonadecane	1889	8.6	1.9	-

P. tragium Vill.

Two species of the more distributed *Pimpinella* genus in Iran are *P. aurea* and *P. tragium*. The *P. tragium* (Boiss.) Benth et Hook (with the synonym names of: *P. pseudotragium* DC., *P. tragium* Vill. Var. *Pseudotragium* (DC.) Boiss., *P. zagrosica* Boiss. & Hausskn) are present in different regions of Iran, Europe, Anatoli, Turkey, Torkamania, Iraq and north of Africa. It is a plant of up to 50 cm length, perennial, erect, white inflorescence and ovoid fruit rare globosus, pubescence.

P. tragium forms an extremely variable complex. In parts of its total area of distribution it might be possible to distinguish taxa which can be treated as species or subspecies, such as *P. pretenderis* in the Aegean, *P. cypria* Boiss. in Cyprus and *P. kurdica* Rech. F. & H. Riedl in North Iraq. According to Matthews it is possible to distinguish three subspecies in Turkey. These are also found in some parts of Iran, but they are all connected by transitional forms making identification very difficult (Mozaffarian, 1996; Rechinger, 1972).

Plant materials were collected from polour (the north-east of Tehran province). Essential oil yield of different parts of *P. tragium* is shown in Table 20.

Table 20: Percentage (w/w) of essential oil from different parts of *Pimpinella tragium*

Samples	Stem/leaf	Inflorescence	Seeds
Chaloos	0.08	0.37	1.33

Eighteen constituents in the stems plus leaves oil, twenty-six constituents in the inflorescence oil and twenty-three constituents in seeds oil were identified. Main compounds have shown in Table 21.

Table 21: Percentage of the major constituents identified in the different parts oils of *Pimpinella tragioides*

Compounds	RI*	Stem/Leave	Inflorescence	Seed
sabinene	974	0.5	6.2	13.6
β-pinene	978	4.5	23.8	25.3
bornyl acetate	1283	15.8	4.1	1.5
β-caryophyllene	1416	5.6	7.3	4.8
germacrene D	1472	34.7	6.2	-
germacrene B	1554	18.3	14.1	17.8
hexadecanol	1875	0.7	10.3	4.7

* Retention indices calculated on DB-5 colum

Discussion

Essential oil yields of *Pimpinella* species were compared together in Table 22. As shown in this Table, the highest percentage of essential oil was found in the seeds of all *Pimpinella* species. The seeds of *P. kotschyana* produced higher oil content than the other species. The lowest oil percentage was obtained from *P. anthriscoides*.

Table 22: Essential oil yield of different parts of *Pimpinella* species

Species	Yield (%)		
	Stem/leaf	inflorescence	Seed
P. affinis (Khojir)	0.04	1.98	5.33
P. affinis (Chaloos)	0.37	1.74	4.05
P. affinis (Noshahr)	0.26	0.86	2.49
P. anisum (Shiraz)	-	-	3.0
P. anisum (Esfahan)	-	-	3.3
P. anthriscoides (Ilam)	Trace	0.05	0.11
P. anthriscoides (Uromieh)	-	-	Trace
P. aurea (Fasham)	0.4	1.5	2.0
P. barbata (Ramhormoz)	0.42	1.3	1.7
P. eriocarpa (Khojir)	-	1.3	5.7
P. kotschyana (Lavasanat)	0.05	0.65	7.1, 5.1 and 5.3
P. puberula (Rahormoz)	0.31	3.81	6.0 and 1.8
P. puberula (Mashad)	0.9	3.6	6.9 and 5.0
P. tragioides (Chaloos)	0.2	0.8	2.5
P. tragium (polour)	0.1	0.4	1.3

As shown in Table 23, the main compounds in different *pimpinella* are different variability. Limonene, pregeijerene, trans-α- bergamotene, *β*-Bisabolene and trans-anethole were the most important of constituents in the seed oils.

Table 23: Percentage of major constituents identified in seed oils of *Pimpinella* species

Compounds	Species									
	P. affinis	*P. anisum*	*P.anthriscoides*	*P. aurea*	*P. barbata*	*P. eriocarpa*	*P. kotschyana*	*P. puberula*	*P. tragioides*	*P. tragium*
β-pinene	-	-	-	-	-	-	3.3	-	-	25.3
limonene	90.5	-	-	-	63.6	49.3	7.8	82.4	-	-
pregeijerene	-				2.6	2.1	-	1.5	87.0	-
methyl eugenol	9.7	-	-	-	18.7	-	-	13.1	-	-
E-caryophyllene	-	-	-	-	-	-	49.9	-	-	4.8
trans-α-bergamotene	95.5	-	-	-	-	-	-	-	-	-
Germacrene D	-	-	-	2.9	-	-	12.4	-	-	-
β-Bisabolene	-	-	-	50.8	-	-	-	-	-	-
trans-anethole	-	91.7	-	-	-	-	-	-	-	-
longipinanol	-	-	-	-	-	-	19.3	-	-	-
elemicine	-	-	-	-	13.8	44.5	-	7.0	-	-
Viridiflorol	-	-	-	37.0	-	-	-	-	-	-
Germacrene B	-	-	-	-	-	-	-	-	-	17.8

The main compounds in inflorescence oils of different *pimpinella* are shown in Table 24. Pregeijerene, *E*-caryophyllene trans-α- bergamotene and viridiflorol were the most important of constituents in the inflorescence oils.

Table 24: Percentage of the the major constituents identified in inflorescence oils of *Pimpinella*

Compounds	Species									
	P. affinis	*P. anisum*	*P.anthriscoides*	*P. aurea*	*P. barbata*	*P. eriocarpa*	*P. kotschyana*	*P. puberula*	*P. tragioides*	*P. tragium*
β-pinene	-	-	-	-	-	-	4.8	-	-	23.8
limonene	47.9	-	-	8.9	46.9	17.6	-	60.8	-	-
pregeijerene	49.1	-	-	-	1.4					
methyl eugenol	2.3	-	-	-	6.9	-	-	10.5	-	-
E-caryophyllene	-	-	-	-	-	-	40.5	-	-	7.3

trans-α- bergamotene	84.9	-	-	-	-	-	-	-	70.3	-
Germacrene D	-	-	-	-	-	-	29.9	-	-	-
β-Bisabolene	-	-	-	29.5	-	-	-	-	-	-
γ-muurolene	-	-	-	-	18.2	-	-	-	-	-
elemicine	-	-	-	-	4.3	12.5	-	27.3	-	-
Viridiflorol	-	-	-	32.5	-	-	-	-	-	-
Germacrene B	-	-	-	-	-	-	-	-	-	14.1

The main compounds in stem plus leaf oils of different *pimpinella* are shown in Table 25.
As shown in this Table pregeijerene and trans-α- bergamotene were the most important of constituents in the stem plus leaf oils.

Table 25: Percentage of the major constituents identified in stem/leaf oils of *Pimpinella* species

Compounds	Species									
	P. affinis	*P. anisum*	*P.anthriscoides*	*P. aurea*	*P. barbata*	*P. eriocarpa*	*P. kotschyana*	*P. puberula*	*P. tragioides*	*P. tragium*
α-pinene	-	-	-	11.5	-	-	-	-	-	-
limonene	1.4	-	-	21.4	24.3	17.6	-	46.6	-	-
pregeijerene	72.8	-	-	-	8.6	59.9	-	38.8	-	-
methyl eugenol	-	-	-	-	8.7	-	-	12.0	-	-
trans-α- bergamotene	94.3	-	-	-	-	-	-	-	77.1	-
Germacrene D	-	-	-	4.9	-	-	-	-	-	34.7
γ-muurolene	-	-	-	-	28.2	-	-	-	-	-
elemicine	-	-	-	-	4.2	12.5	-	14.0	-	-
Viridiflorol	-	-	-	12.8	-	-	-	-	-	-
Germacrene B	-	-	-	-	-	-	-	-	-	18.3

Acknowledgments:

The author would like to acknowledge the financial support provided by the Research Institute of Forests and Rangelands. I would like to thank Dr. Mirza and Mr. Naderi for injection of the oils to GC/MS and GC. Also I like to express my thanks to Dr. Sefidkon for identification of compounds, Dr. Mozafarian for identification of species and Marzieh Kazemi for editing this manuscript.

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Variation in mechanical properties of Beech (*Fagus orientalis Lipsky*) wood in Asalem northwestern of Caspian Forests (Northwestern of Iran)

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Abstract:

To determine major engineering properties of Beech wood (*Fagus orintalis* Lipsky) in different Location of Caspian Forests (North of Iran), adopting ASTM (D-143) standard specification, the matched small clear specimens were prepared. The test materials were derived from randomly chosen trees. Mechanical and physical properties were measured on two moisture level: green and air-dried (12 % moistures content).

The influence of locations of specimens in height of tree trunks and geographical directions were tested on target properties. From the results of this study it could be concluded that, there was no significant differences between the geographical directions of pith for the most of the properties investigated.

Static bending strengths of different location showed that strength of Asalem is higher than the locations.

Toughness was not influenced by moisture content. The average values of hardness of Beech wood in transverse sections was the same as the other side in green condition, but air-drying caused increasing the value of cross-sections about 30%.

The compression strength perpendicular to the grain had differences in wet and air-dry conditions.

Based on the result of this study, Beech wood of Asalem region (*Fagus orintalis* Lipsky) had higher strength properties than the other regions in Iran.

Key words: Beech, Physical and Mechanical properties

Introduction:

The Eastern beech (*Fagus orientalis Lipsky*) as the main species, this community make up the most beautiful and richest Iranian forests. It is the most important commercial hardwood species in Iran forestry. Although this species indigenously grows from Bulgaria to the Cacuasus, there are abundant forest areas of Eastern beech along the hyrcanian region in Iran. The standing volume on average has been estimated almost 600 and in some cases 800 m^3 some beech trees grow up to 50 m. This forest has remarkable significance due to its production and economical value and has better been preserved as compared to other communities. It grows at high altitudes on Alborz Mountains along the Caspian coast, from Astara to Gorgan. Beech wood is classified as a medium density hardwood and thus, it is heavy, hard, strong, high in resistance to shock, and is highly suitable for steam bending (Bozkurt and Erdin, 1997). Mostly it is used for furniture, veneer, carpenters work benches.

Hyrcanian Zone:

This location selected for cutting and sampling. This location is green belt (figure 1) stretching over the northern slopes of alborz mountain ranges and covers the southern coasts of the Caspian Sea. This area stretches from Astara in the northwest to Gorgan vicinity in the the northeast of Iran. Based on the latest data from the Iranian Forests and Rangelands Organization, this area is approximately 800 km long and 110 km wide and has a total area of 1.85 million ha. Comprising 15 % of the total Iranian forests and 1.1 % of country`s area.

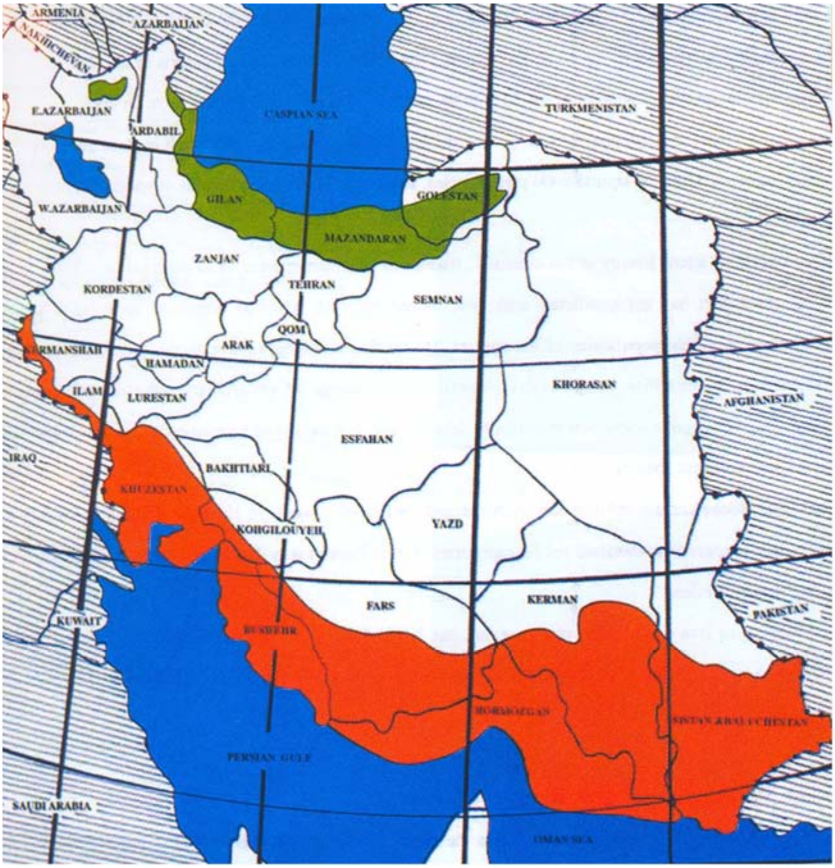

Figure 1: Hyrcanian Zone (green belt)

Figure 2: Hyrcanian Zone stretches from Astara in the northwest to Gorgan vicinity in the the northeast

Hyrcanian Zone

Hyrcanian forests stretch out from sea level up to an altitude of 2800 m and encompass different forest types thanks to their 80 woody species (trees and shrubs). The area is rich in hardwood species.

In this research, some mechanical properties of eastern beech, indigenously grown in Asalem (Northwestern Caspian Sea region), were determined and these data were compared with other research results, available in the literature.

Materials and Methods

The selection of test areas and trees

The trial trees from which the wood samples were taken were obtained from Asalem Forests located in the Northwestern Caspian sea region of Iran. First of all, by taking ASTM D-134 into consideration, the average diameters of all trees at breast height were determined in two trial areas of the above-mentioned region. From each of those trial areas, two trees with a straight trunk and representing the average diameters of trees at breast height were cut. More detailed information can be found about these test trees in Table 1.

Then, 1 m long end-matched log sections were prepared from the whole tree, cut from heights of between 2 and 4 m from the base as mentioned in ASTM D-143 (Figure 3). Test specimens were prepared for the determination of compression strength parallel to the grain, static bending strength, impact bending strength and shear strength parallel to the grain. The determinations of physical properties (density and moisture content etc.) were described in a previous paper (Bektaş and Güler, 1999). The test was performed on a universal testing machine (Instron Model of 1186) and crosshead motion or rate of loading was 0.5 mm/min. Specimens were conditioned at a temperature of 20 °C and 65 ± 5 % relative humidity to the moisture content (MC) of about 12 %. Specimen dimensions were measured to the nearest 0.001 mm. The test was performed on 100 specimens.

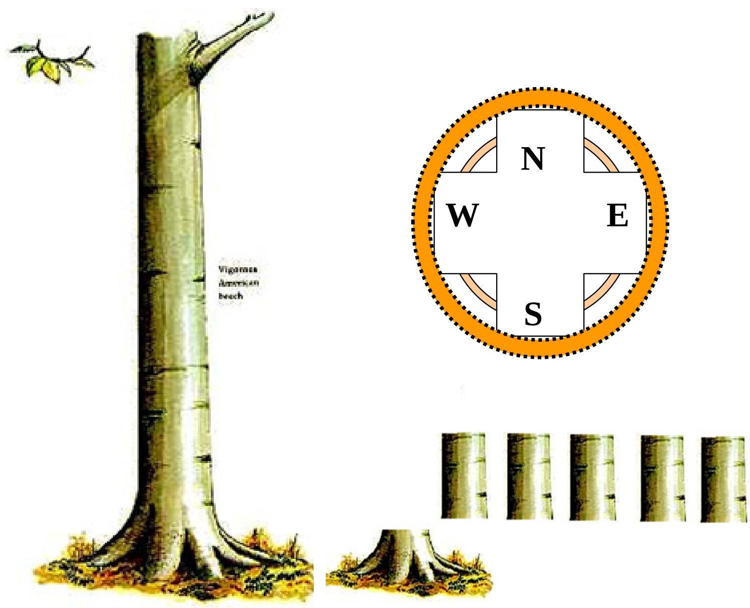

Figure 3: Location of the experimental log section in tree

The compression strength parallel to the grain was calculated by the following equation (Bozkurt and Göker, 1986):

$$\sigma_u = \frac{P_u}{A} \ (\mathrm{N/mm^2})$$

Where σ_u is the compression strength (N/mm^2), P_u is the maximum load at the break point (N) and A is area of cross section of a specimen on which force was applied (mm^2). The effects of the moisture content in the broken specimens were determined according to ASTM D-143.

In this case, the compression strength of the specimen in which moisture content deviated from 12% was adjusted by the following equation:

$\sigma_{12} = \sigma_a$ [1+0.06 (M-12)] (N/mm^2)

Where σ_{12} is the compression strength at the moisture content of 12% (N/mm^2) σ_a is the compression strength at the actual moisture content level (N/mm^2), and M is the moisture content.

Static bending strength

The test of bending strength perpendicular to the grain, i.e. modulus of rupture (MOR=σ_u), was performed according to ASTM d-143/2002 with the exception that specimens had a dimensions of 20 x 20 x 400 mm. Specimens were conditioned at a temperature of 20 °C and 65±5 % relative humidity to the moisture content of about 12 % as in the other tests. The bending test was done on the same universal testing machine as used for the compression test. The load was applied to the radial surface of specimens and the loading speed was one mm/min and for this test; 100 samples were used. The MOR of the specimens was calculated by the following equation (Örs, 1986):

$$\sigma_u = \frac{3.Pu.L}{2.b.h^2} \text{ (N/mm}^2\text{)}$$

Where σ_u is MOR (N/mm^2), P_u is the maximum load at break point (N), L is the length of span (360 mm), b is the width of specimen (mm), and h is the thickness of the specimen (mm). The moisture contents of the broken specimens were determined according to ASTM D-143/2002. The bending strength of the specimen whose moisture content deviated from 12 % was adjusted by the following equation (Bozkurt and Göker, 1996):

$\sigma_{12} = \sigma_a$ [1+0.04 (M-12)] (N/mm^2)

Where σ_{12} is the bending strength at a moisture content of 12 % (N/mm^2), σ_a is the bending strength at actual moisture content (N/mm^2) and M is the moisture content.

Impact bending strength Impact bending strength was determined according to ASTM D-143/2002 and the specimen size was 20 x 20 x 300 mm. Specimens were conditioned at a temperature of 20 °C and 65±5% relative humidity for 3 months to the equilibrium moisture content of about 12 %. The impact bending strength of the specimens was tested on an impact tester (Instron Model PW5). The impact bending strength was calculated by the following equation (Berkel, 1970):

W_t =Bl(cosß-cosδ) (N.m)

Where W_t is the impact bending strength (N.m), B is the hammer weight (N), l is the distance between the pendulum axis and point of impact of striking edge in the center of the specimen (m), ß is the angle rise hammer without sample and δ is the angle rise hammer with sample.

$$W_{st}= \frac{A_{st}}{A_t} W_t$$

Where W_{st} is the standard impact bending strength (N.m), A_{st} is the standard area hammer weight (m^2), A_t is the area in testing position and W_t is the impact bending strength (N.m).

Shear strength parallel to the grain

The test was done according to ASTM d-143/2002 on a ton universal testing machine (Instron Model 1186). Shear strength was calculated from the following equation (Bektaß, 1997):

$$\sigma_u = \frac{P_u}{b.l} \ (N/mm^2)$$

Where σ_u is shear strength (N/mm^2), P_u is the maximum load at break point (N), b is the thickness of specimens (mm) and l is the length of samples (mm).
The following equation was used for this purpose:

$$\sigma_{12} = \sigma \ [1+0.03 \ (M-12)] \ (N/mm^2)$$

Where σ_{12} is shear strength at 12 % MC (N/mm^2), σ is shear strength at actual MC (N/mm^2) and M is moisture content (%).

Results and Discussion

In this section, these results (Table 1) and other available research results (Table 2) will be compared. According to Table 3, Eastern beech trees grown in Asalem have the highest static bending strength among other of the beech species in Iran but lower than that from of the beech species in that Table 3. However, compression strength is lower than that for Visar (Iran) and Blake sea beeches, but higher than that for beech species in that Table. Impact bending strength is lower than that for Visar (Iran) and Black sea beeches, but higher than that for beech species in that Table. Shear strength is the highest than that from of the beech species in that Table.

Table 1: The characteristics of trees

No	Tree A	Tree B
Age	97	110
Diameter (cm)	31	40
Length (m)	18	20

Table 2: Descriptive statistic of the results Asalem beech

Beech wood	Compression strength parallel to grain (N/mm2)	Static bending strength (N/mm2)	Impact strength (N.m)	Shear strength (N/mm2)
Number of samples	100	100	100	100
Average	50.57	107.88	23.25	12.25
Standard deviation	3.52	78.54	7.58	2.65
Coefficient of variation	2.5	5.5	12.25	3.54
Minimum value	68.49	80.03	16.00	7.987
Maximum value	75.37	159.93	29.00	17.390

Table 3: Comparison of some mechanical properties of Asalem beech with other beech species.

Tree specices	Air-dry density (gcm^3)	Compression strength parallel to grain (N/mm^2)	Static bending strength (N/mm^2)	Impact strength (N.m)	Shear strength (N/mm^2)	References
Fagus orintalis (Asalem, Iran)	0.693	50.57	107.88	23.25	12.25	(Golbabaei, 2007)
Fagus orintalis(Sangdeh,Iran)	0.608	45.13	75.59	21.72	9.98	(Golbabaei,2003)
Fagus orintalis(Visar,Iran)	0.623	33.50	82.5	36.29	10.7	(Ebrahimi, 1990)
Fagus orintalis (Iran)	0.630	56.40	87.00	17.16	-	(Pajoh, 1974)
Fagus orintalis (Black Sea)	0.669	57.20	112.30	23.29	9.97	(Malkoçoğlu, 1994)
Fagus silvatika(European)	-	64.80	-	23.05	-	(Hotvat, 1969)
Fagus silvatika(European)	0.698	52.70	110.2	24.03	-	(Cividini, 1969)
Fagus silvatika(European)	0.716	52.10	110.5	20.85	9.83	Stoyanoff and Entcheff, 1949)

Beech trees generally grow at 650-2200 m in Iran, and the Eastern beech grows at high altitude (1200 m) in Asalem. Furthermore, the variations in the mechanical properties in the same species are due to different factors, such as growth conditions and ecological factors. In particular, exposure, altitude, soil and climate conditions can affect the mechanical properties of wood. Sample size and properties (e.g. ring orientation), and the test procedure can also affect the test results. For all these reasons, some properties of Asalem beech wood showed properties slightly different to those of other beech species.

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The cooperation between Iranian and German scientists is one of the most important topics of the special program "German-Arabian/Iranian Education Dialogue" which is funded by the German Academic Exchange Service (DAAD). Within the scope of this special program an exchange between young scientists of Iran and Germany took place. The book contains sessions and talks of junior scientists of both countries in research fields of forestry, wood science and wood biotechnology.

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ISBN 978-3-940344-21-2

Universitätsdrucke Göttingen