UNIVERSIDADE DO ALGARVE

FACULDADE DE CIÊNCIAS E TECNOLOGIA

SARAH A. RAUTENBACH

Assessment of the marine biodegradation and suitability of textile carrier substrates for *Zostera marina* transplantation

2021

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Master in Marine and Coastal Systems (MACS)
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Work authorship statement /Declaração de autoria de trabalho

Assessment of the biodegradation of textile substrates in the marine environment and their suitability as carrier substrate for seagrass transplantation of Zostera marina

I declare to be the author of this work, which is unique and unprecedented. Authors and works consulted are properly cited in the text and are included in the listing of references included.

Declaro ser o(a) autor(a) deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída.

Faro, 30.09.2021

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Sarah A. Rautenbach

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Abstract

Seagrass meadows provide essential eco-system services for humankind but have been declining over the past and still ongoing, mainly attributed to anthropogenic disturbances. The development of cost-effective and large-scale strategies for seagrass restoration has been challenging. In this study fundamental knowledge was generated to identify textile fabrics from natural derivatives to serve as carrier substrate for transplantation purposes. In a series of experiments the biodegradation behavior of textiles was assessed, differing in material and design. Specimen were buried in the intertidal of the Ria Formosa Lagoon and retrieved after set intervals. Weight, tensile strength and oxygen consumption rate were used as descriptors for biodegradation. The least degraded fabric was composed from coir, followed by the jute and sisal layouts, which performed similarly. The response of *Zostera marina* shoots towards the textiles was analyzed by placing shoots, incorporated into the fabrics, into mesocosms. Survival rates along with the development of new leaves was higher in shoots growing on sisal layouts than in controls and shoots in coir nets. This study demonstrated that the fixation of the plants onto a dense mesh as the sisal one offers significant support for shoots to grow on, resulting in superior health compared to single lose shoots. Additionally, earlier induced biodegradation in sisal layouts possibly fostered shoots with plant-growth-supporting substrates, according to the health state of these shoots. Hence, time of biodegradation was found to be vital for seagrass transplantation. Rapid degradation, leaving no carrier substrate as in controls and fertilized shoots, was proven to reduce survival chances. Retarded degradation like in coir fabrics, decelerates the supply of growth supporting substrates. Concluding, the dense sisal mesh was found to be the most successful fabric for transplantation of *Zostera marina* due to its biodegradation rate, high tensile strength, facilitating handling, along with sufficient fixation of the shoots.

Keywords: Seagrass, restoration, *Zostera marina*, cost-effective, geotextiles, biodegradation

Resumo

A sociedade actualmente enfrenta um grande número de desafios ambientais que precisam de ser enfrentados e resolvidos. O ambiente marinho é essencial para o bem-estar humano e proporciona vários serviços ecossistêmicos, como zonas favoráveis á práctica de pesca, rotas de transporte de mercadorias e pessoas, serviços recreativos e muito mais. Com o aumento da influência antropogênica adversa neste ambiente, os serviços do ecossistema tornam-se mais escassos, dando origem a uma variedade de problemas para a população humana. As ervas marinhas desempenham um papel fundamental na boa continuação de vários desses serviços ecossistêmicos, servindo como habitat de berçário para diferentes espécies, protegendo as costas da erosão e sequestrando o carbono atmosférico. No entanto, os prados de ervas marinhas têm diminuído nas últimas décadas, em grande parte devido a distúrbios antropogénicos. O foco principal deste trabalho é o restabelecimento dos prados de ervas marinhas.

O desenvolvimento de estratégias econômicas e em grande escala para a restauração de ervas marinhas tem sido um desafio. A falta de recursos, dificuldades de logística, baixa eficiência e eventos ambientais adversos, como tempestades, foram os principais contribuintes para o fracasso de muitos programas de restauração. Neste estudo, conhecimentos fundamentais foram gerados para identificar uma nova abordagem de restauração de ervas marinhas em que tecidos de derivados naturais serviram como substrato de transporte para fins de transplante. Formulando e colocando em práctica um conjunto de experiências, o comportamento de biodegradação de tecidos no ambiente marinho foi avaliado, uma vez que, até ao momento, só há informações disponíveis sobre a degradação terrestre. Os tecidos diferenciam-se em material (fibra de coco, sisal, juta) e design (malha, tapete não tecido). Os tecidos foram combinados em uma chamada “estructura de sanduíche” na qual uma esteira não tecida foi colocada entre duas malhas do mesmo tipo, gerando assim um composto estabilizador (malha) e base de enraizamento (esteira) para os brotos de *Zostera marina*. Os espécimes foram enterrados na zona entre-marés do estuário da Ria Formosa e avaliados semanalmente durante o primeiro mês, e posteriormente, mensalmente durante mais dois meses. A perda de peso e a perda de resistência à tracção foram usadas como descrictores físicos, e a taxa de consumo de oxigênio como descrictor biológico para a taxa de biodegradação. O tecido com menor taxa de degradação foi o composto de fibra de coco, seguido pelos layouts de juta e sisal,

que tiveram desempenho semelhante. No entanto, as telas de sisal possuem a maior resistência observada à tração inicial e final, sendo a melhor escolha de material.

A resposta dos rebentos da *Zostera marina* aos têxteis foi analisada através da incorporação dos mesmos nos têxteis, que posteriormente foram colocados em mesocosmos. Os mesocosmos foram dotados de um fluxo de ar coerente e afluência de água do mar do estuário da Ria Formosa. Parâmetros físicos como temperatura, salinidade, intensidade da luz e oxigênio dissolvido foram monitorizados durante todo o período da experiência. A saúde dos brotos diminuiu em todos os tanques e tratamentos após um período de sete semanas, conforme demonstrado na diminuição das taxas de sobrevivência. Os brotos que cresceram em layouts de sisal mostraram maior resistência ao stress do que os controles e os brotos incorporados às redes de coco. Isso foi revelado pela menor mortalidade de brotos que crescem em tecidos de sisal, juntamente com um aumento do desenvolvimento de novas folhas. Além disso, o rendimento quântico efectivo - um proxy para a atividade fotossintética - foi maior nesses brotos. Desse modo, este estudo demonstrou que a fixação das plantas em uma malha densa como a do sisal oferece um suporte significativo para o crescimento de brotos, resultando em saúde superior quando comparado com brotos isolados. Além disso, a biodegradação induzida mais cedo em layouts de sisal (comprovada pelos testes de biodegradação), possivelmente promoveu brotos com substractos de suporte de crescimento de plantas, melhorando a sua integridade e capacidade de produzir novas folhas. Portanto, o tempo de biodegradação foi considerado vital para o transplante de ervas marinhas. A rápida degradação, sem deixar substracto portador como nos brotos de controle e fertilizados, demonstrou reduzir as chances de sobrevivência. Em contraste, a degradação retardada, como em tecidos de coco, desacelera o fornecimento de substratos de suporte de crescimento. A integridade dos brotos fertilizados estava mais intacta do que a dos brotos incorporados à malha de fibra de coco, apoiando a suposição de que a nutrição é crucial para a saúde das ervas marinhas. A nutrição saudável pode até superar o efeito positivo derivado de um substracto de suporte a longo termo. Portanto, um dispositivo de ancoragem como o tecido de sisal com um efeito secundário de fertilização parece ser a solução ideal.

A distinção entre as esteiras não-tecidas - que eram compostas de fibra de coco, mas diferiam em sua densidade e espessura - não poderia ser feita porque estas

comportaram-se de forma contrária durante as experiências do mesocosmo. A esteira mais densa apresentou melhor desempenho embebida na malha de sisal, porém comportou-se inferiormente na malha de coco. Assim, uma investigação mais aprofundada deve ser realizada para examinar o efeito do enraizamento, testando diferentes materiais por um período mais longo, uma vez que nenhum enraizamento foi observado durante as sete semanas da experiência.

Concluindo, a malha densa de sisal mostrou-se o tecido de maior sucesso para transplante de *Zostera marina* em condições controladas com base em sua taxa de biodegradação e alta resistência à tracção, que facilita o manuseio para o transporte, além de proporcionar fixação suficiente para os brotos. No entanto, os testes foram realizados em escala de laboratório por um curto período de tempo e não foram submetidos a forças hidrodinâmicas. É possível que a rápida biodegradação da malha de sisal seja muito pronunciada a longo prazo, não dando aos brotos o tempo adequado para se enraizarem no solo de sedimentos. Mais pesquisas na tradução destas descobertas para o ambiente "selvagem" devem ser realizadas.

Palavras-chave: Ervas marinhas, restauração, *Zostera marina*, custo-benefício, geotêxteis, biodegradação

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ABBREVATIONS

C	Control
CC	Coir net – Coir mat
CCMAR	Center of Marine Sciences
CT7	Coir net – Type 7 mat
FT	Fertilizer
JC	Jute net – Coir mat
JT7	Jute net – Type 7 mat
N	Nitrogen
OCR	Oxygen Consumption Rate
P_2O_5	Phosphorus pentoxide
PAM	Pulse-Amplitude-Modulation
PS I	Photosystem I
PS II	Photosystem II
SC	Sisal net – Coir mat
SiO_2	Silicon Dioxide
ST7	Sisal net – Type 7 mat

1 INTRODUCTION AND MOTIVATION

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) identified that, nature is declining world-wide at an unprecedented rate. The rate of ecosystem loss and species extinction is accelerating, resulting in severe impacts on ecosystem services such as food security, livelihood, economy, health and more (IPBES, 2019). The current extinction rate is 1,000 times higher compared to natural background rates and is most likely to rise up to the 10,000 fold (Vos *et al.*, 2015). According to IPBES, global indicators of ecosystem extend and conditions decreased 47 % from the estimated natural baseline. Main driver for loss of biodiversity and ecosystems are assigned to significant habitat alteration through human activity. In between the 18th and 21st century more than 85 % of wetlands have diminished as well as 66 % of the marine environment has been drastically transformed up to this day.(IPBES, 2019).

Especially marine environments suffer from anthropogenic exploitation. Overfishing, aquaculture, exploitation of resources and other coastal engineering activities contribute to habitat changes, in a possibly even synergistical manner (Halpern *et al.*, 2008). The majority of human activities operate in the intertidal and nearshore zone such as marshes, mangroves, sand beaches, dunes, seagrass beds, and coral and oyster reefs, pressuring these ecosystems to a higher extent than the offshore regions (Halpern *et al.*, 2008; Barbier, 2017). Terrestrial and marine environments along with human welfare depend strongly on the ecosystem services, provided by the coast and the high seas (Barbier, 2017) due to the profound interconnectivity between ecological and socioeconomic systems (Margerum, 1999). Marine systems protect coasts from storms and erosion, provide food, oil, minerals and other resources, are used for recreational purposes, transport and pollution control (Barbier, 2017). The decline in fish populations, for example, results in a decreased food provision (humans and animals) and water quality, increased algae blooms, hypoxia and possibly the loss of complete ecosystems (Barbier, 2017). Densely populated coastal regions are directly impacted by these ecosystem losses, endangering 100-300 million people (IPBES, 2019).

The diminishing of natural environments, and thus decreases in ecosystem services for humankind and environment, calls for protection and restoration efforts. Many systems cannot recover themselves as efficient as through assisted action, even if stressors are minimized or completely removed, therefore active restoration must be emphasized (Perrow & Davy, 2004; Rey Benayas *et al.*, 2009). The integrity of ecosystems can be either entirely restored, recreated and/or enhanced, depending on their initial state and the desired purpose of restoration (Wilson & Forsyth, 2018). The success of restoration programs can be determined by measuring the improvement of ecosystem services (Basconi *et al.*, 2020).

A vast number of essential ecosystem services are provided by organisms such as seagrass meadows. They provide nursery homes for juveniles or food for other organisms. Seagrass patches are one of the most productive ecosystems in the world (Reynolds, 2013; Descamp *et al.*, 2017a), and are crucial for anthropogenic purposes such as protection of beaches from erosion and sequestering carbon from the atmosphere (Descamp *et al.*, 2017b; Unsworth *et al.*, 2019). However, seagrass meadows suffer from high stress and have been constantly declining since the preindustrial times (Eriander, 2017). Over the past 130 years, one third of worldwide seagrass meadows disappeared with a decrease of 7 % yr^{-1} since 1990 (Waycott *et al.*, 2009).The diminishing of seagrass meadows can be primarily attributed to anthropogenic stressors. These include the input of chemical loads into the system, physical damage (dredging, mooring and propeller scars), input of increased nutrient loads and more (Fonseca *et al.*, 1998; Descamp *et al.*, 2017b; IPBES, 2019). Worldwide restoration efforts have been made since the late 1930's (Tan *et al.*, 2020). Especially, the United States and Australia are well experienced in seagrass restoration and were amongst the first nations to give attention to these ecosystems (Fonseca *et al.*, 1998; Erftemeijer, 2020). Nevertheless, due to the slow recovery rate of seagrasses and the low germination rate of their seeds, large scale and long term restoration of meadows has turned out to be a difficult task and success rates are therefore considerably low (average 37 % success rate) (Fonseca *et al.*, 1998; Xu *et al.*, 2016; Eriander, 2017). Currently, a wide number of innovative methodologies and approaches are under development and tested globally on different seagrass species at different latitudes. Traditional and most conventional techniques of seagrass restoration include the sod, single shoot and/or seed transplant method, including different planting and anchoring systems such as metal frames, mussels, rocks, textile bags and strips, simple burying and more (Erftemeijer, 2020).

The main issue, arising with the application of traditional transplanting methods, is the adverse effect on the donor meadows. Adult plants are used for transplanting efforts therefore, the population of the donor meadow declines for restoration efforts. Especially, in large scale projects, existing seagrass meadows suffer from the exploitation of sods and shoots from their system. Many times the donor meadow cannot recover from the loss due to their slow recovery rate (Fonseca *et al.*, 1998; Xu *et al.*, 2016). Furthermore, various studies on seagrass restoration report their transplantation attempts as successful, although the monitoring periods of often less than a year are not sufficient to give reliable results (Zhou *et al.*, 2014). Premature meadows suffer from hydrological pressures such as waves and storm events and often cannot withstand the disturbing forces (Paulo & Cunha *et al.*, 2019). Beyond that, environmental and biological factors vary within years, therefore a short monitoring period lacks these variabilities and shoots that survived in one year might not survive the following (Zhou *et al.*, 2014).

Combined, these problems call strongly for the development of donor-free methods for seagrass restoration in order to protect the donor population and additionally, provide a carrier substrate, that can function as growing surface for the premature seagrass shoots, therewith they can withstand the first winter storms of the year after transplantation.

This work focus on the establishment of basic knowledge on the response (survival rate) of seagrass shoots, planted into different carrier substrates (textiles) and their ability of the roots to entangle into substrates as well as on the performance (degradation and mechanical strength) of these textiles in the marine environment. Solely textiles, that are fully biodegradable, without releasing adverse by-products during degradation into the system, were assessed experimentally. The intention was not to disturb the marine system by placing synthetic structures into the environment and, to develop an innovative and feasible transplanting method, which does not harm donor meadows to such an extent as traditional transplanting does. A variety of requirements must be met for the textiles to be successful in the field. The material needs to be resistant against permanent hydrological pressures such as currents from tides, wave action as well as winter storms. Beyond physical pressures, the materials must withstand microbial attacks and saline marine conditions for an extended period. Hence, the biodegradation rate of each textile was evaluated by monitoring weight and tensile strength loss along with aerobic microbial activity of buried textiles in the marine environment. Moreover, the textiles must supply a matrix, which allows the roots of the seagrass to incorporate in, thereby stabilization of the shoots in the environment can be assured. Shoots were incorporated into the textiles and their response monitored and analyzed.

This work bears great potential in providing essential information on a new method for restoration. Future studies of the project aim at the multiplication of harvested seagrass shoots in artificial tanks and eventually, transplant the multiplied population back into the environment. The textiles will serve as a large-scale base, which facilitates transport and results in effortless out bedding of the new plants. Thereby, donor meadows face less disturbances and, new shoots have sufficient time to root into the seabed due to the stabilization by the carrier substrate

1.1 RESTORATION PROGRAMS

The unprecedent deterioration of marine ecosystems related to human activities bears adverse effects on human welfare. Marine ecosystems provide several essential functions with respect to food supply, coastal protection, erosion control and more. Coastal and marine managers face the challenge on sustaining and restoring these ecosystems to assure security for humankind. Artificial solutions, such as groins and jetties have been used to control the degradation of these ecosystems, however these man-made solutions fall short in resiliency and may further complicate the status of the nearby ecosystem along with generating exorbitant costs (Ferrario *et al.*, 2014). Recently focus has been set on so-called ecosystem engineers such as corals, mangroves, seagrasses and others. These organisms modify their abiotic environment and create favorable abiotic and biotic conditions for other species and men (Jones *et al.*, 1994; Rossi *et al.*, 2013; Basconi *et al.*, 2020). Ecosystem engineers are a cost-effective option for restoration programs of ecosystem services (Byers *et al.*, 2006). However, these organisms are part of the diminishing ecosystem and therefore, lose their ability to protect and sustain ecosystem services (Rossi *et al.*, 2013). Consequently, ecosystem engineers can either be newly introduced into a system or, more importantly, conserved and restored where they already exist in order to reestablish and maintain their supporting impact on their environment (Law *et al.*, 2017).

According to Basconi *et al.*, (2020) restoration ecology gained strong interest in the past two decades. The intention of this emerging scientific branch is to rehabilitate ecosystems in comparison to a historical baseline. Hence, it aims at habitats, in which the ecosystem of concern was present beforehand and suffered damage and loss. In order to succeed, Bayraktarov *et al.*, (2016) suggest four criteria, that must be considered; (1) understanding of the functions of the ecosystems, (2) removal of anthropogenic disturbances, (3) clearly defined success evaluation, (4) long term monitoring > 5 years (approx. 15-20 years). Different restoration techniques have been developed, ranging from planting juveniles to adult organisms, collected from a donor site, or the introduction of artificial structures, hosting the target species (Basconi *et al.*, 2020). During an analysis of 235 articles on marine restoration programs conducted by Bayraktarov *et al.*, (2016) the main target species, costs as well as main challenges with respect to rehabilitation actions were identified. Ecosystems from most interest for restoration purposes include salt marshes, coral reefs, oyster reefs, seagrass meadows and mangroves. Costs range widely depending on methodology and resources. Estimated costs can range from US$ 2.508/ha for mangrove restoration up to US$ 383,672/ha for seagrass restoration (Bayraktarov *et al.*, 2016). According to Bayraktarov *et al.*, (2016) total restoration costs appear not to increase with expansion of the project scale in regard to coral reef and seagrass meadow restoration. Though, most projects were conducted on a small scale; <1 ha and <10 ha, for coral reef and seagrass respectively, wherefore the estimation might not be accurate (Bayraktarov *et al.*, 2016). The least successful (38 % success rate), but at the same time one of the most cost-intensive programs is related to seagrass (Bayraktarov *et al.*, 2016), therefore already existing approaches must be improved or new innovative strategies must be developed.

1.2 SEAGRASSES: BIOLOGY AND DISTRIBUTION

Seagrasses are aquatic plants, distributed throughout shallow marine systems around the world, from the Southern Hemisphere to tropical regions up to the Arctic (Reynolds, 2013). They are angiosperms (flowering plants) and inhabit coastal areas from the intertidal up to depths excess of 50 m (Duarte, 2001; Reynolds, 2013; Encyclopedia Britannica, 2020). Seagrasses are further categorized as monocotyledons (angiosperms), implying they possess one embryonic leaf in their seeds (Encyclopedia Britannica, 2020).

There are 72 species of seagrasses identified, assigned to four main taxonomic groups; *Zosteraceae, Hydrocharitaceae, Posidoniaceae* and *Cymodoceaceae* (Reynolds, 2013).

According to Short *et al.*, (2007) species are distributed to different extent throughout the six global bioregions: Temperate North Atlantic, Temperate North Pacific, Mediterranean, Temperate Southern Oceans, Tropical Atlantic, Tropical Indo-Pacific. The Temperate North Atlantic features an overall low species diversity and is dominated by the species *Zostera marina*, which grows predominantly in estuaries and lagoons. Extensive species diversity can be found in the estuarine and surf zones of the Temperate North Pacific including species of *Zostera spp*. and *Phyllospadix spp.*.Closer towards low latitudes, the Mediterranean waters host a modest amount of different seagrasses including temperate and tropical species, dominated by *Posidonia oceanica*. The Temperate Southern Oceans are habitat to a vast number of seagrass meadows ranging from low to high diversity temperate seagrasses. *Posidonia* and *Zostera* dominate this area. The highest biodiversity of seagrass species can be found in the tropical regions of the Indo-Pacific as well as the Tropical Atlantic, both dominated by *Thalassia testudinum*. (Short *et al.*, 2007; Eriander *et al.*, 2016)

The morphology of seagrasses can be divided into above and below ground parts (Fig. 1). According to the definition of Kuo & Hartog, (2006) above ground, multiple elongated leaves are embraced in shoots. A basal sheath wraps each leaf, protecting the apical meristem. Sugar production via photosynthesis occurs in the distal blade as well as transpiration of water vapor. Above ground parts are characterized by three tissues; the epidermis as a surface layer, regulating transpiration and aeration together with provision of mechanical support, the vascular bundle, which contains the phloem and the xylem, responsible for organic and inorganic solute transport and the parenchyma tissue, controlling photosynthesis and storage. Below ground parts anchor the seagrass to the seabed and include roots, rhizomes and in some cases erected stems, which together construct a widely interconnected underground system. Roots, shoots and stems are connected to the creeping rhizomes at each node or every other node. Additional to the mechanical support, the rhizomes provide essential functions for regulation and maintenance of seagrass growth, including the storage of nutrients. During sexual reproduction seagrasses develop flowers, which produce seeds for pollination and fertilization. (Kuo & Hartog, 2006)

Seagrasses produce offspring either asexually by growing new rhizomes and thus, producing new shoots or sexually by the transport of male pollen through the water, fertilizing female flowers and producing seeds (Reynolds, 2013). Genotypic diversity is assured via sexual reproduction, which offers advantages in maintaining and withstanding climatic changes (Paulo & Diekmann *et al.*, 2019), whereas during clonal propagation, offspring feature the identical genetic information as the parent and amongst each other (Eckert, 2001). Billingham *et al.*, (2003) identified, that the preferred reproduction mode changes throughout shoot location within a meadow. Clonal reproduction appears to be the favored strategy at outer margins of a meadow, in contrast to an increased sexual reproduction in the central regimes (Billingham *et al.*, 2003).

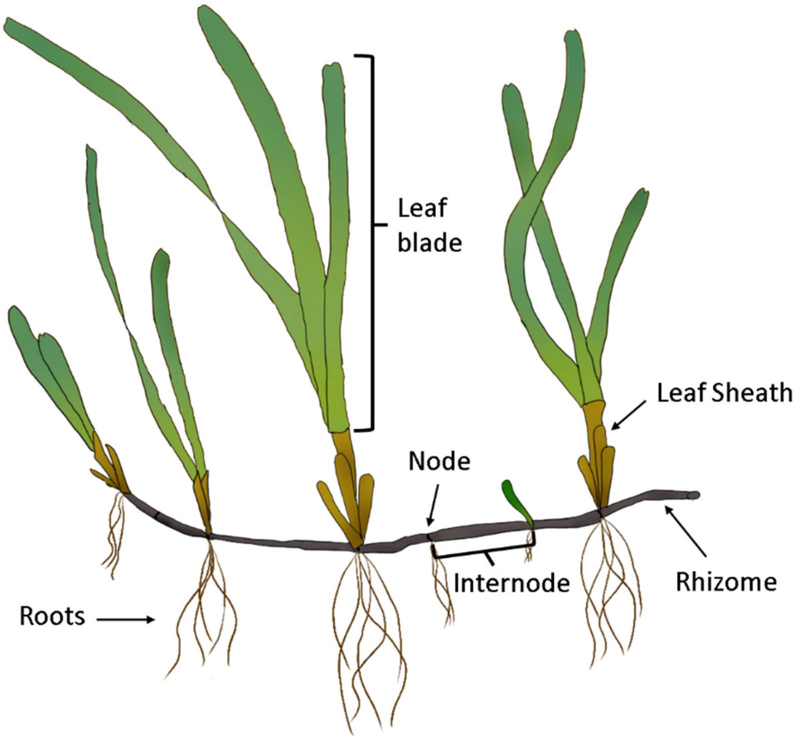

Fig. 1. Illustration of *Zostera Capensis* as an example for seagrass morphology adapted from (Collier, 2004).

Seagrasses provide a variety of ecosystem services for their surrounding environment and therefore, contribute to marine and human welfare (Eriander *et al.*, 2016). They are one of the most productive ecosystems globally and, hence, are essential for primary production and the export of its compounds into the surrounding environment (Fonseca *et al.*, 1998; Reynolds, 2013; Descamp *et al.*, 2017a). Furthermore, seagrasses function as recruiting areas for many marine organisms for instance for fish, prawns and invertebrates. Moreover, seagrasses supply food for invertebrates to large fish, carbs, mammals and birds as well as protection for smaller species (Reynolds, 2013; Descamp *et al.*, 2017a). Beyond the provision of biological and ecological ecosystem services, seagrasses also influence the physical environment positively for humans by securing lose sediment from the seabed via their widely distributed underground root and rhizome system, inhibiting erosion of beaches and controlling sediment flow (Fonseca *et al.*, 1998; Descamp *et al.*, 2017b). Furthermore, hydrodynamics and wave height can be reduced by more than 36 %, contributing to coastal protection (Narayan *et al.*, 2016). Additionally, seagrasses can be a useful tool for management purposes such as water quality assessment and improvement (Fonseca *et al.*, 1998) by trapping fine particles in and therefore, cleaning the water column (Eriander *et al.*, 2016; Narayan *et al.*, 2016). Beyond the direct influence of the seagrasses on the marine environment, they also affect the atmosphere in a beneficial manner. Seagrasses are considered a blue carbon storage, due to their ability to sequester atmospheric carbon and store it in the soil, accounting for10–18 % of global carbon burial in the marine environment (Röhr *et al.*, 2018; Unsworth *et al.*, 2019; Bedulli *et al.*, 2020). A recent study from Bedulli *et al.*, (2020) (Bedulli *et al.*, 2020)(Bedulli *et al.*, 2020)conducted on Rottnest Island, Australia, even identified an approximately storage capacity from mixed seagrass populations of 22 % of the island's carbon dioxide emissions (Bedulli *et al.*, 2020). These studies prove that seagrasses can play a key role in fighting anthropogenic induced CO_2.

The importance of seagrass meadows for assuring socioecological security requires intensified conservation and restoration actions of these ecosystems.

1.3 MODEL SPECIES: *ZOSTERA MARINA*

Zostera marina, also known as "common eelgrass", is the most dominant angiosperm species throughout the Northern Hemisphere, distributed from the Arctic down to the warm waters of the Mediterranean Sea (Fig. 2) (Setchell, 1935; Borum *et al.*, 2004; Eriander *et al.*, 2016). It populate the intertidal as well as subtidal (10-15 m depth), determined by water clarity and light penetration (Borum *et al.*, 2004; Short *et al.*, 2007). Populations differ in their morphology, with increasing size towards higher latitudes, in their tolerance to temperature and salinity as well as in their lifecycle, confirmed by occurrences of perennial, biennial and annual populations (Larkum *et al.*, 2006; Short *et al.*, 2007).

Zostera marina (Fig. 2) predominantly grows in monospecific meadows and varies seasonally in biomass production, shoot density and morphology (Solana-Arellano *et al.*, 1997;

Borum *et al.*, 2004; Short *et al.*, 2007). It is composed of three to seven leaves per shoot, which feature a width of 2 mm to 10 mm and an average length between 30 to 60 cm, depending on their maturity status. Shoots are connected to below ground rhizomes, which form a new rhizome segment (internode) for each new leaf along with 2 - 20 cm long root bundles on each node. Flowering occurs during spring to fall and 2-4 mm long seeds develop, which distribute by either floating away with the detached shoots or fall to the nearby ground within the same meadow (Borum *et al.*, 2004).

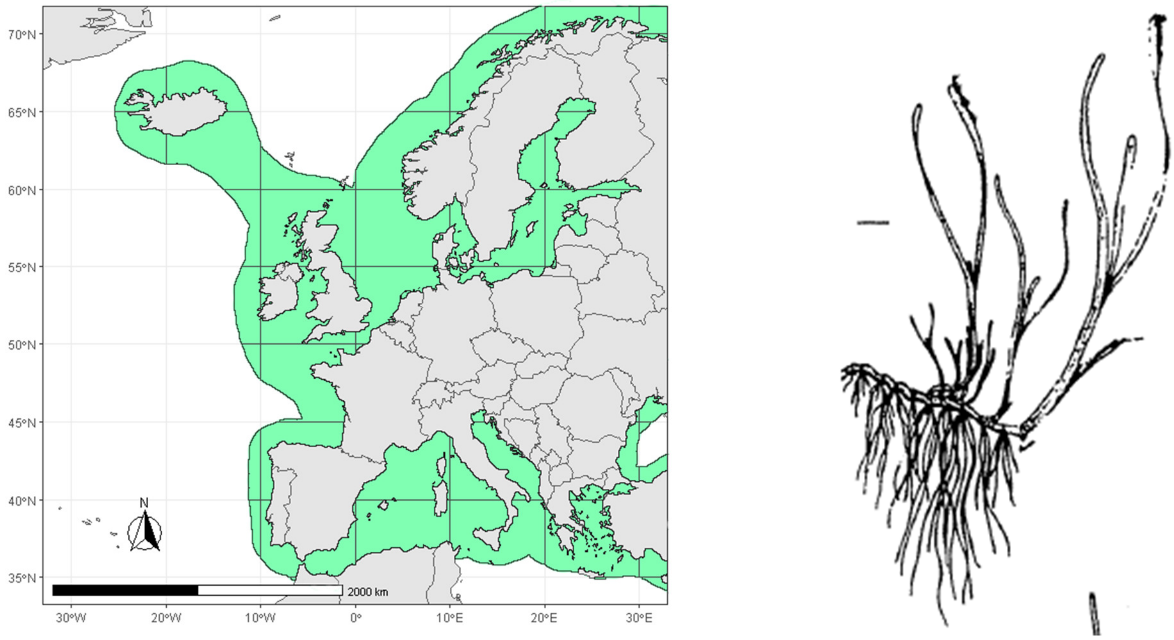

Fig. 2. *Zostera marina* distribution (left), adapted from (Borum *et al.*, 2004) and scheme of *Zostera marina* morphology (right) (Fonseca *et al.*, 1998).

Zostera marina populations have suffered strongly from variations in abundancy throughout the last century. In the 1930's almost the complete population (90 %) in the Northern Atlantic has been diminished due to an epidemic disease known as the saprophytic net slime mold, *Labyrinthula spp.* (TUTIN, 1938; Ralph & Short, 2002; Keser *et al.*, 2003). Beyond that, long term decline in *Zostera marina* populations has been attributed to anthropogenic disturbances in e.g. Rhode Island, United States (Short *et al.*, 1996). Particularly increasing eutrophication is detrimental to the high light requiring species of *Zostera marina* due to its reducing effect on water clarity and therefore, light attenuation (Dennison *et al.*, 1993; Eriander, 2016). Additionally, eelgrass lacks the ability to re-establish itself once destroyed in a larger scale even if, pressures are minimized or eliminated (Boström *et al.*, 2014). The vast decline of eelgrass meadows and the inability to recover on their own, leaves them one of the most endangered and vulnerable ecosystem worldwide(Dennison *et al.*, 1993; Waycott *et al.*, 2009; Boström *et al.*, 2014).

Zostera marina was identified as the most threatened species along the Portuguese coast, impacted by bivalve hand trawling, boat mooring and channel dredging (Cunha *et al.*, 2013). Meadows of this species are abundant in only two sites in Portugal; Lagoa de Óbidos and the Ria Formosa Lagoon, covering a total area of 0.075km^2 (Cunha *et al.*, 2013).The Ria Formosa Lagoon in the south of Portugal accommodates 42 meadows of *Zostera marina*, which account for an area of 5.01 ha (Cunha *et al.*, 2009). Restoration efforts of *Zostera* in other regions of the country such in the Arrábida national park were subject to failure (Cunha *et al.*, 2013).

1.4 NATURAL FIBERS

Natural fibers are gaining increased popularity in the field of geotextiles, especially attributed to their green biodegradation (Ghosh *et al.*, 2017; Wu *et al.*, 2020). As of today, according to Wu *et al.*, (2020), geotextiles made of natural fibers have the ability to replace 50 % of the synthetic products on the market (Wu *et al.*, 2020).

Natural fibers can be divided into three categories: plant fibers, animal fibers and mineral fibers. Plant fibers are the most favorable fiber, due to their low cost in sourcing and processing as well as their superior mechanical performance (Wu *et al.*, 2020).The three main components of plant fibers are cellulose, hemicellulose and lignin, whose weight proportion determines the physical properties of the fibers (Table 1) (Wu *et al.*, 2020).

Textiles offer a wide range of applications and are often found in the geotechnical sector (Wu *et al.*, 2020). These so-called geotextiles are commonly produced from petrochemical derivates (Wu *et al.*, 2020). Nowadays the demand for green geotextiles is rising and where applicable preferred (Mahuya *et al.*, 2009; Wu *et al.*, 2020). Green geotextiles are composed from natural fibers and have no adverse effect on the environment (Mahuya *et al.*, 2009). Among plant fibers jute and coir convince with their outstanding mechanical performance, hence are used in this branch (Mahuya *et al.*, 2009). Sisal fibers feature distinctive seawater resistance and are prominent materials for maritime applications such as ropes and nets (Mukherjee & Satyanarayana, 1984).

Table 1. Composition and properties of natural fibers commonly used to make natural geotextiles, (Koohestani *et al.*, 2019; Wu *et al.*, 2020).

Type of Fiber	Cellulose (wt%)	Lignin (wt%)	Hemicellulose (wt%)	Density (g/m3)	Strain at Break (%)	Tensile Strength (Mpa)	Young's Modulus (Mpa)
Flax	71-78	2.2	18.6-20.6	1.4-1.5	1.2-3.2	345-1500	27.6-80
Hemp	57-77	3.7-13	14-22.4	1.48	1.6	550-900	70
Jute	45-71.5	12-26	13.6-21	1.3-1.46	1.5-1.8	393-800	10-30
Kenaf	31-57	15-19	21.5-23	1.2	2.7-6.9	295-930	22-60
Ramie	68.6-76.2	0.6-0.7	5-16.7	1.5	2-3.8	220-938	44-128
Nettle	86	5.4	4	1.51	1.7	650	38
Sisal	47-78	7-11	10-24	1.33-1.5	2-14	400-700	9-38
Abaca	56-63	7-9	21.7	1.5	2.9	430-813	33.1-33.6
Cotton	85-90	0.7-1.6	5.7	1.21	3-10	287-597	5.5-12.6
Coir	36-43	41-45	0.15-0.25	1.2	15-30	175-220	4-6

Source: (Koohestani *et al.*, 2019; Wu *et al.*, 2020)

1.4.1 COIR (COCONUT)

Coconut fibers (*Cocos nucifera*) are considered fruit/seed fibers, which are obtained from the surrounding husk of the coconut (Satyanarayana *et al.*, 1981; Ramamoorthy *et al.*, 2015). Palm trees take up 10 million ha of land throughout the tropical regions, making coir fibers an easily accessible, economic and renewable resource (LEKHA & KAVITHA, 2006; Lal *et al.*, 2017; Bui *et al.*, 2020). The Food and Agriculture Organization of the United Nations FAO elaborated the five nations that contribute to 90 % of the global coir fiber production (0.78 million tons/year; (Satyanarayana *et al.*, 1981), which are India, Sri Lanka, Thailand, Vietnam, and Philippines (Bui *et al.*, 2020). The application of these fibers reaches from ropes over mattresses and geotextiles to automobile seats and more (Bui *et al.*, 2020).

The multicellular coir fiber[1] features a polygonal or round cross section (diameter approx. 0.3 mm) and fiber length ranges between 5 to 350 mm on average (Satyanarayana *et al.*, 1981; Lekha, 2004; Daria *et al.*, 2020). The fibers consists mainly of 36-43 % of cellulose

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[1] 30 to 300 or more cells in the total cross-section of the coir fiber Satyanarayana *et al.* (1981)

and 0.15-0.25 % of hemicellulose with a lignin content of 41-46 %, being the highest lignin content found in all natural fibers (Lekha, 2004; Daria *et al.*, 2020). Further components are pectin (2.75-4 %) and water solubles (Satyanarayana *et al.*, 1981; Lekha, 2004). The high density of these fibers leaves them more durable than other natural fibers such as jute and sisal (Lekha, 2004; Daria *et al.*, 2020). The increased lignin percentage gives the fiber the advantage of lower water absorption capacity, hence increasing its resistance towards microbial attack as well as higher resistance towards elongation (Sumi *et al.*, 2018; Daria *et al.*, 2020). Most important, coconut fibers feature resistance towards seawater and are utilized e.g. in the control of sea-erosion (Satyanarayana *et al.*, 1981) or other applications in maritime engineering (Ramamoorthy *et al.*, 2015; Daria *et al.*, 2020). The main disadvantage of this fiber is its low tensile strength, which can be only improved via specific physical and chemical treatments (Ramamoorthy *et al.*, 2015; Bui *et al.*, 2020; Daria *et al.*, 2020).

1.4.2 JUTE

Jute fibers are considered bast fibers, which are won from the stem of the *Corchorus capsularis/ Corchorus olitorius*, making them one of the most low-cost natural fibers (Singh *et al.*, 2018). The plants are mainly grown for their fiber, since they are cheap to cultivate and process. Furthermore, their annual growth pattern results in vast material supply (Ramamoorthy *et al.*, 2015; Singh *et al.*, 2018). The global annual production accounts for 2300 x 10^3– 2850 x 10^3 tons, which for the most part comes from India, China, Bangladesh, Nepal, Thailand, Indonesia, and Brazil (Ramamoorthy *et al.*, 2015; Singh *et al.*, 2018). Mean fiber length accounts for 2.5 mm (Alloftextiles Online Limited, 2015). The reported chemical composition varies slightly amongst studies. According to Ramamoorthy *et al.*, (2015) and Daria *et al.*, (2020) cellulose content ranges between 56-71.5 %. Reported values for hemicellulose lie between 29-35 % and for lignin 11-14 %. Despite the low resistance of jute fibers against moisture, acid and UV light (Singh *et al.*, 2018) they perform sufficiently in geotechnical applications at low cost such as consolidation, drainage, soil filtration, road construction, stabilization and protection of slopes, and erosion control (Datta, 2007; Chattopadhyay & Chakravarty, 2009; Daria *et al.*, 2020). Jute fiber are prone to degrade rapidly in saltwater (Daria *et al.*, 2020). However, studies have not been performed in marine environment but only laboratory conditions, therefore the fiber's behavior in realistic conditions will be assessed in this research.

1.4.3 SISAL

Sisal fibers are categorized as hard fibers, harvested from the leaves of the *agave sisalana* plant (Ramamoorthy *et al.*, 2015). The total fiber production worldwide accounts for approximately 4.5 million tons per year, mainly cultivated in Tanzania and Brazil, but also found in China and Kenya (Chand *et al.*, 1988; Ramamoorthy *et al.*, 2015). Sisal fibers are utilized for ropes and twines and chords, especially for marine and agricultural purposes as well as for upholstery, padding, fish nets and decorative articles (Li *et al.*, 2000; Ramamoorthy *et al.*, 2015). Values for the chemical composition of the fiber vary strongly amongst source and age of the plant (Li *et al.*, 2000). According to Li *et al.*, (2000) the cellulose content ranges between 49.62-60.95 %, and the lignin content from 3.75-4.40 %. Differing values are reported from Ramamoorthy *et al.*, (2015) with a range of 67-78 % and 8-11 %, respectively. The fiber length is between 1.0 and 1.5 m and the diameter around 100-300 µm (Li *et al.*, 2000). Sisal fibers feature a high tensile strength and are robust against deterioration in saltwater, making them suitable for this study (Haque *et al.*, 2015).

1.5 BIODEGRADATION TEXTILES IN MARINE ENVIRONMENT

The term ‘biodegradable’ must be clearly defined. Illustrated by Endres & Siebert-Raths, (2009) there are two steps taking place during degradation. Primary degradation implies the splitting of macro-molecules of a material by microorganisms into smaller particles. The decomposition products are subsequently converted into H_2O and CO_2 enzymatically, resulting in the final decomposition and, can be absorbed by the microorganisms. If a material cannot be decomposed completely it cannot be considered biodegradable. External conditions such as time, temperature and humidity influence the efficiency of biodegradability (Deutsches Institut für Normung e.V.; Endres & Siebert-Raths, 2009).

Biodegradability tests do not follow a standard test procedure. The understanding and test methods of biodegradability relate to the field of application such as wastewater treatment or biodegradation in marine environments and can vary strongly. Timescale and decomposition stage are not defined, hence the term ‘biodegradability’ can result in misleading assumptions (Harrison *et al.*, 2018b). Arshad & Mujahid, (2011) categorizes biodegradability in three stages of the progression of decomposition (Arshad & Mujahid, 2011; Harrison *et al.*, 2018a):

1. **Biodeterioration stage** = depolymerization by enzymic hydrolysis or peroxidation of carbon chain polymers; mass loss and loss of mechanical properties (mass loss > 90 % assumed to be degraded)
2. **Bio fragmentation stage** = disintegration and fragmentation without significant gas evolution
3. **Microbial assimilation stage** = digestion of low molecular weight species = gas evolution and mineralization

Biobased fibers can be composed of natural fibers like animal or plant fibers or synthetic fibers, which are spun from starch, lipids, sugar and other extracted compounds derived from plants and other natural resources (Thyavihalli Girijappa *et al.*, 2019). Despite the biological origin of a fiber, fully biodegradation is not granted (Siracusa, 2019). Especially biosynthetics often do not undergo all three stages of biodegradation in a natural environment (Siracusa, 2019). Therefore, in this study we focus on solely natural fibers, therewith no harmful byproducts are released in the environment.

Several studies on the terrestrial biodegradation of natural fibers have been conducted in laboratory condition as well as in the natural environment. A widely used standardized test procedure is the so-called *Soil Burial Test* (*DIN EN ISO 11721-1:2001*) applied to natural and synthetic fibers (Arshad & Mujahid, 2011; Sülar & Devrim, 2019) along with the standard test procedure on biodegradation via composting (*DIN EN 13432:2000-12*) (FITR, 2008). Nevertheless, data on material degradation rate vary strongly within studies and cannot be directly compared due to modifications of the test procedures and differences in reporting (Table 2).

Information on the biodegradability rate of natural fibers in the marine environment is lacking. Public and socioeconomic interest lie in the behavior of synthetic fibers in marine systems primarily, due to the release of synthetic microfibers into aquatic environments during clothes laundering as well as the utilization of synthetic geotextiles (Dilkes-Hoffman et al., 2019). Only recently, a study from Zambrano et al., (2020) drew attention to the biodegradation process of cotton and rayon yarns in lake water, seawater and sludge (30 ppm of total suspended solids) according to the standards *DIN EN ISO 14851:2019-07* and *ASTM D6691-09*. The study identified an increased degradation of the yarns after 30 days exposed to sludge (87-89 %), followed by lake water (72 %) and least degradation in seawater (45-48 %) (Zambrano *et al.*, 2020).

Table 2. Terrestrial biodegradation rate of Coir, Jute and Sisal from different test procedures and test environments.

Material	Environment	Degradation time	Source
Coir	n/a	6-36 months	(Daria *et al.*, 2020)
Coir	compost (50 ºC)	215 days	(FITR, 2008)
Coir	soil	36-48 months	(Greenfix)
Jute	n/a	6-18 months	(Daria *et al.*, 2020)
Jute	soil	40 % weight loss after 3 months	(Arshad & Mujahid, 2011)
Sisal	n/a	12 months	(Daria *et al.*, 2020)
Sisal	compost (50 ºC)	41 days	(FITR, 2008)
Sisal	soil	24-36 months	(The East Africa Sisal Company Ltd.)

2 RESEARCH OBJECTIVE

The main goal of this work is to generate basic knowledge for the development of a feasible and large-scale solution for seagrass restoration, based on the utilization of textiles. This is achieved by identifying suitable materials and textile structures, used as a carrier base for seagrass shoot transplants. The fabrics act as an anchoring device for roots and rhizomes of seagrasses to entangle in and hence, shoots can overcome heavy storm events until they are fully capable to withstand hydrological pressures. The model seagrass of this work is the in the Northern Hemisphere most dominant seagrass species *Zostera marina*.

Two main objectives were pursued in this study in order to acquire a suitable material selection for seagrass restoration studies.

1. **To investigate the performance over time of the different textile substrates in regard to durability and physical properties after extended exposure to the marine environment.**
   i. Burial of six different textile layouts in the intertidal of the Ria Formosa Lagoon and retrieval after set time intervals in order to assess:
      a. Weight loss over time
      b. Tensile strength loss over time
      c. Aerobic microbial activity
2. **Assessment of *Zostera marina* response to the incorporation into the textiles in a mesocosm**
   ii. Replicates of five seagrass shoots were inserted in each of the textiles and placed in independent mesocosms in order to examine:
      a. Survival rate
      b. Plant and root morphology

3 STATE OF THE ART

3.4 RESTORATION AND CREATION OF SEAGRASS MEADOWS

Restoration efforts of seagrass meadows have been made around the world for over seventy decades, with emerging interest from the 1970's on (van Katwijk *et al.*, 2016). The majority of the reported studies since the 70's were conducted in the temperate and subtropical latitudes of the Northern Hemisphere (68 %) (van Katwijk *et al.*, 2016). Numerous species with various morphologies were used in the trials, *Zostera marina* being the most popular (50 %). Most studies were conducted in developed countries such as United States, Australia and Europe (van Katwijk *et al.*, 2016). Especially in the United States high expertise in seagrass restoration has been developed, since it was initiated there already in the 1940's (Fonseca *et al.*, 1998) in conjunction with the longest restoration program of 48 years (planted in 1973, Florida) (van Katwijk *et al.*, 2016). Another lucrative example is the four decade long, large scale restoration program of *Zostera marina* in Chesapeake Bay, USA (Fonseca *et al.*, 1998; Erftemeijer, 2020) along with the restoration of *Posidonia australis* and *P. sinuosain* in Oyster Bay, Australia, convincing with high long term survival rate of over 90 % (Bastyan & Cambridge, 2008). In contrast, nations in tropical latitudes lack knowledge and experience and awareness on conservation and rehabilitation matters is just gaining political and socioeconomical interest in present days (Eriander *et al.*, 2016; Erftemeijer, 2020).

Transplanting strategies for seagrasses can be divided into traditional transplanting methods, in which mature plants are used as donors, and seed germination, a more recent approach (Eriander *et al.*, 2016; Erftemeijer, 2020). Traditional restoration methods can be subdivided into sediment and sediment-free methods (Fig. 3). One approach, including sediments, is the plug method. Here, donor seagrasses, including attached sediments, are collected in tubes and transported to the restoration site (Fonseca *et al.*, 1998; Riniatsih *et al.*, 2018). Another approach is, to dig up a shovel of sediments including shoots and transplant the whole sod with shoots, sediment and benthic fauna all together (so-called sod/turf technique). Various variations of the sod method have been established, adapted to the in situ environments (Erftemeijer, 2020). Sediment-free methods are e.g., the staple method, which promises high success rates, though, is labor intensive, as it requires SCUBA diving.

Shoots, roots and rhizomes are collected, while sediments are removed, and subsequently stapled onto the seabed. Various devices can be used for anchoring the plants like shells, stones and rods (Erftemeijer, 2020). In order to decrease costs, an improved version of this method, so called Transplanting Eelgrass Remotely with Frame Systems (TERFS), was created, in which a metal frame, together with anchored shoots, is submerged. However, the metal frame must be retrieved after some time (Park & Lee, 2007). Another technique, which holds high innovative potential was tested in Kenya and Western Australia. Shoots were attached to sand filled hessian bags, which served as stabilization for root and rhizome growth and subsequently submerged (UNEP-Nairobi Convention/WIOMSA). Beyond the traditional methods, various attempts on seed transplantation have been made. Seeds are collected from fertile shoots and stored in tanks for several weeks until seeds accumulate on the bottom of the tank. Eventually, the seeds can be released into the aquatic system via different methods

Fig. 3. Sediment and sediment-free methods of seagrass transplantation. (1) Sod method on the left and two types of the plug method in the middle and right. (2) Hessian bag transplant of shoots (3) Seagrass shoots tied to metal frame (4) Staple method (5) Staple method. Placing staples into sediment. (Erftemeijer, 2020).

such as burying, placed into hessian bags etc. (Christensen *et al.;* Fonseca *et al.*, 1998; Unsworth *et al.*, 2019; Erftemeijer, 2020).

Suitable practice and donor meadow are selected for the individual restoration programs, based on environmental conditions and the economical/financial resources. Latitude, tidal regime, grain size, water depths, salinity are factors, that must be taken into consideration during the decision process. Exemplary, in intertidal zones access is simple and the staple technique can be a convenient solution without increased logistical efforts, whereas transplantation of seagrasses in deep subtidal waters may require SCUBA diving or the submerging of frames with attached shoots in order to be more cost-effective. (Erftemeijer, 2020)

Additional to the choice of planting methodology, site selection plays an essential role in restoration success (van Katwijk *et al.*, 2016). Protection from severe hydrodynamical activity, light availability and acceptable water quality, free from deterioration, are the minimum requirements for prosperous transplanting (Bayraktarov *et al.*, 2016; van Katwijk *et al.*, 2016).

3.5 RISK AND PROBLEMS OF CONVENTIONAL METHODS

State-of-the-art restoration methods predominantly depend on adult plants as donor material, collected from native meadows (Basconi *et al.*, 2020). However, an increased withdrawal of individual units from a meadow impedes the functionality of a holistic system, resulting in increased vulnerability of the meadow towards biotic and abiotic stressors. Patchy meadows, with increased margins, are more likely to be subject of increased grazing activities of herbivores, whereas dense meadows rather function as nursery than nourishment (Statton *et al.*, 2015). Moreover, changes in the spatial distribution of seagrass meadows alter the provision of ecosystem services such as the sequestration of carbon from the atmosphere. Stocks were found to be 20 % higher in the meadow's interior, in contrast to lower stocks at the edges and bare patches (Ricart *et al.*, 2015). Decrease in meadow density, furthermore, gives opportunity to fast-growing invasive species to colonize within the meadow, resulting in competition and disruption (Williams, 2007; Cullen-Unsworth & Unsworth, 2016).

Beyond selection of appropriate methodology, scientists have been facing the challenge of evaluating and quantifying restoration success. Conventionally, success rate has been measured on the mortality of the transplants, nevertheless the variety of used metrics leads to profound differences in the assessment of success, resulting in biased reporting (Basconi *et al.*, 2020). Biased reporting is further nurtured through the pressure put on the scientific community from stakeholders and regulators to publish successful results, withdrawing the opportunity for follow up research to improve from already made mistakes (Zedler, 2007).

Amongst the challenges in assuring non-biased reporting, the monitoring intervals as well as duration of restoration programs play a key role (Basconi *et al.*, 2020). Most transplanting programs undergo irregular and short monitoring periods, thereby making the program appear successful. Consequently, in reality failed programs cannot be detected and, opportunities for improvement dissipate (Tan *et al.*, 2020). Unfortunately, many shoots do not survive in the long term and the success rate of transplanting studies might even result in a negative balance, due to the harm induced on the donor population and the loss of the newly transplanted meadow due to storm events or other environmental/biological factors (Cunha *et al.*, 2012; Tan *et al.*, 2020). In order to enhance resilience and long term success of the restoration site, small scale trials must be translated into large scale programs, which has been challenging up to present day (van Katwijk *et al.*, 2016).

In particular logistics can bear challenges, often resulting in high costs. Obstacles, summarized in the UNEP Nairobi Convention, include e.g., the high weight of sediments and shoots, collected using the sod method, complicating transport and transplanting. Sediment-free methods are very labor intensive due to the cleaning of roots and rhizomes from sediments and the individual transplanting of the shoots, which may require SCUBA diving. Difficulties deriving using seed transplanting is the low germination rate of the seeds, which accounts for approximately 5 – 10 %. Additionally, seeds might be transported far away from the original transplanting site through currents or get eaten by predators, decreasing the chances of successful restoration (Erftemeijer, 2020). Crucial is, that in the majority of cases the transplantation rate cannot compete with the mortality rate, amplifying the importance of finding large-scale restoration solutions (Fonseca *et al.*, 1998).

Textiles appear as a cost-effective solution, offering the opportunity of large-scale deployment. They are applicable for seed transplanting techniques as well as growing surface for cultivating seagrasses (Erftemeijer, 2020). Seeds can be placed into small bags, inhibiting grazing and relocation through currents (Delefosse & Kristensen, 2012). Utilized as a carrier substrate, they assure stability for the immature shoots and allow efficient and easy handling (Irving *et al.*, 2014). Design and material of the substrate are essential factors when developing textile-based solutions for seagrass transplants and methodologies must be further investigated as well as adapted to the targeted environment (Irving *et al.*, 2014; Tan *et al.*, 2020).

3.6 TEXTILES IN SEAGRASS RESTORATION

The application of textiles for seagrass restoration is not a new approach (Tan *et al.*, 2020). Some research, examining different configurations of textiles as carrier substrate for either shoots or seeds, is already existing. Advantages associated with textiles are for example the protection of predation (Tan *et al.*, 2020), stabilization of shoots (Ferretto *et al.*, 2019) and the protection of meadows from bioturbating animals, therewith increasing chances of survival (Wendländer *et al.*, 2019). In a continuing research in Adelaide, Australia, sprigs of *Amphibolis antarctica* were sewed on coarse and fine hessian bags and, seedlings were placed into sand filled hessian bags (Irving *et al.*, 2010; Irving *et al.*, 2014; Tanner *et al.*, 2014). After eight months of monitoring the hessian bags were degraded, eroded and dislodged due to intense storms and excessive wave energy. Despite the premature failure, this methodology is promising, since the hessian bags provide a stable sediment base, they degrade fully, they are inexpensive and easy to handle (simply be thrown off the boat). The authors concluded that the coarse bags performed better than the fine ones but, must be more robust to withstand hydrodynamics. In continued studies the authors proposed the treatment of the hessian bags with organosilanes (non-toxic silicone coating), thereby decelerate degradation (Irving *et al.*, 2010; Irving *et al.*, 2014; Tanner *et al.*, 2014). Another attempt on using hessian bags as carrier textile was made in the United Kingdom, though, using seeds instead of sprigs (Unsworth *et al.*, 2019). During this study seeds of *Zostera marina* were sown on hessian bags as well as approximately 100 seeds placed in small hessian bags with 100 cm^3 sand. The hessian bags were eroded after eight to nine months and some rhizomes rooted into the sediment below (Unsworth *et al.*, 2019). Furthermore, the so-called *Tortilla Method*, which was developed in the United States, was applied in a study on seagrass transplantation at the University of

Algarve. Fine and coarse woven coir textiles were selected, and shoots were sown into the textile. After a timeframe of two weeks *Zostera marina*, established into the fine mesh, showed no signs of survival. On the contrary, shoots entangled into the coarse mesh appeared fine (Pickerell *et al.*, 2012; O'Brien, 2019).

Overall, textiles appear to bear high potential for seagrass transplantation, since they are feasible and simple to deploy into the marine environment. However, in most studies the textile degraded too fast for the roots to incorporate into the seabed, hence a long-term success could not be achieved. Therefore, the efficiency on material selection and design requires refinement. Moreover, most experiments were conducted on the small scale and did not provide any information on the large-scale performance. Beyond that, many authors seek for different approaches, from the use of sand-filled bags for shoot recruitment to the use of small bags for seed germination. This results in non-comparable data, which cannot build on top of one another. Therefore, it is from importance, that an approach is funded continuously over a long period in pursuance of achieving large scale and long-term success. To the present day there are yet abounding knowledge gaps on the utilization of textiles for seagrass rehabilitation. Further research must be conducted in order to gather more information on textile’s behavior in marine environment and their influence on seagrass growth.

4 MATERIALS AND METHODS

This research was divided into two series of experiments (Fig. 4). The biodegradation behavior amongst different textiles in the marine environment was examined (Fig. 4, (1)) along with the assessment of the response of *Zostera Marina* shoots incorporated into these fabrics and accommodated in an outdoor mesocosm (Fig. 4, (2)).

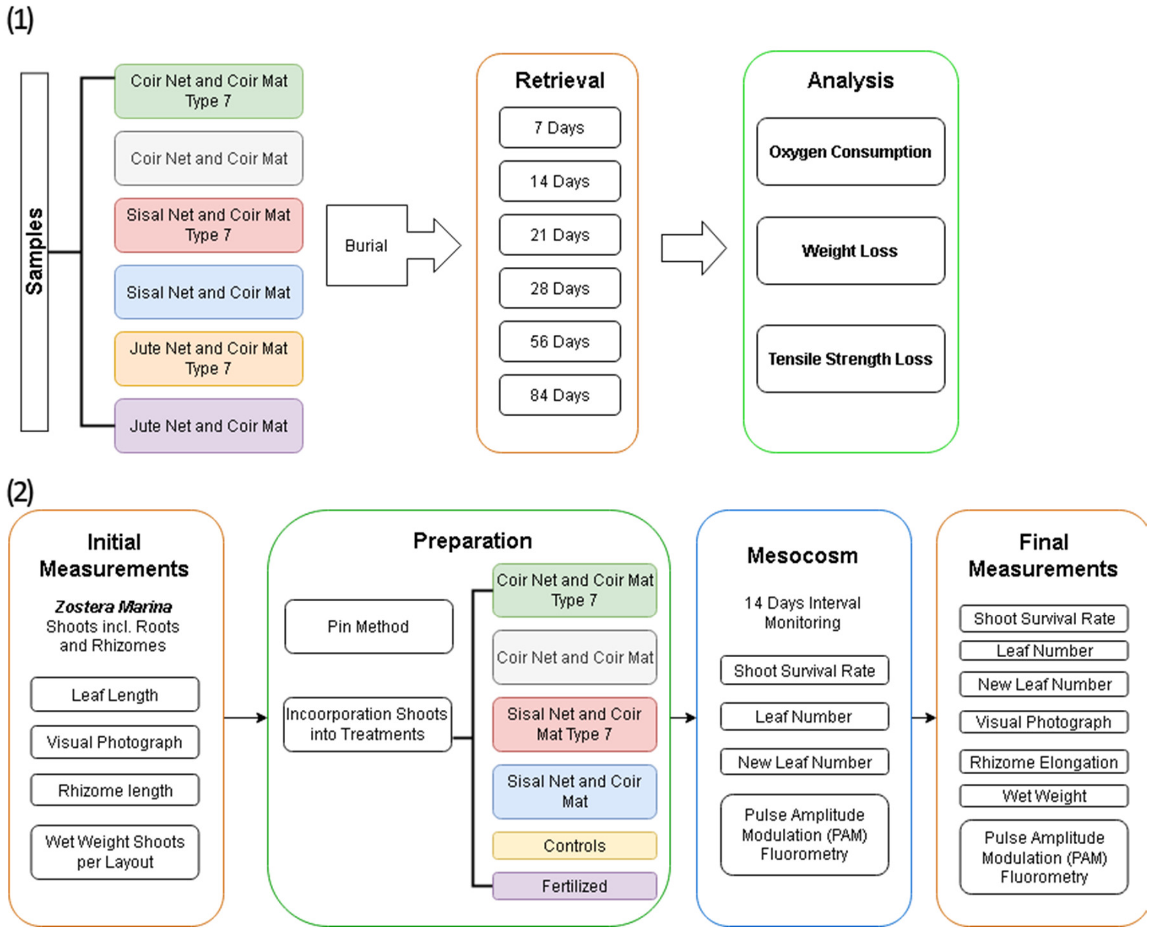


Fig. 4. Experimental flow chart textile burial trials (1) and mesocosm trials (2).

4.1 STUDY SITE

The study was conducted in the south of Portugal on the Algarvian Coast at *Ramalhete Marine Station* , CCMAR (Center of Marine Sciences) (Fig. 5). The field station is situated in the Ria Formosa near Faro. The Ria Formosa is a barrier island system and is one of the most vital systems for seagrass populations in Portugal. It provides a surface area of 84 km^2 and is classified as a mesotidal system, which is connected to the ocean through six tidal inlets (Guimarães *et al.*, 2012). The back-barrier is dominated by mudflats, but some sandflats occur as well. Three seagrass species (*Cymodocea nodosa, Zostera marina, Zostera noltii*) can be found to large extent in the Ria Formosa in the intertidal and subtidal areas of the lagoon (Guimarães *et al.*, 2012; Cunha *et al.*, 2013). Water temperature in the Ria Formosa ranges from 12 °C in the winter to 27 °C in the summer and salinity accounts for 13 - 36.5 ppt, depending on the fluvial or oceanic influx at a given point (Newton & Mudge, 2003). The southern coasts is highly impacted by the frequent and intense southern storms throughout the year, which bear challenges for seagrass transplantation (Cunha *et al.*, 2013).

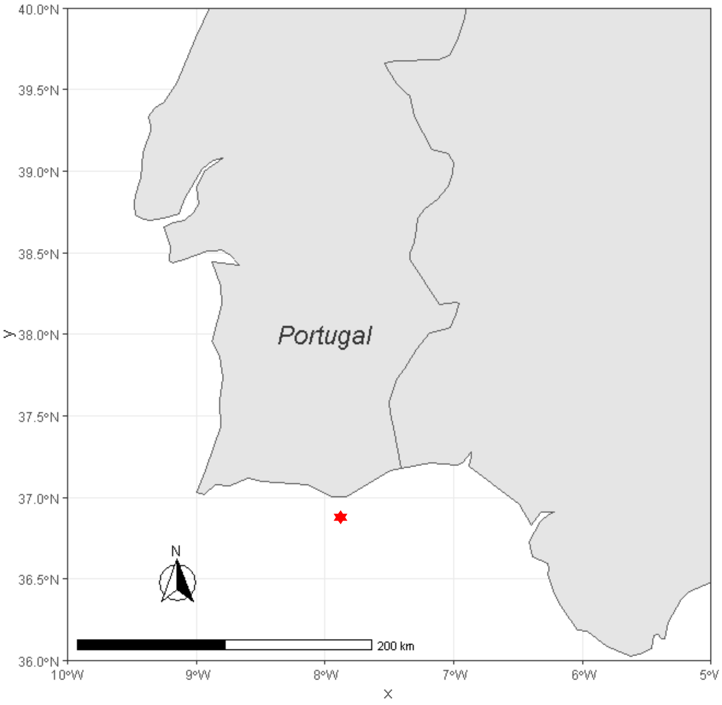


Fig. 5. Study site at research station 'Ramalhete' in Praia de Faro, Portugal. Burial experiments were executed in the adjacent lagoon of the Ria Formosa. Establishment of mesocosms for seagrass transplant trials were conducted in the facilities of the research center.

4.2 TEXTILE SELECTION

Distinct demands on the textiles were made, which were divided into primary and secondary demands. Essential was that exclusively textile of natural derivatives were selected for this study due to the adverse effect of petroleum based fibers during production and degradation on the environment and organisms (Cole, 2016). Biobased and/or biodegradable polymers such as Polylactic Acid (PLA) appeared on the market in order to substitute petroleum derivatives and thus, tackle resource scarcity and greenhouse gas emission (Hottle et al. 2013). However, harmful effects of these types of plastics are not well understood to date and therefore, were also excluded from this research (Senga Green; Shruti & Kutralam-Muniasamy, 2019). Further essential requirements included resistance against hydrological activity in particular tides, wave action, currents as well as against relocation of the textile from shoot cultivation tanks into the open ocean, along with the provision of an open matrix, for enabling the roots to entangle into the textile. Secondary demands were desirable, but not compulsory. The biodegradation period should be no longer than the period, that shoots need to securely anchor into the seabed and, preferably degradation products should support seagrass growth by functioning as natural nutrient supply.

Materials, composed of sisal, coir and jute were adjudged to meet the criteria for this study. The fabrics came in form of a mesh and a nonwoven mat and were combined to six different layouts, resulting in six net-mat combinations (Fig. 6; Table 3). Coconut-based materials were selected, because coconut possesses high resistance against outer influences from environmental and biological processes (e.g. wave action or microbial attack) attributed to their high content of lignin (Food and Agriculture Organization of the United Nations; Sumi *et al.*, 2018). Beyond its physical properties, coir fibers are also produced in a sustainable matter, due to low water and energy consumption during production (Healabel). Alongside with coir, jute is a popular material used as natural geotextiles, by reason of its superior performance in environmental conditions (Wu *et al.*, 2020). Furthermore, jute is one of the most feasible natural fibers on the market (Food and Agriculture Organization of the United Nations). The third material chosen for this study was sisal. Sisal features high tensile strength and high resistance against seawater, as it is conventionally used for marine ropes, therefore it appeared to be suitable for this research (Yu, 2015). The mesh size and weight varied significantly amongst the nets likewise the weight between the mats. Both mats were

Table 3. Presentation of five different selected textile substrates as carrier substrates for implantation of *Zostera marina* shoots and their weight and tensile strength.

Product	Material	Matrix	Weight [g/m²]	Tensile strength [kN/m]
Coconet 400	Coir	Net	400	11.2
Geo-Sisal Peatsock	Sisal	Net	1000	1.2
Geojuta	Jute	Net	500	15.0-20.0
Cocomat	Coir	Mat	450	0.5
Type 7	Coir	Mat	762	2.1

composed of a coconut nonwoven, held together by a polypropylene net and thread, which were removed before the beginning of the trials.

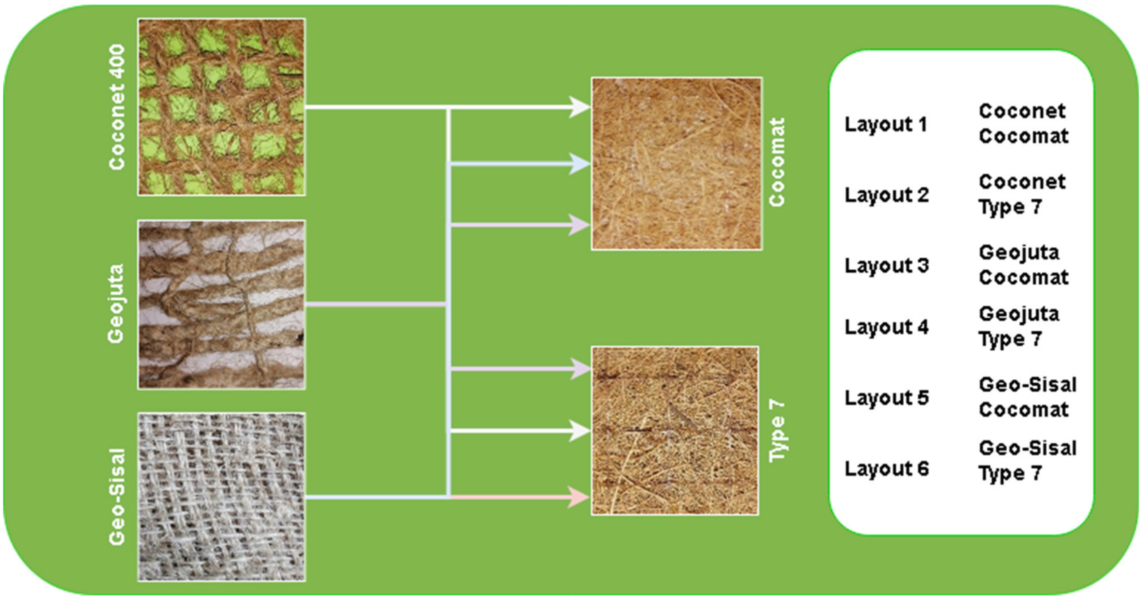


Fig. 6. Illustration of the substrate selection. Each mesh was combined with a mat, resulting in six different layout designs. The mat was placed in between two layers of the mesh and the three layouers were sewn together with a sisal thread, creating a so-called sandwich structure.

The textiles were coupled in six different combinations. Each mat was incorporated into one net on the top and bottom and sewn together with a sisal thread, resulting in a so-called sandwich structure (net-mat-net layout). The specimen measured 50 x 300 mm, the standardized sample size for determining the maximum force at break (ISO 13934-1:1999).

Up to present, the performance and degradation rate of natural textiles placed in the marine environment lacks knowledge and, data is primarily available on terrestrial degradation processes. The following presented data on terrestrial biodegradation is based on a comprehensive review of published peer-reviewed academic papers (Table 4) (Daria *et al.*, 2020).

Table 4. Terrestrial degradation behavior of natural materials. Data based on a comprehensive review of several studies. Hence, the individual methodologies on testing the degradation behavior vary and therefore, degradation time varies strongly. (Daria *et al.*, 2020)

Material	Time Interval [months]
Coconut	6-36
Jute	6-18
Sisal	12

Biodegradation rate can be assessed using differing methodologies including e.g. soil burial test, composting and heating. Hence, the degradation rate of the selected materials ranges widely throughout literature and collected data must be compared critically with respect to the difference in applied methods and standards.

It was expected that due to the saline environment, coupled with hydrodynamical activities, the degradation process will be accelerated and hence, textile integrity will diminish more rapidly than reported in studies conducted in the terrestrial environment. Furthermore, it was assumed that ***Geo-sisal*** layouts will degrade slower than the other nets (***Coconet, Geojute***) due to the enclosed and narrow structure of the mesh, leaving less contact surface for microbial attack coupled with the material's high resistance to saltwater. The mats did not differ in their material, thus assumptions on their biodegradation behavior were only based on the structure of the mat. Hence, it was believed that ***Type 7*** mat will degrade more rapid than the ***Cocomat***, because its less dense and lighter, leaving it more vulnerable to biological, physical and chemical activity.

4.3 ANALYSIS OF BIODEGRADABILITY OF TEXTILES

This study examined the biodegradation rate of natural fibers (coir, jute, sisal), buried in the intertidal zone during a period of three months. In order to identify the rate of mechanical decomposition (Stage 1), the weight loss and the loss in tensile strength over time, according to DIN EN 12127:1997-12 and DIN EN ISO 13934-1, were determined. Beyond mechanical examination, the oxygen consumption rate on the surface of the substrates was measured as a proxy for microbial activity (Stage 3).

4.3.2 BURIAL EXPERIMENT

Specimen were buried 5 cm underground during the low tide in the intertidal of the Ria Formosa Lagoon. The layouts were grouped in clusters per time intervals. Samples within the interval were buried in a random manner thereby, comparable environmental conditions were assured for each testing round (Fig. 7). According to a study from the Fraunhofer Institute (FITR, 2008), degradation of natural fibers is initiated after approximately five to seven days.

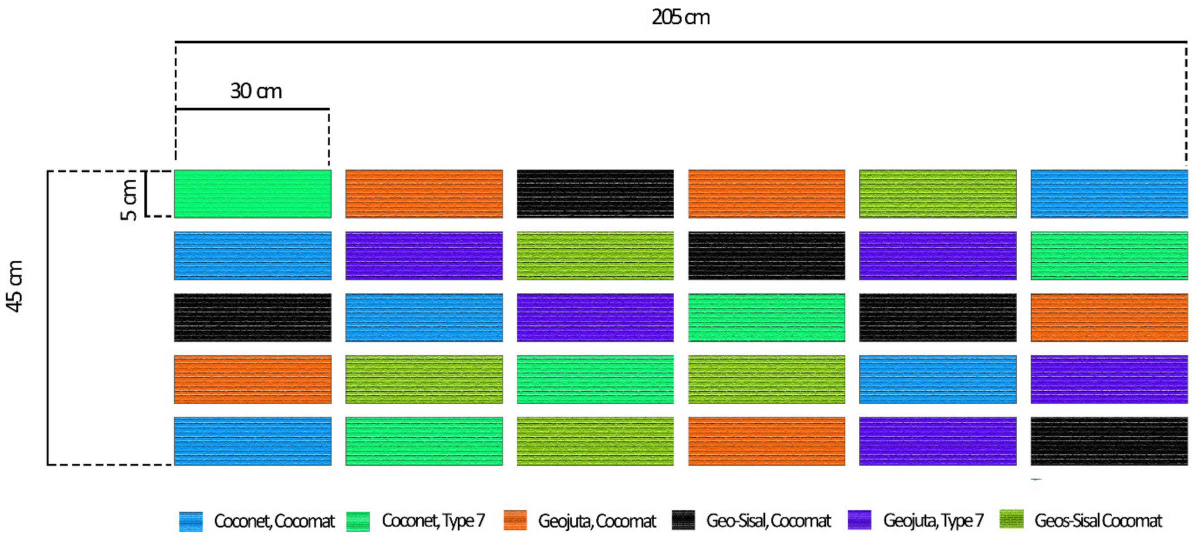


Fig. 7. Schematic spatial plan for the burial of one time interval (one sampling round), showing the six layouts of the sandwich structures including 5 cm spacing in between the specimen. Five replicates per layouts were buried, n=30 for one sampling round. Six patches as showcased above were located next to another in the intertidal zone of the Ria Formosa Lagoon. Total n=180.

Therefore, sampling was conducted in intervals of seven days in the first month, hence four sampling rounds. Subsequently, specimen were collected on a monthly basis as it was expected that, degradation slows down in the following month compared to the first phase. In total 180 samples, including replicates, lasting for six sampling rounds were buried (Table 5). Average temperature in the sediment at same depth accounted for 22.5 ºC.

Table 5. Summary of total sample number and required burial area.

Layout No.	6
Replicates per Layout	5
Sampling Intervals	6
Total Sample No.	180
Sample Size [mm]	300 x 50
Total burial area (including spacing of 5 cm) [m²]	5.4

After the retrieval of the substrates per time interval, the samples were rinsed with fresh water. The water was collected during the process and filtered through a nylon sieve with a mesh size of 80µm in order to retain fibers, that were washed out during the process. The substrates and the gathered fibers (incl. residues of sediments) were dried at 60 ºC for

72 h. Subsequently, the dried fibers were separated via sieving (1 mm) from the sediments and weighted in order to record the weight loss during rinsing of the samples.

4.3.1 GRANULOMETRY

Grain size analysis of the study area was conducted (Rosa *et al.*, 2013) and classified according to the phi (Φ)scale intervals (Krumbein, 1934) and gravel-sand-mud composition-triangle (Folk & Ward, 1957). Seven cores of sediments with a length of 8 cm and a radius of 3 cm were collected from each of the interval areas. Organisms were sorted from the sediment cores and stored in 70 % ethanol before granulometry analysis. In order to conduct granulometric analysis as well as determine the content of organic matter in the sediments, organic matter was degraded according the the method described by Robinson, (1927), using hydrogen peroxide. Concentrations of H2O2 of 60 Vol and 130 Vol were added to the sediments, respectively. Subsequently, the samples were placed in a warm bath, catalyzing the process of degradation. Hydrogen peroxide and deionized water were added frequently, in order to prevent the samples from drying through evaporation of the fluids. The samples were kept in the warm bath overnight, hence full degradation of organic matter was assured. The final weight of the organic matter was calculated by subtracting the final sample dry weight w_f from the initial weight w_i. (Robinson, 1927)

TEXTURAL ANALYSIS

To distinguish coarse and fine sediments, wet separation was carried out. This involved washing the sample with deionized water in a sieve of 63 µm to split the coarser sediment (> 63 µm) from the finer sediment (< 63 µm). The coarser sediment fraction was then transferred and dried in the oven at 60 ºC(Rosa et al., 201 3) whereas the finer, suspended sediments were filtered with a ceramic filter, filled with active coal, and collected in a 1 L measuring cylinder, which was filled with deionized water up to 800ml. Following, the coarse sediment was analyzed dry sieved with a mechanical shaker (Rosa *et al.*, 2013). Any aggregates were gently removed to allow grains to be retained. Each sieve on the mechanical shaker was separated by fractions by phi (Φ) levels, with (Φ)= -log2d, where d is the grain size in mm^2 (Krumbein, 1934). Each weight retained on the sieve was noted for further analysis. Fine sediments, that were not obtained during wet separation but collected after dry sieving, were added to the 800 ml suspension of fine sediments. The finer sediments obtained were analyzed by using the pipette method (Rosa *et al.*, 2013). 70 ml of Sodium Hexametaphosphate (3.04g/L) were added to the suspension and the samples homogenized by mixing them with a rubber rod for two minutes and then letting them rest overnight. Temperature was recorded before the analysis, on which the depth at which samples were taken was based on. At the defined depth, a small portion of the suspension was taken from the measuring cylinder using a graduated pipette at an increment of 20ml. Six withdrawals per sample were collected in prior defined time intervals (Appendix 2). The withdrawals were dried, and the weights taken and the associated scale phi (Φ) value intervals were calculated (Krumbein, 1934)

GRANULOMETRIC PARAMETERS

A grain size distribution and statistics program, GRADISTAT was used to calculate granulometric parameters, which runs within a Microsoft excel spreadsheet package (Blott & Pye, 2001). Method of Moments was calculated in this program arithmetically (metric units), geometrically and logarithmically (phi units) and using graphical moment of Folk & Ward, (1957), allowing Folk and Ward descriptive terms to be applied to moments statistics (Blott & Pye, 2001).

4.3.3 RELATIVE WEIGHT LOSS

In order to determine the relative weight loss over time, the initial weight w_i of each specimen, dried in the oven for 24 h at 60 ºC, was taken before the burial experiments. The final weight w_f of the retrieved samples was taken and the relative weight loss calculated in percentage from the arithmetic means of w_i and w_f for each layout (adapted from Chakraborty *et al.*, (2014)). The average weight of the retained fibers during washing w_w was added to the final weight in order to not falsely attribute it to the degradation process;

$$\frac{w_i - w_f + w_w}{w_i} \; x\, 100 \qquad (1)$$

w_i	*Initial weight*
w_f	*Final weight*
w_w	*Weight rinsed out fibers*

4.3.4 TENSILE STRENGTHS LOSS

Tensile strength loss over time of the textiles was used as a descriptor for biodegradation as well as for the evaluation of their suitability for this research. The carrier substrates must feature sufficient tensile strength, when relocated from the mesocosm into the coastal environment as well as resisting hydrodynamical forces, hence the slower the decline in mechanical properties, the better. Examination of maximum force was conducted according to the DIN EN ISO 13934-1 (Table 6) (ISO 13934-1:1999),executed on the INSTRON 5565. Before testing, the sisal thread of the prior sewing process was removed.

Table 6. Parameters for tensile strength test procedures for textiles according to DIN EN ISO 13934-1 (ISO 13934-1:1999).

Specimen number	Width [mm]	Length [mm]	Rate of Extension [mm/min]	Pretension [N]
5	50 ± 0.5	200 + Clamps	100	0.5

Along with the samples, five controls were tested. Thereby, providing a set of data for comparison, indicating the initial maximum force ts_i of each layout prior burial. The arithmetic mean was calculated for all layouts and controls and the relative tensile strength loss over time computed;

$$\frac{\overline{ts_\iota - ts_f}}{intervals} \qquad 2$$

ts_i *Initial tensile strength*

ts_f *Final tensile strength*

4.3.5 AEROBIC BIODEGRADATION

As a proxy for the aerobic microbial biodegradation (Stage 3) oxygen levels were measured on the surface of the textiles and converted into oxygen consumption rate (OCR) by fitting a linear regression of the decreasing concentration and quantifying the negative slope in µmol $m^{-3}min^{-1}$ (Dietz *et al.*, 2019). A higher abundancy of organisms results in an increased oxygen consumption rate, therefore it was expected, that the oxygen consumption rate will increase throughout the experiment. Field luminescent DO sensors of the Hach OxygenHQ40D Portable Dissolved Oxygen Meter were placed on top of the textile directly after retrieval. Measurements were taken every 30 s for 5 mins.

The oxygen optodes are composed of an oxygen sensitive membrane and measure the oxygen in an optical manner. A manufacturer explains (Häck, 2003) how a sensing foil is excited by a modulated blue light and, red light is emitted. The intensity of the emitted red light expresses the amount of oxygen in the sample. As a control, a reference red LED is emitted at the same time, without exiting the foil. (Häck, 2003) Controls, layouts prior burial, were tested additionally. It was believed that the oxygen levels stay rather constant due to the absence of aqueous aerobic microorganisms in the controls.

4.4 ANALYSIS OF *ZOSTERA MARINA* RESPONSE TO TEXTILES

4.4.1 SHOOT COLLECTION

A total number of 150 shoots of *Zostera marina* including roots, rhizomes and leaves were harvested from donor meadows in the coastal lagoon Ria Formosa, on Culatra Island with the required license. Plants were collected during low tide, ensuring easy accessibility. The shoots were stored in outdoor tanks, at *Ramalhete research center* with incoming coarse-filtered seawater at local temperature and salinity until preparation. According to Cunha *et. al.* (2009) Culatra Island is a suitable donor site. However populations favor clonal production, resulting in lower genetic diversity in the Ria Formosa meadows compared to central sites (Billingham *et al.*, 2003), which was found to limit transplantation success (Pazzaglia et al. 2021).

4.4.2 SHOOT PREPARATION

The shoots were digitally photographed next to a measuring tape and each leaf was measured and its length (cm) recorded. Leaf elongation was obtained using the pin method according to Short & Coles, (2001). A needle was poked through the leaf sheats allowing the growth assessment at defined monitoring points (Fig. 8). The wet weight of five shoots was taken and the shoots placed randomly into the textile with dimensions of 20 x 20 cm. Roots were pushed through the top grid of the sandwich structure and placed on top of the nonwoven mat, allowing the roots to interconnect with the mat (Fig. 9, left).

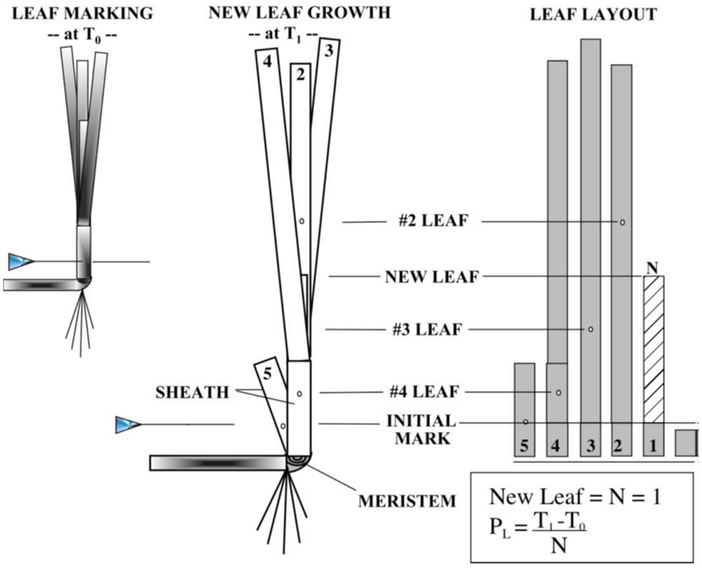


Fig. 8. Pin method for marking seagrass in order obtain leaf elongation over time (Short & Coles, 2001).

A plan of the shoot location in each textile was drawn in order to identify the individual shoots after the experiments and to draw a visual and morphological comparison of the shoot development (Fig. 9, right).

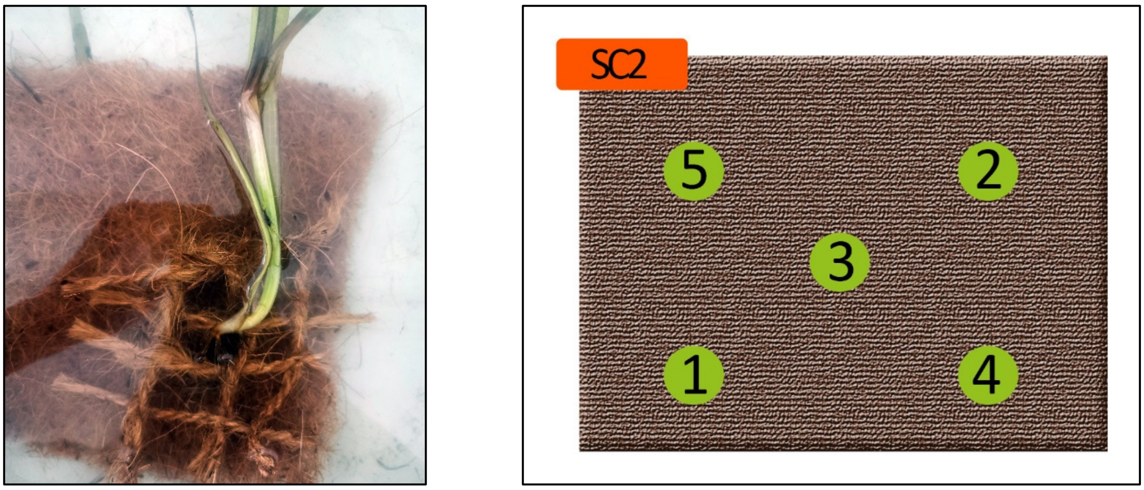


Fig. 9. Left: Shoot incorporation into sandwich structure. Shoot incl. rhizomes and roots was placed through the mesh but kept on top of the mat. Right: Example of schematic plan of shoot localization within textile. Green dots represent the shoots and the orange tag identifies the textile layout and replica number.

Five replicas of each textile layout were prepared. The jute net was excluded from this experiment due to its poor performance in the biodegradation trials, therefore a total number of 20 mesocosms, accommodating textile + shoots, were prepared.

4.4.3 MESOCOSM EXPERIMENT

Each textile was installed into a mesocosm (bucket) with a dimension of 30 L. The textiles were fixed to the bottom of the bucket with 1.5 L of local sediment. The mesocosms were placed randomly in outdoor tanks (Appendix 3) and supplied with perpetual inflow of air as well as coarse filtered seawater from the surrounding lagoon (0.85 l/min; Fig. 10). The mesocosms ensured independency of the replicates among one another, inhibiting interchange of water or spreading of diseases within the tanks. Consequently, the risk of large-scale sample loss was decreased. Additional to the textile treatment, 30 g of rooting fertilizer from the shelf (N:1 %, P_2O_5: 20 %, SiO_2: 36 %) was added to five mesocosms each (excluding textiles) and mixed with 2.5 L of sediments. Five shoots were planted into each mesocosm. Furthermore, five controls (2.5 L sediments, 5 shoots each) were prepared. In total 30 mesocosms (five per treatment), were distributed among four outdoor tanks, resulting in 6-8 buckets/tank. The tanks were under shading at all times (Fig. 10, top). Two temperature loggers were deployed

Fig. 10. Outdoor tanks under shading (top). Mesocosms placed in outdoor tanks and close up of mesocosm with constant incoming waterflow and airflow (airflow tube was removed for purpose of taking the photograph) (bottom).

on the two outer sides of the tanks, alongside with two more loggers inside the buckets on the outer edges of the tank. Additionally, two HOBO light intensity loggers were fixed to two buckets on each outer edge of the tanks. Salinity, pH and dissolved oxygen data was supplied from the *Ramalhete* field station.

4.4.4 EXAMINATION OF SEAGRASS RESPONSE TO TEXTILE

The shoots were monitored in biweekly time intervals for seven weeks and assessed on their

i. Shoot survival rate (number shoots/ mesocosm)
ii. Leaf number per shoot
iii. Number of new leaves per mesocosm
iv. Leaf elongation per mesocosm – aborted due to failure of monitoring
v. Total root segment elongation per mesocosm
vi. Pulse-Amplitude-Modulation (PAM): Effective yield of three shoots per mesocosm

The shoots were removed from the textiles after seven weeks and final measurements were taken along with digital photographs of each shoot.

Each new leaf that appeared was marked and counted. Total number of new developed leaves over the course of the experiment was recorded per treatment.

Root segments were measured from the digital photographs in the program *ImageJ* and summed up to a total length per mesocosm. Same measurements were taken at the end of the experiment and the relative rhizome elongation or loss were computed.

In order to identify the stabilization effect of the carrier textile on the shoots, the root entanglement into the textile was inspected at the end of the experiment.

4.4.5 PULSE-AMPLITUDE-MODULATION (PAM)

The transformation of light energy into chemically fixed energy gives origin to chlorophyll (Chi) *a* fluorescence, which channels the absorbed light into the reaction centers photosystems I (PSI) and II (PSII) of an organism, where photochemical energy conversion and heat dissipation happens (Wageningen University & Research, n.a.; Papageorgiou & Govindjee, op. 2010).

Therefore, determination of Chlorophyll (Chi) *a* fluorescence has been used widely as estimate for photosynthesis (Papageorgiou & Govindjee, op. 2010). The PSII is mainly responsible for fluctuation in fluorescence and, thereby indicates variations in PSII photochemical efficiency and heat dissipation (Wageningen University & Research, n.a.).

Pulse-Amplitude-Modulation (PAM), a combination of fluorometry and the saturation pulse method, has been one of the most powerful *in situ* and *in vivo* technique in quantifying photosynthetic productivity (Wageningen University & Research, n.a.; Papageorgiou & Govindjee, op. 2010; Pavlovic *et al.*, 2014). The F_v/F_m ([$(F_m - F_0)/F_m$]) ratio, which derives from the minimal fluorescence yield (F_0) and the maximum yield (F_m), after superimposing a light beam onto the prior dark-adapted leaf, indicates the maximum photochemical efficiency of the PSII and is proportional to the effective yield of photochemistry (Guidi *et al.*, 2019).

The effect of the different treatments on the integrity of the seagrasses was assessed by measuring the quantum effective yield Y of three representative shoots per replicate every two weeks using a Walz DIVING-PAM (Pavlovic *et al.*, 2014; Appendix 11). Prior measurements, a section of each leaf, 2 cm above the sheath, was darkened with a non-destructive clip (6.5 g), that possesses a small shutter, preventing light from entering. The shutter was reopened after five minutes and the fiberoptic positioned on the leaf (Heinz Walz GmbH, 1998). The Dark Clip allows a precise placement of the fiberoptics on the sample. The fiberoptics were positioned in a 90º angle with regard to the leaf surface and were kept at a distance of 3 mm (Heinz Walz GmbH, 1998). Background signals were compensated through the AUTO-ZERO command, which was initially performed (Heinz Walz GmbH, 1998).

4.5 STATISTICAL ANALYSES

For all analyses the significance level **α = 0.05** was defined. Outliers were removed and substituted with the median. Subsequently, the data was logarithmized and normalized in *PRIMER 6*. Normality test and trend detection were conducted with the programming language *R Commander 4.1.0.* Despite the normalization of the data, the *Sharpio-Wilk* test detected a non-normal distribution (Appendix 5), therefore non-parametric methods were applied to the data.

PERMANOVA analysis was executed in *PRIMER 6* in order to detect differences among textiles along with PERMADISP analysis in case of increased variance within a parameter. The analysis was applied for burial as well as mesocosm experiments.

Boxplots and line graphs were generated in the program *Matlab.* Boxplot charts were generated from five replicates per layout and time interval for burial and mesocosm experiments. Values for the line graphs of the mesocosm experiment were computed from the median of the concerned parameter per layout and monitoring point, always consisting of five replicates together with the standard deviation.

Statistical hypothesis tested:

H_0: Growth and integrity of Zostera marina shoots does not perform differently by the fixation of the shoots into a carrier substrate than single shoots out planted directly into the sediment.

5 RESULTS

5.1 BIODEGRADATION EXPERIMENT

Sediments of the study site were categorized as “medium sand” with some inclusions of muddy and gravely sediments according to the Wentworth scale (Wentworth, 1922); Appendix 4) Grain size distribution was narrow, with the mode ranging between 1.2-1.8 ϕ implying sediment conditions were homogenous, assuring comparability among samples.

Average sediment temperatures ranged around 21°C and 24°C during the night and day, respectively. However, sediments were slightly cooler in April compared to July and increases approximately 0.4 °C per week over the period of the experiment (Fig. 11).

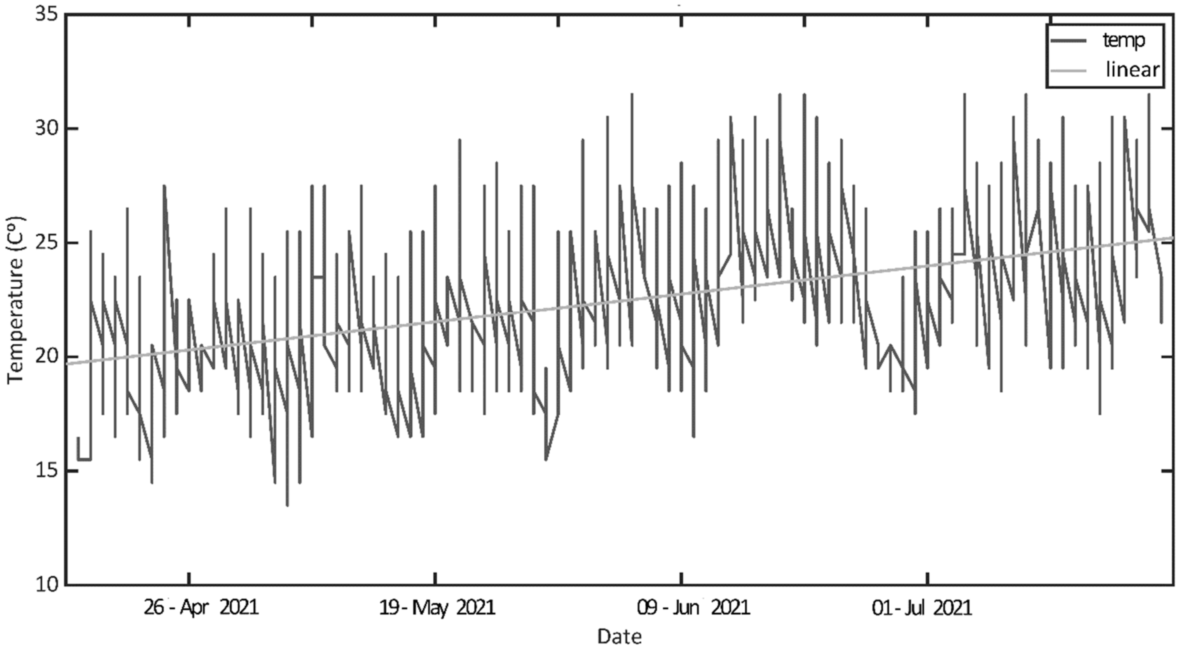


Fig. 11. Temperature profile of the sediments from the burial site from April 15th to July 12th, with an increase in temperature of approx. 0.4°C per week over the time of the experiment.

Biodegradation of the samples was proven by the detected negative trend throughout the different parameters for most the samples (Appendix 6).

Visual inspection of the controls compared to the samples after 84 days of burial demonstrated that samples of **CC** and **CT7** layouts appeared intact throughout the experiment, indicating a low degradation (Fig. 12). The nonwoven mats of **JC** and **JT7** samples were thinned out, implying lack of protection of the mat through the jute net, due to its open grid. Specimen from **SC** and **ST7** layouts suffered loss of yarns on the outer corners of the mesh, causing a thinning of the sample. Nevertheless, the high thread density of the sisal nets offered protection for the mats, which did not show signs of degradation.

Weight loss was monitored as a proxy for mechanical degradation and analyzed via PERMANOVA (Table 7;Appendix 8). Layouts composed of coir nets showed an overall constant weight until the final phase of the experiment, in which they experienced marginal drop in weight (Fig. 13). The average weight of **CC** layouts increased by approx. 3 % in the first three weeks (**p=0.001**) and dropped to the initial weight in the fourth week, indicating no weight loss (**p=0.005**). After twelve weeks weight reduced by 0.66 % (**p=0.009**). **CT7** samples showed a similar behavior, with weight fluctuating between in- and decreasing trends in the first three weeks. In week eight the weight reduced by 2 % (**p=0.018**) and stayed constant after for the

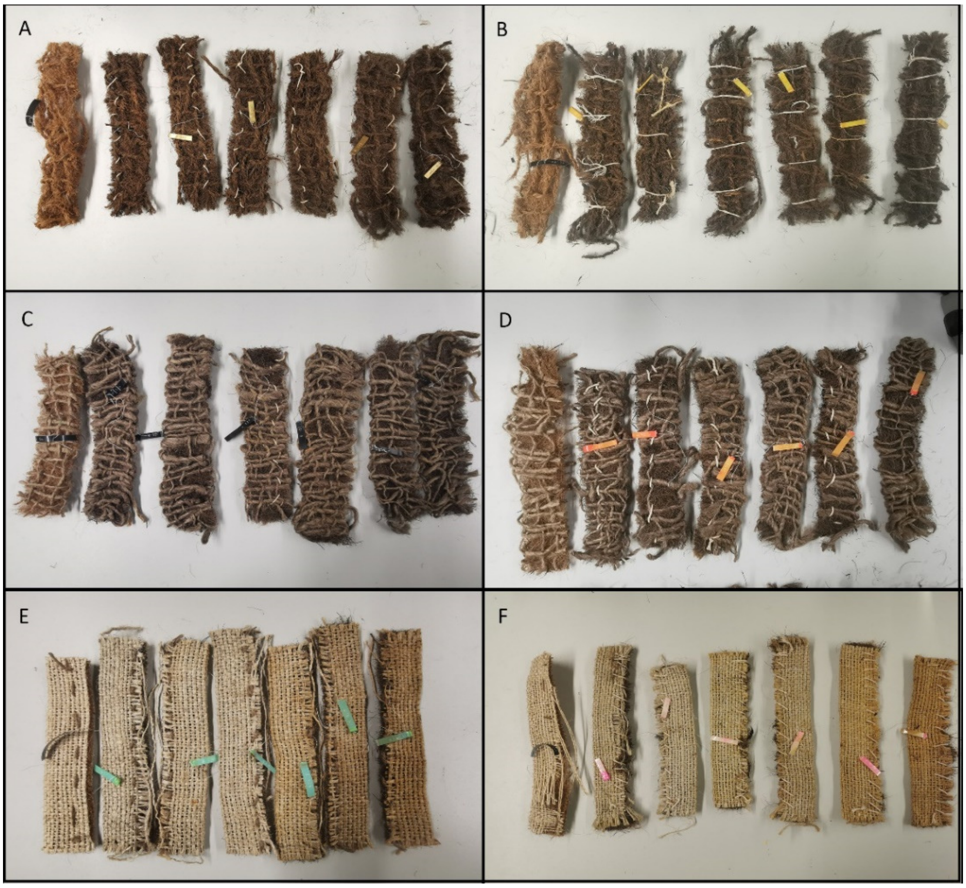


Fig. 12. Photograph of six different textile layouts after burial in the Ria Formosa Lagoon for 1,2,3,4,8 and 12 weeks. Samples were rinsing with freshwater after exhumation and dried for 72h at 60°C. Top left: CC, top right: CT7, middle left: JC, middle right: JT7, bottom left: SC, bottom right: ST7. Controls on the left with burial time increasing towards the right. For layout code see refer to Fig. 6.

following month (**p=0.393**). No weight loss was recorded for the **JC** layout within the first four weeks but a sudden drop was recorded after eight weeks with a final weight loss of 15 % (**p=0.002**). **JT7** replicates varied among each other within the first four weeks, indicated by the high variance in week three and four, though lowered overall 7 % after eight weeks, which was doubled after twelve weeks (**p=0.001**). Weight of **SC** textiles reduced in the first week of burial by 7 % (**p=0.001**) and stayed constant for the following three weeks until it dropped by 14 % and 21 % in week eight and twelve, respectively (**p≤0.013**). The same pattern of weight loss was observed for **ST7** samples, which lost in total 18 % of their initial weight (**p=0.001**). Among layouts, samples composed from coir nets showed the lowest weight loss, opposed to the 30x and 10x higher weight loss of sisal net layouts for **CC** and **CT7**, respectively (**p=0.001**) (Fig. 17, top). Final weight loss of jute net layouts ranged in between coconut (avg. 10x higher) and sisal layouts (avg. 1.5 x lower) (**p≤0.017**). No differentiation between the mats within one group of nets could be made.

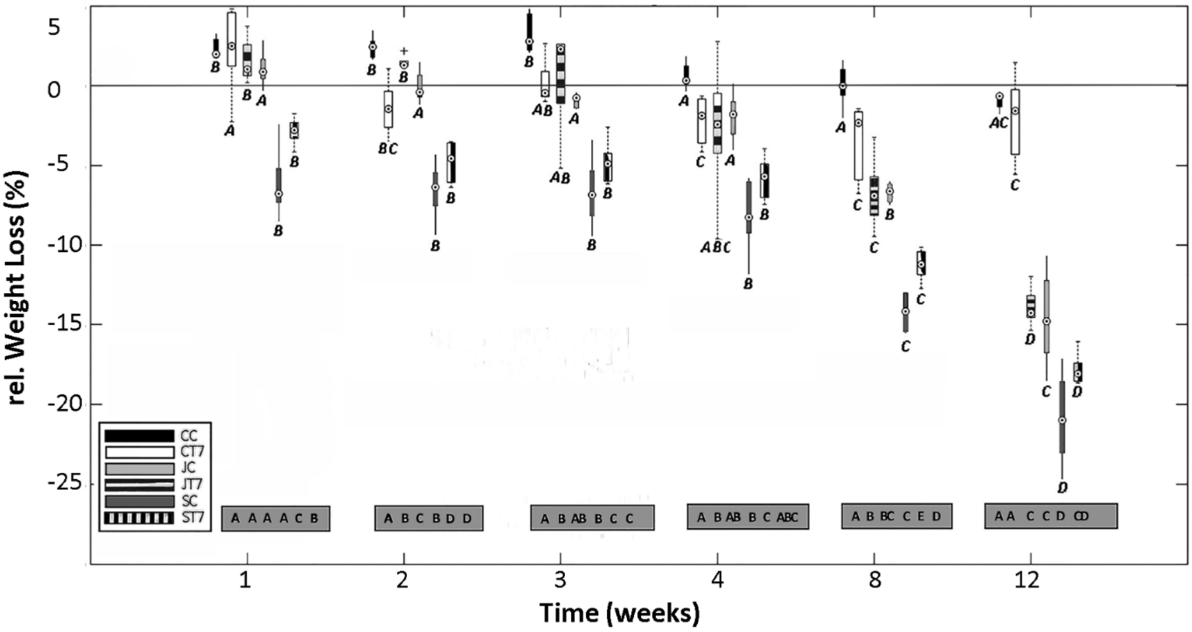


Fig. 13. Relative weight loss of buried textile layouts over time starting after week 1 until week 12. Each boxplot represents five replicates per time interval. Letters below boxplot charts explain differences within individual layouts over time. Letters in the box below boxplot charts explain difference in one time interval among the layouts.

The second indicator examined for mechanical degradation was tensile strength loss (Fig. 14;Appendix 7). Tensile strength loss of **CC** layouts did not show differences up to three months of burial, after which a decrease of 34 %, compared to the control, was recorded (**p=0.003**). **CT7** layouts showed high durability throughout the whole experiment and tensile strength only reduced after two months by 25 % (**p=0.009**), featuring some fluctuations (±12 %) of in- and decrease beforehand. Tensile strength of **JC** layouts stayed constant until the final period of the experiment, in which strength was 3x times lower, compared to the controls (**p=0.001**). Loss of tensile strength was initiated a month earlier for **JT7** layouts than for **JC.** The samples experienced a reduction of strengths after eight weeks of 55 % (**p=0.037**) and after 12 weeks of 78 % (**p=0.006**) in total. Sisal layouts showed low resistance against degradation regarding preservation of tensile strength. A first drop of 25 % in tensile strength was observed for **SC** layouts after 7 days of burial (**p=0.004**). Subsequently, strength loss stagnated and did not lower up until the two months mark, where tensile strength lost 58 % of its original strength. This was followed by another drop at the three months mark, resulting in a total strength loss of 74 %. (**p≤0.001**). **ST7** samples revealed a similar behavior as **SC** layouts with 4 % lower final tensile strength loss of 70 % compared to the **SC** (**p=0.001**). Tensile strength of all layouts differed right to begin with. The tensile strength of sisal net layouts was 6x higher in the controls compared to coir net layouts and even 25x higher than jute net

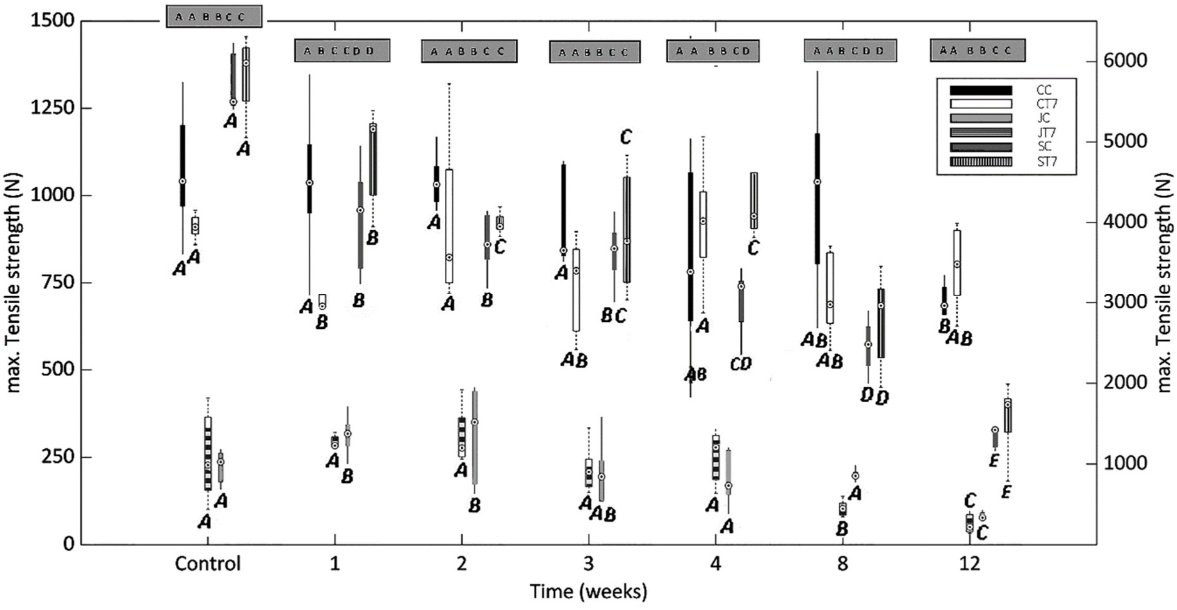


Fig. 14. Tensile strength loss profile of controls and buried textile layouts over time from week 1 to week 12. Letters below boxplot charts explain differences within individual layouts over time. Each boxplot represents five replicates per time interval. Letters in the box below boxplot charts explain difference in one time interval among the layouts. Left y-axis describes tensile strength of coir net and jute net layouts. Right y-axis describes tensile strength of sisal layouts.

layouts (**p=0.001**). Due to the durability of the coir net, the magnitude of difference between sisal net and coir net layouts decreased from 6x to a 2x lower tensile strength after three months of burial (**p=0.005**;Fig. 17, middle). The magnitude of difference between sisal and jute stayed the same as the controls after three months (**p=0.001**). No difference between the two mats was detected, as results between same net type resulted in comparable values.

Table 7. General permutational MANOVA results of physical (weight loss, tensile strength loss) and biological (OCR) descriptors of biodegradation of textile layouts, buried in the Ria Formosa lagoon with factor Layout and time of burial. Per Layout and Time interval five replicates were buried, total n=180. α-level=0.05, significant result presented by *.

Parameter	Factor	DF	Pseudo-F	P (MC)	Significance
Weight loss					
	Layout	5	124.12	0.001	*
	Time interval	6	173.13	0.001	*
	Layout * Time interval	30	15.22	0.001	*
	Residuals	168			
Tensile Strength					
	Layout	5	1066.80	0.001	*
	Time interval	6	84.79	0.001	*
	Layout * Time interval	30	26.55	0.001	*
	Residuals	168			
OCR					
	Layout	5	7.10	0.001	*
	Time interval	6	11.37	0.001	*
	Layout * Time interval	30	1.97	0.002	*
	Residuals	168			

Microbial degradation, measured as oxygen consumption rate (OCR), showed controls featured low to absent aerobic micorbial activity, with OCR values revolving around zero (Fig 15). Among controls, **ST7** was different from all layouts (**p≤0.007**). OCR within **CC** layouts was initiated in the first week, indicating the settling of aerobic microbes within the fabric, resulting in an final OCR 416x higher compared to controls (**p≤0.014**; Fig. 16). The variance within **CT7** samples resulted in no statistical difference between the controls and the final samples. Nevertheless, OCR appeared to increase 104x, comparing medians at the start and the end of the experiment. OCR in **JC** layouts increased 415x over the course of the experiment (**p=0.014**). OCR for **JT7** textiles appeared to increase almost 50 % between the fourth and eighth week, followed by a minor decrease after eight weeks, but overall featuring a 207x higher OCR at the final stage compared to the controls (**p≤0.016**). Differences of OCR for **SC** layouts were recorded after two months, accounting for a 63x higher OCR than the controls (**p=0.018**). Threshold for **ST7** structures was observed after twelve weeks, featuring a 27x higher OCR than at the start (**p=0.006**). Up until the second week OCR among layouts did not indicate any distinction. After the third week some differentiation was noted in between **sisal** net structures and **JC** as well as in between **SC** and **CT7** layouts (**p=<0.018**), which however, disappeared towards the end of the experiment. Although final values of OCR are only half as high in **CC** layouts than in the other layouts (**p≤0.04**), the highest increase over time, in comparison with the control, was recorded for this structure, followed by **JC** and **JT7** layouts. Similar pattern was observed for sisal net layouts. Despite comparable final values, **SC** experienced a 2x higher increase of OCR than **ST7** layouts, when comparing controls and final rates. Variance increased on average 1400x from the controls to the final time point of three months (**p= 0.001**), possibly influencing PERMANOVA results.

In conclusion **coir** net layouts sustained their morphological appearance along with mechanical integrity the greatest throughout the experiment (Fig. 17). Yet, especially **CC** layouts possessed a pronounced duplication of microbial respiration. Despite the increased duplication, total OCR was rather low in **coir** net layouts. In contrast, **sisal** net layouts suffered from instant weight and tensile strength loss as well as increased total microbial respiration, regardless of the comparatively low duplication. Weight loss in **jute** net layouts was slightly slower than in **sisal** net ones, however tensile strength loss appeared to be similar. Aerobic activity was increased, comparable to the **sisal** net layouts.

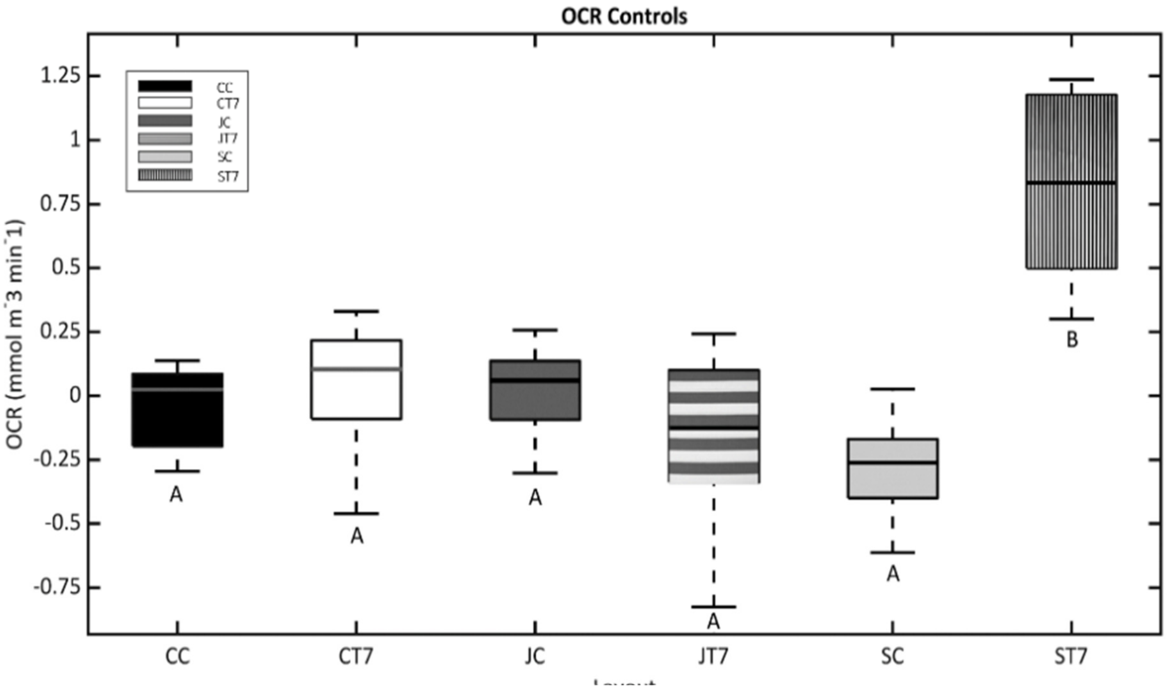


Fig 15. Representation of the initial differences in OCR controls of textile layouts. Each boxplot represents five replicates. Letters below demonstrate differences among layouts. OCR rates revolve around zero, indicating no to low aerobic microbial activity. Differences among layouts possibly attributed to different surface structures.

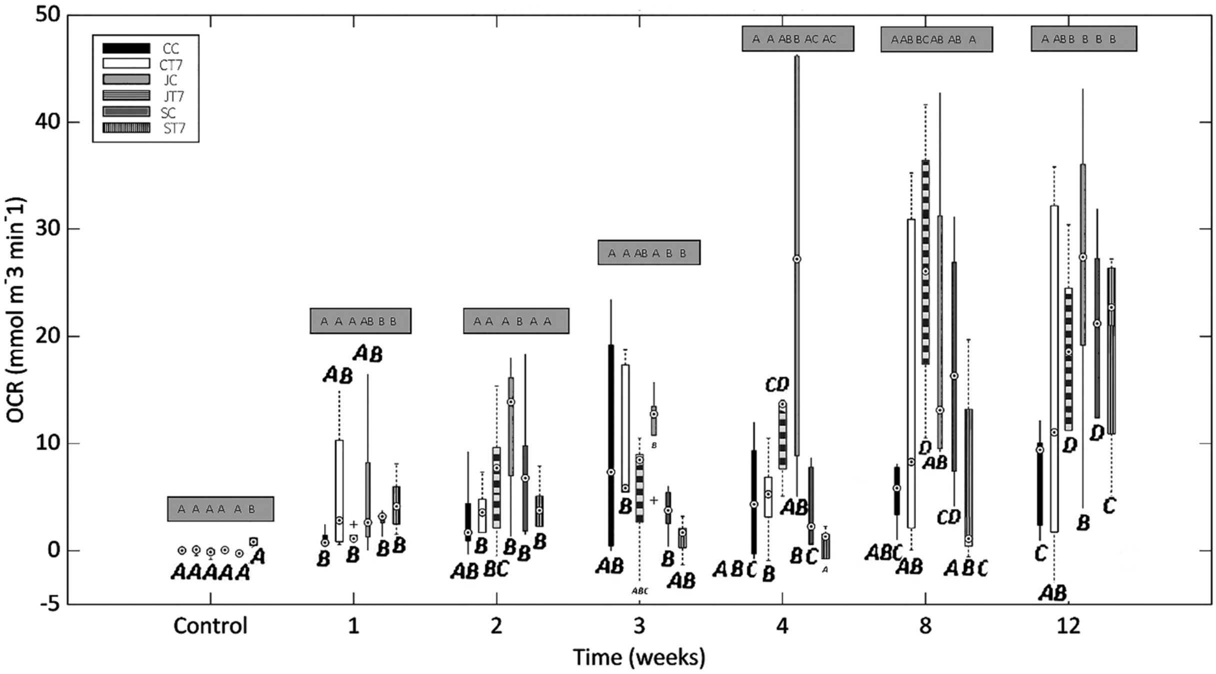


Fig. 16. OCR evolution profile of controls and buried textile layouts over time of controls and specimen from week 1 to week 12. Letters below boxplot charts explain differences within individual layouts over time. Each boxplot represents five replicates per time interval. Letters in the box above boxplot charts explain difference in one time interval among the layouts.

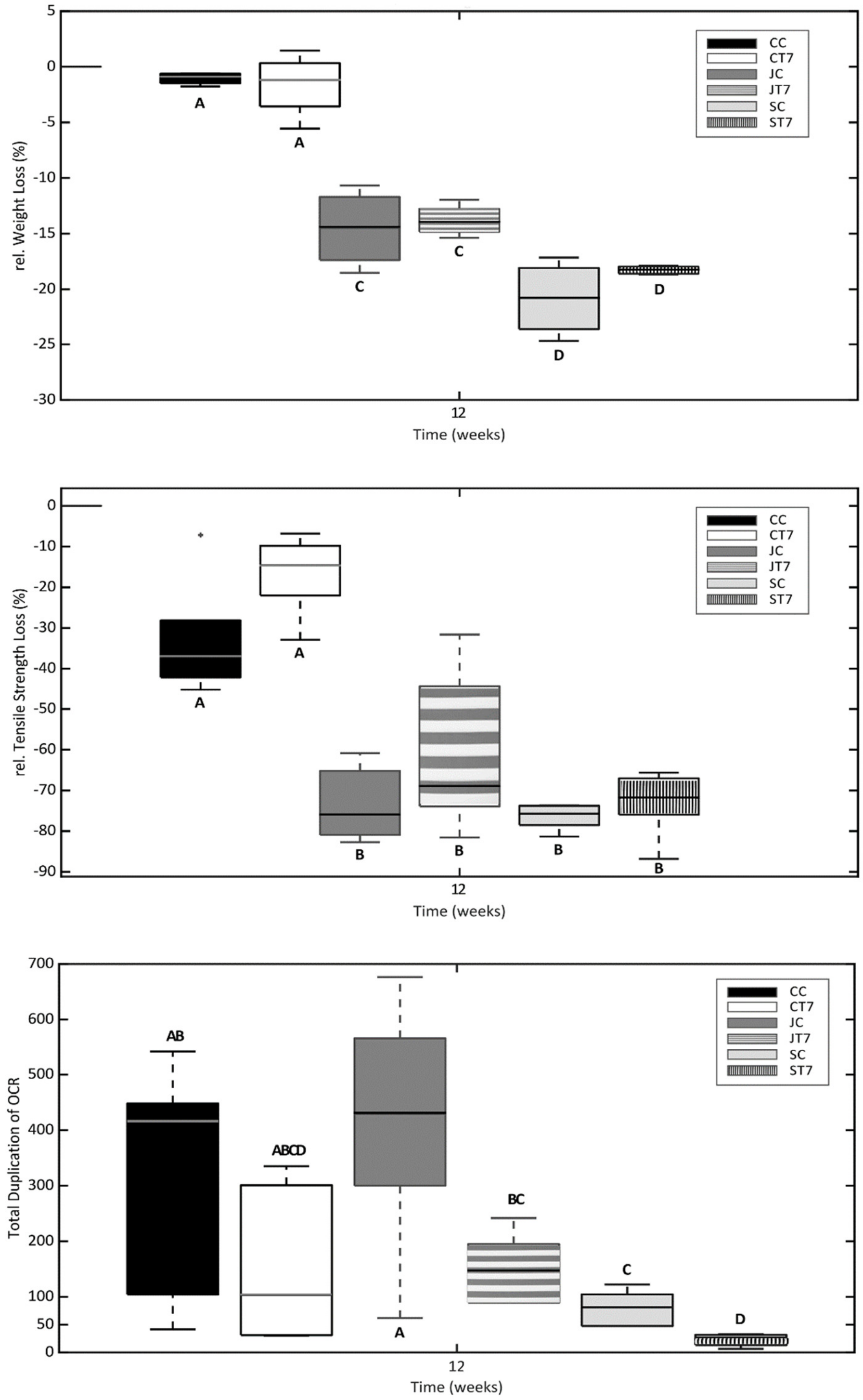


Fig. 17. Top: Relative weight loss of buried textile layouts after twelve weeks. Each boxplot represents five replicates per time interval. Letters below boxplot charts indicate final differences among layouts. Middle: Relative tensile strength loss of buried textile layouts after twelve weeks. Each boxplot represents five replicates per time interval. Letters below boxplot charts indicate final differences among layouts. Bottom: Duplication of microbial respiration (OCR) in textile layouts, comparing control rates with rates of layouts, retrieved after twelve months. Each boxplot represents five replicates per time interval. Letters below boxplot charts indicate final differences among layouts.

It was observed that the three parameters followed a similar pattern over the time of the experiment for **sisal** layouts, experiencing an initial steep drop in the first week and second one after the fourth week (Fig. 18). For **coir** net layouts it appeared as tensile strength loss and the increase in OCR were related. In **CC** layouts the two parameters experienced a drop in the third week, continuing into the fourth week for tensile strength. A sudden increase in both parameters was noted subsequently, followed by another drop after the eighth week. Tensile strength and OCR of **CT7** layouts went through a cycle of de- and increase throughout

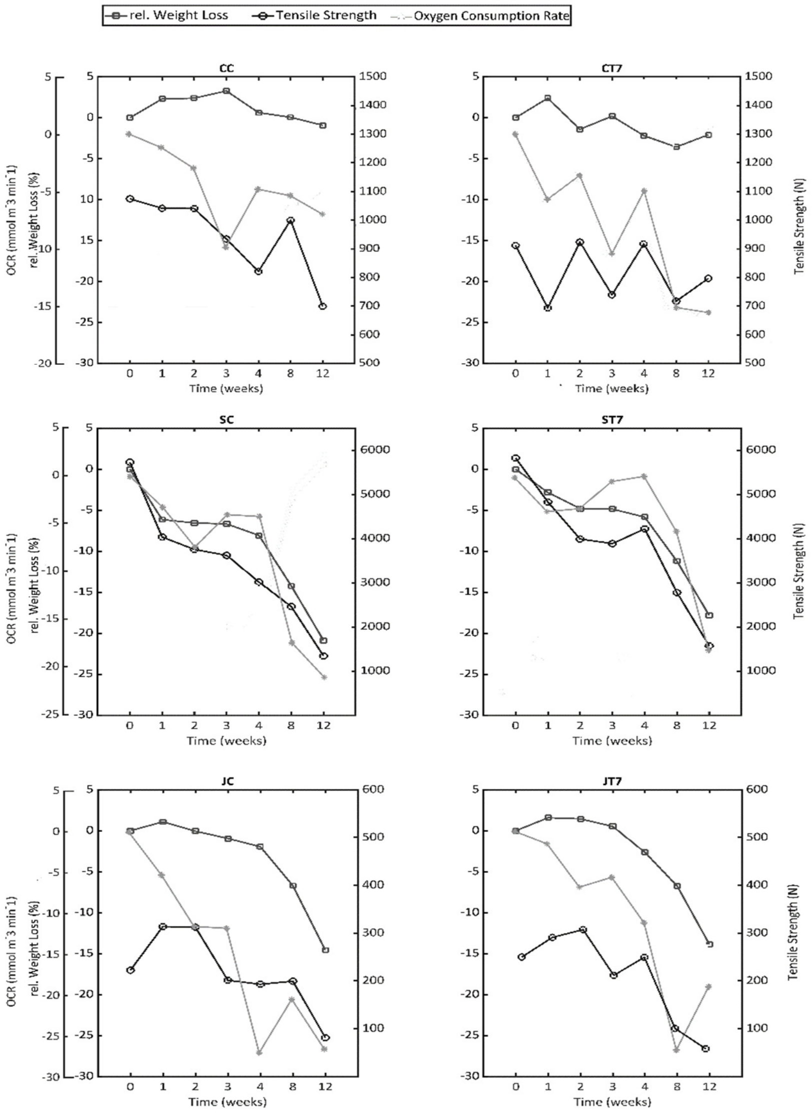


Fig. 18. Relative weight loss, tensile strength and OCR per layout over the period of the experiment. Outer left y-axis refers to OCR. Y-axis is reversed compared to figures above to showcase relation among parameters. The more negative the datapoint, the higher was the OCR in this figure. Inner left y-axis refers to rel. weight loss. Right y-axis refers to tensile strength. Demonstration of average values, each computed from five replicates. Error bars are not depicted in order to facilitate understanding of the relation among parameters but information of variance can be extracted from the boxplot charts of the result section.

the experiment. The three descriptors of biodegradation showed no analogous behavior for **jute** layouts. All parameters featured a terminal decrease but the fluctuations in between time intervals were different among them.

5.2 MESOCOSM EXPERIMENT

Water temperature ranged between 19 °C and 28 °C (night/day) and was on average 24.5 °C (σ = 1.19) from June to August (Fig. 19). No temperature difference between the two sides of the tanks was observed (Appendix 9). Dissolved oxygen accounted for 94 % (σ = 0.16) and showed an average difference of 2 % between June and August. The pH was 7.91 (σ = 0.16) and stayed constant over the period of the experiment. Constant behavior was also observed for salinity with an average of 37.4 psu (σ = 0.46).

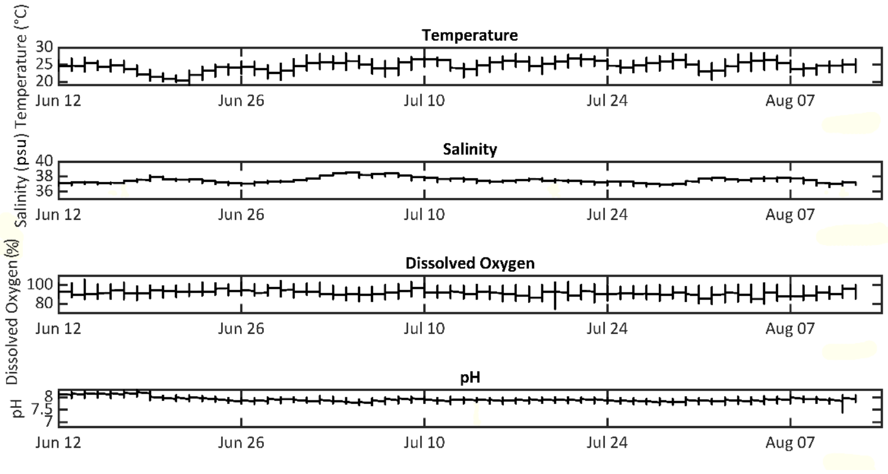


Fig. 19. Physical parameters of the water pumped from the Ria Formosa Lagoon into Ramalhete research station. Mesocosms were provided with this water and supplied with a constant water inflow at all times. Temperature shown here is analogous to logged temperature in the tanks and buckets.

Daily light intensity on the northeast face of the tanks was on average 526.17 lux (σ = 401.06) (Fig. 20). The southwest facing side showed a higher illuminance, accounting for 2316.13 lux (σ = 2245.01).

Shoot integrity suffered severely over the course of the experiment (Fig. 21; Appendix 10). On average the relative leaf number decreased by 80 - 100 % in all treatments (**p≤0.015**) after seven weeks (Fig. 22, top). No overall difference among the layouts was detected (**p=0.968**). Yet, after one week **CC** layouts had 15 % and 20 % more leaves than **SC** layouts and **fertilized mesocosms**, respectively **(p≤0.019)**. Nevertheless, no distinction could be made anymore at the final time interval of seven weeks (Fig. 23, top). Survival rate of shoots in all layouts was stable the first three weeks and declined by avg. 10 % up to the fifth week in **CC**

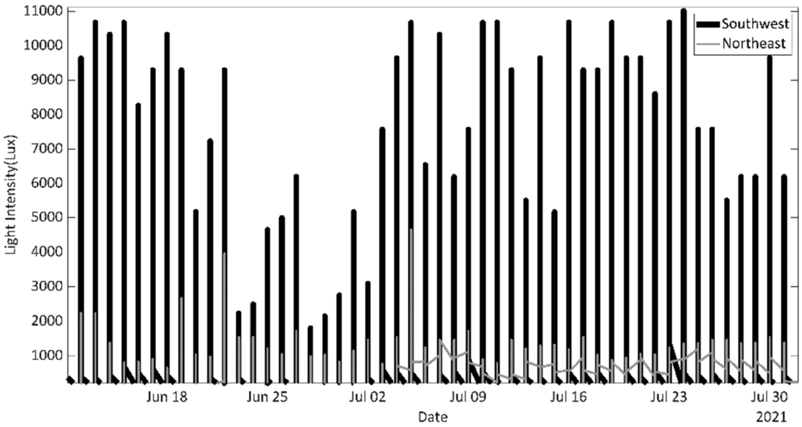


Fig. 20. Daily light intensity (6:00 am to 8:00pm) over time from the start until the end of the experiment of two Hobo loggers placed on the northeast side and the southwest side of the tank set up. Grey bars indicate northeast side. Black bars indicate south west side of the tanks.

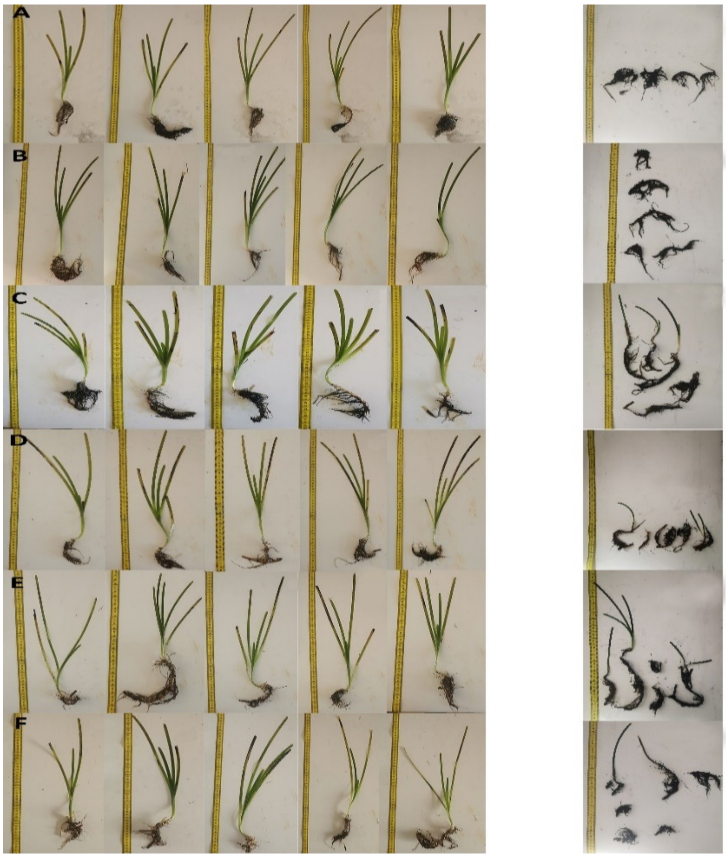


Fig. 21. Exemplary replicated of seagrass shoots before and after the experiment. Five replicates per layout accommodated five shoots. Left: Intact shoots before. Right: Leftover of shoots after seven weeks of experiment. A=CC, B=CT7, C=SC, D=ST7, E=Fertilizer, F=Controls. For layout code see refer to Fig. 6.

and **CT7** layouts (**p≤0.021)** (Fig. 22, bottom). Subsequently, after seven weeks, the number of shoots reduced in all layouts by another 55 % (**p≤0.038)**. Among layouts variations in survival rate were revealed (**p=0.008;** Table 8). After three weeks survival rate of shoots in **CT7** layouts was 20 % lower than in layouts **SC**, the **controls** and the fertilized mesocosms (**FT**) **(p≤0.044)**. The following two weeks the differences disappeared and a difference between layout **CC** and **SC** appeared, with **SC** showing a 40 % higher survival rate than **CC (p=0.003).** The difference persisted throughout the final stage of the experiment (seven weeks) and eventually survival rate in **SC** layouts was twice as much as in **CC** as well as in **controls** (Fig. 23, bottom; **p ≤0.013**).

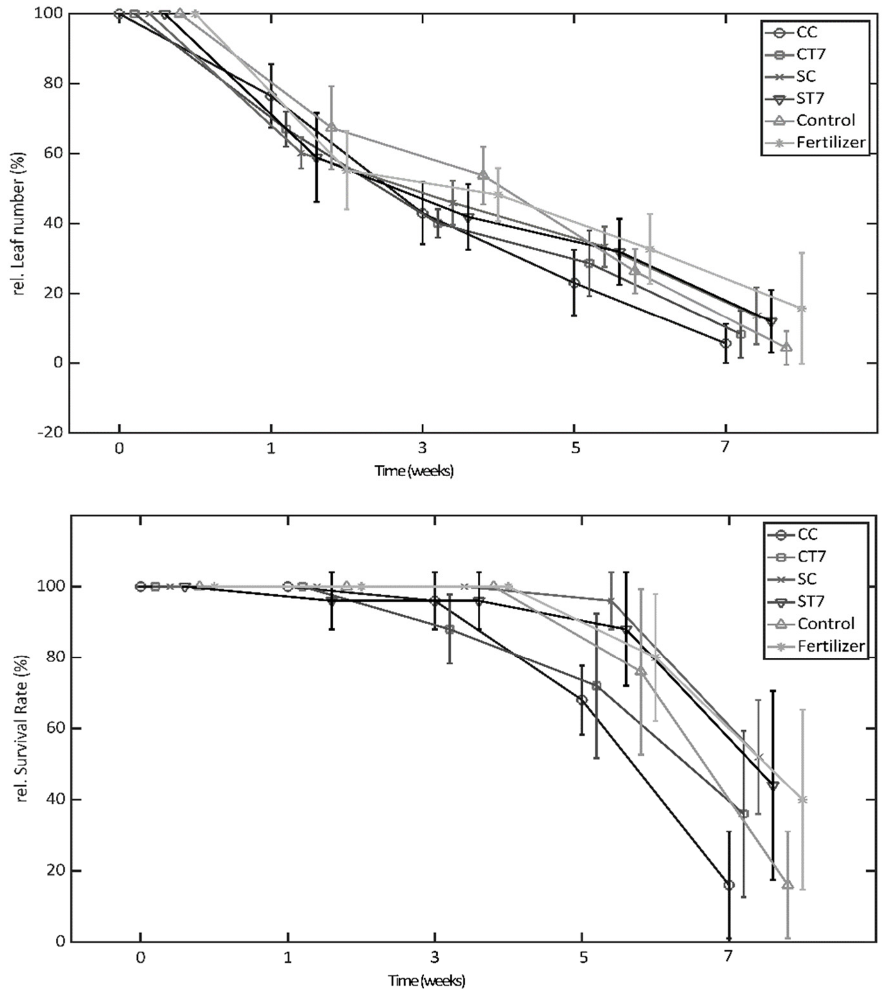
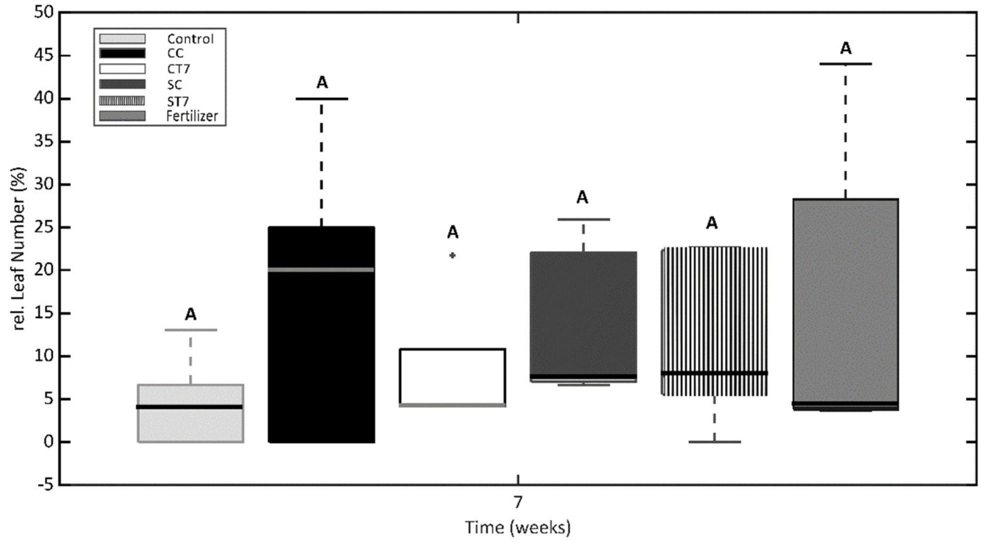


Fig. 22. Decrease of average relative leaf number (top) and survival (bottom) of eelgrass leaves over seven weeks. Shoots were integrated into four different textile layouts (CC, CT7, SC, ST7) along with fertilized shoots (FT) and controls (C). Experimental set up consisted of five shoots per textile and five textiles per layout. Textile with shoots were placed in outdoor flow-through mesocosm, with seawater from the Ria Formosa lagoon. Demonstration of average values each computed from five replicates and standard deviation. For layout code see refer to Fig. 6.



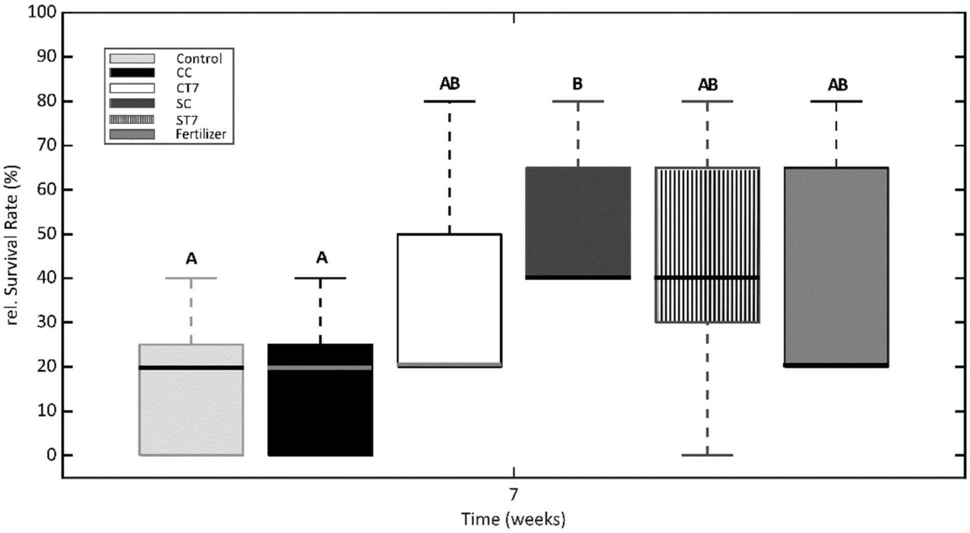


Fig. 23. Boxplot chart of relative leaf number (%) at the start and after seven weeks (top), Boxplot chart of relative survival rate (%) at the start and after seven weeks (bottom). Letters indicate differences among layouts within time interval.

Total length of root segments within a substrate lowered from the beginning to the end of the experiment for all layouts similarly **(p=0.545)** (Fig. 24, top). However, it was observed (not statistically significant), that some replicates increased in their segment length especially, shoots incorporated in **SC** layouts. Although the replicates featured an extensive spreading, variance ranged in the positive spectrum of root segment elongation, implying better growth of these samples compared to shoots, placed into other layouts. Replicates within the other layouts (**Control, CC, ST7, FT**) featured positive elongation in some replicates but negative in others, though, medians entirely ranged in the negative spectrum. Biomass decreased excessively during the experiments and the median of the wet weight loss for all substrates ranged around 50 to 70 % (Fig. 24,middle). Wet weight loss was observed to be 25 % higher of shoots growing on **ST7** layout than on **SC** layouts (**p=0.018**). Moreover, **control** shoots experienced 15 % higher wet weight loss than shoots in **SC** layouts (**p=0.017)**.

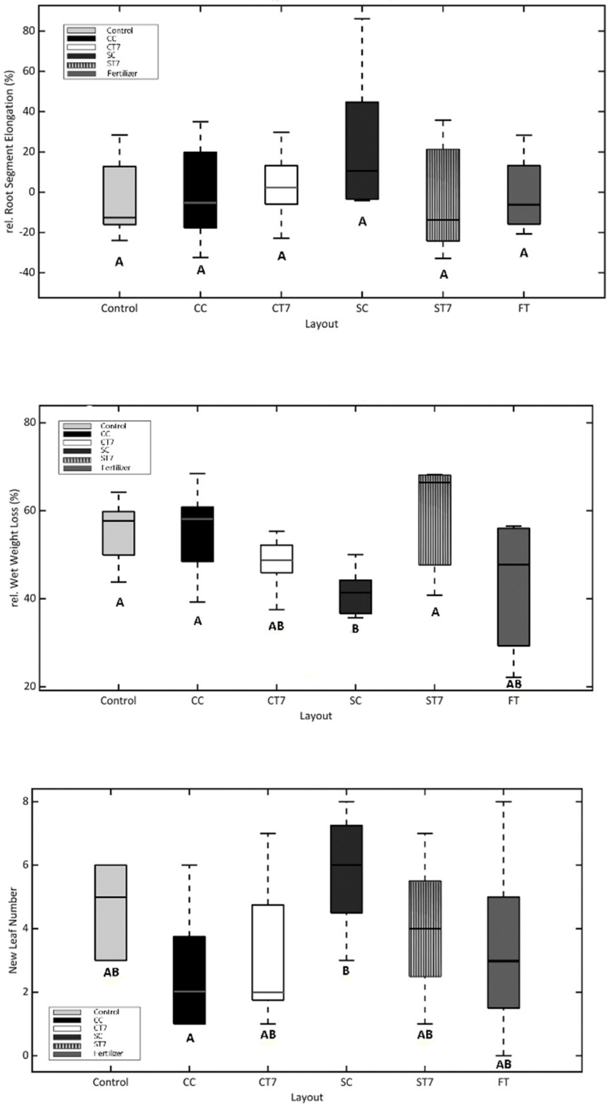


Fig. 24. Eelgrass relative root segment elongation (top), relative wet weight loss (middle) and total number of new developed leaves (bottom) after seven weeks in the mesocosm. Letters indicate differences among layouts within time interval.

New leaves emerged over the time of the experiment and were recorded at every monitoring period and summarized at the end of the experiment (Fig. 24, bottom). Shoots growing on **SC** substrates developed 3x more leaves than shoots in **CC** layouts (**p=0.036**). Shoots incorporated into other fabrics produced an intermediate number of leaves (approx. between 2-6 leaves) (**p=0.293**)

Overall shoots in all mesocosms showed ananalogous trend in effective quantum yield as the survival rate, dropping abruptly after five weeks (**p≤0.008**), except for shoots incorporated in layouts **ST7** and the fertilized shoots, which experienced a decrease after seven weeks (**p≤0.033**). Shoots incorporated into **CC, CT7** and **SC** sandwich structures behaved in a similar matter, with an final averaged effective quantum yield ratio of **0.14** (Fig. **25**, bottom). Effective quantum yield appeared to be decreasing 3x less in shoots of layout **ST7,** followed by a 2x less decrease in the fertilized plants (**FT**). Contrary to the decreasing yield in most shoots, yield increased for some shoots in **ST7** substrates. Shoots in **controls** showed no more effective quantum yield, differing from shoots incorporated into **CC** and **CT7** layouts (**p≤0.026**). Effective quantum yield measurements presented 7.5x higher variances at the final stage than at the start, leaving results questionable (**permadisp p=0.001**; Appendix 8; Fig. 25,top).

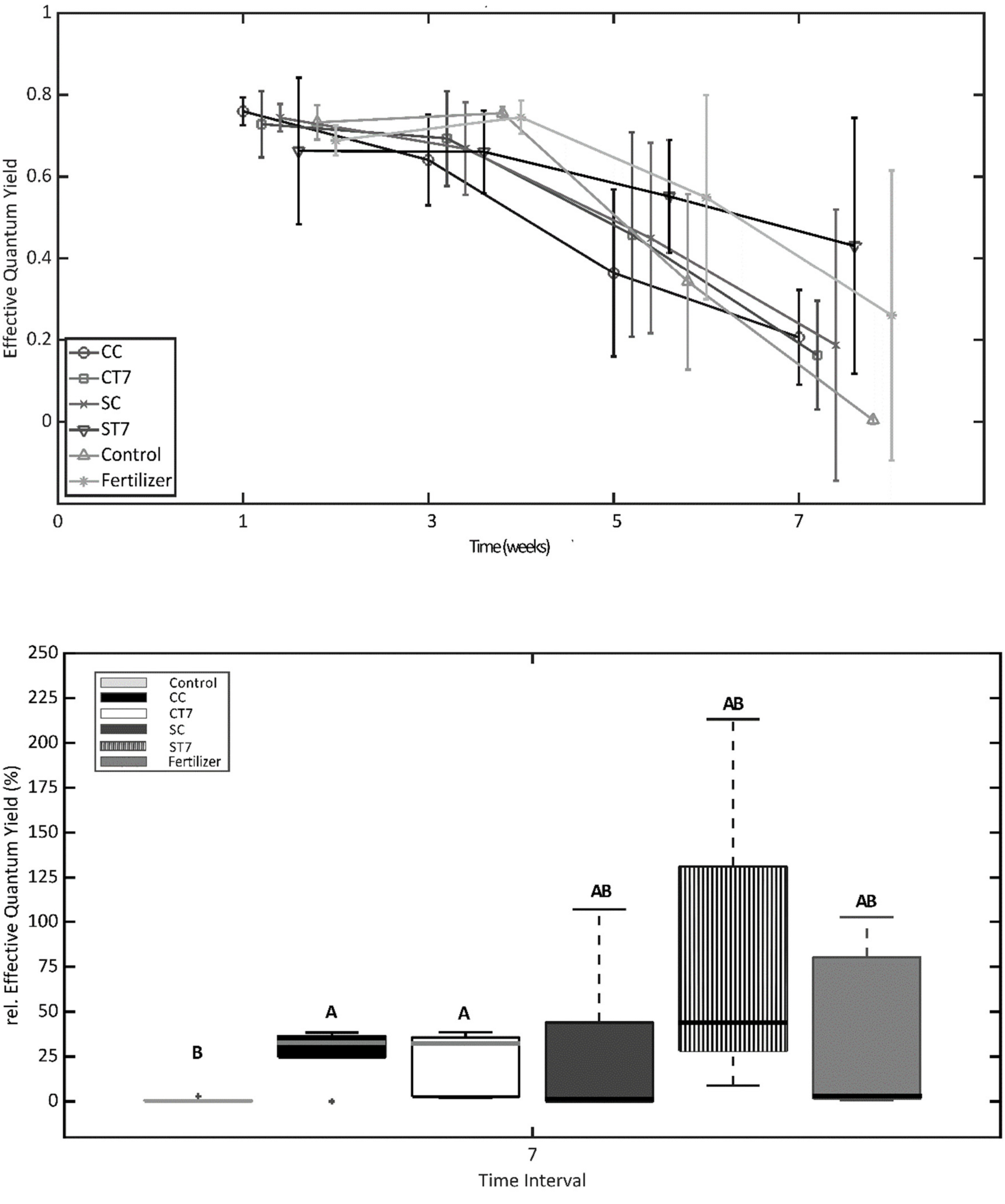


Fig. 25. Averaged effective quantum yield over time from week1 until week 7 (top). Average values are each computed from five replicates together with standard deviation. Boxplot chart of rel. effective quantum yield before and after seven weeks (bottom). Letters indicate differences among layouts within time interval.

Table 8. General permutational MANOVA results of morphological and photosynthetic parameters of *Zostera marina* shoots with factors 'Layout' and 'Time Interval'. Used layouts were CC,CT7,SC, ST7 along with fertilized shoots and controls (see composition Fig. **6**) Per Layout five replicates were placed into independent mesocosms with five shoots each. Total shoot n=150. α-level=0.05, significant result presented by *.

Parameter	Factor	DF	Pseudo-F	P (MC)	Significance
Survival rate					
	Layout	5	3.31	0.008	*
	Time interval	4	123.81	0.001	*
	Layout * Time interval	20	1.50	0.085	-
	Residuals	120			
Leaf number					
	Layout	5	0.197	0.968	-
	Time interval	4	463.92	0.001	
	Layout * Time interval	20	1.915	0.012	*
	Residuals	120			
PAM					
	Layout	5	1.76	0.136	-
	Time interval	4	85.18	0.001	*
	Layout * Time interval	20	1.88	0.024	*
	Residuals	336			
New Leaves					
	Layout	5	1.32	0.293	-
	Residuals	24			
Root segment elongation					
	Layout	5	0.79	0.545	-
	Residuals	24			
Wet Weight Loss					
	Layout	5	2.43	0.070	-
	Residuals	24			

Despite differences in light intensity between the outer edges of the tanks, no differences within the survival rate, leaf number, new developed leaf number along with rel. effective quantum yield were detected among tanks (**p≥0.137,** Appendix 8).

It was observed that effective quantum yield and shoot survival rate followed a similar pattern over the time of the experiment. During the first three weeks both parameters were rather stable and experienced a sudden drop after the third week continuously until the end of the experiment. Leaf number suffered from loss from the beginning of the trials and followed a linear decrease throughout the entire period of the seven weeks.

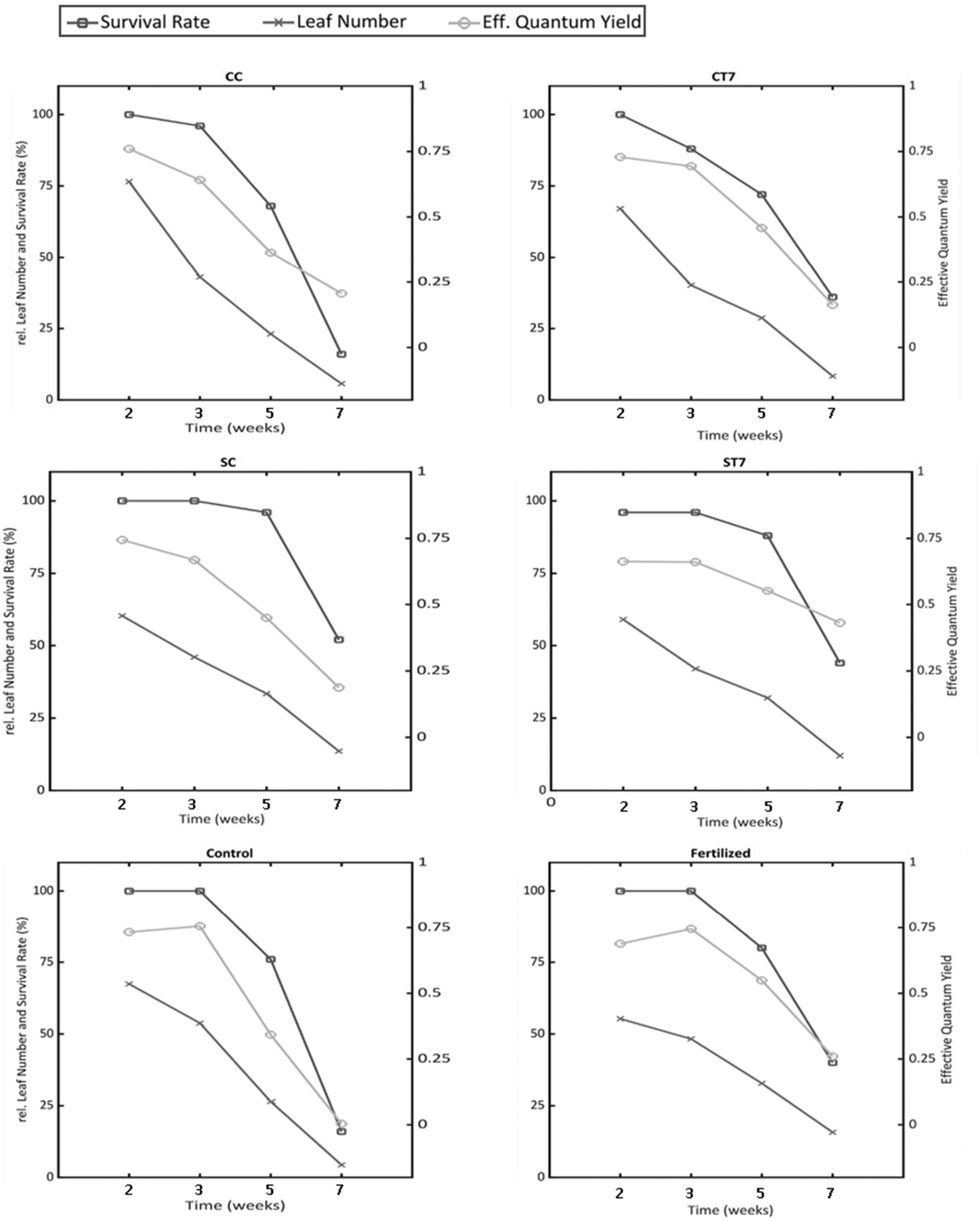


Fig. 26. Relative survival rate, relative leaf number and quantum effective yield per layout over the period of the experiment. Left y-axis refers to rel. survival rate and rel. leaf number. Right y-axis refers to effective quantum yield. Demonstration of average values, each computed from five replicates. Error bars are not depicted in order to facilitate understanding of the relation among parameters but information of variance can be extracted from the boxplot charts of the result section.

6 DISUSSION

6.1 BIODEGRADATION

Physical properties of the individual fibers as well as their processing into woven textiles influenced the outcome of the biodegradation experiments. Coir fibers are considered the most durable fiber (Lekha, 2004), agreeing with the marginal weight loss of both **coir** net layouts. Increase in weight might be associated to the very porous structure of the net and mats, making it easily accessible for microorganisms or sediment accumulation, obscuring weight loss through degradation. This assumption agrees with findings from Di Franco *et al.*, (2004), who claimed that weight determination is sensitive to errors due to the prior described cause. Contrasting behavior was observed in **sisal** layouts leading to the assumption that the dense grid did not allow any accumulation of biomass or sediments and resulting in an initially measurable weight loss. Because of the wide grid of the **jute** mesh entrapment of any kind within the substrates might have been possible, indicated by the initial increase in weight, comparable to the **coir** net layouts. Nevertheless, the wide grid could not prevent eventual weight loss, leaving the mats unprotected and degrade faster than the **CC** and **CT7** layouts. It appeared that the threshold of initiating biodegradation with regard to weight loss was reached after eight weeks for **jute** and **sisal** net layouts, which both experienced sudden drops in weight after that point of time. In the following month weight dropped more rapidly than before, implying that, as soon the degradation process is initiated, it proceeds much faster than at the start and, thus is not a linear function of exposure.

Tensile strength loss analysis was only applied to the nets, as the machine brackets hold on to the outer layer of the substrate (net). Mats were not relevant for this analysis since their purpose was not to increase stability but serve as rooting ground for the shoots. Tensile strength varied between the layouts from the beginning due to differences in yarn thickness as well as weaving design. Mechanical properties of textile fabrics are influenced by the individual fiber properties and subsequently modified by the conversion into yarns and into the final fabric (Saiman *et al.*, 2014).During tensile strength testing the longitudinal applied load foremost attacks the fiber friction among fibers, followed by the elongation of the yarns (Saiman *et al.*, 2014).Furthermore, force at break increases with weft yarn density (Nassif, 2012).The original superior performance of the **sisal** net layouts can be attributed to its high tensile strength of the individual fibers (Haque *et al.*, 2015) in combination with the high density weft design of the net. Coir fibers possess lower tensile strength than jute fibers (Wu *et al.*, 2020). Yet, tensile strength of the **coir** net fabrics was far better than tensile strength of the **jute** nets probably due to the very low density of yarn count within the **jute** nets, leading to inferior capability of withstanding the applied load. Nevertheless, the baseline of tensile strength of the individual layouts did not influence their over time performance after burial. Although **sisal** layouts possessed the highest tensile strength in the controls, they experienced the most significant loss in tensile strength over time. The decrease of tensile strength as a function of exposure of these layouts was associated with the weight loss. Within both variables **sisal** nets reduced performance in the first week and subsequently stayed constant until the 8th week of the experiment, in which another significant drop in performance was discovered. The magnitude of diminution between the 4th and the 8th week ranged around 1.3-2x for both parameters, demonstrating analogous reduction. Additionally, oxygen consumption rates correspond to the behavior of the mechanical parameters. Though, differences between the first and second month were not significant (p=0.051) a clear upward trend of OCR was observed, initiated after eight weeks alike weight loss and tensile strength loss. Furthermore, differences in variance between the first four weeks and the following (Permdisp p=0.001, Appendix 7) might have influenced the PERMANOVA results, and therefore not indicating the significance of difference between these two time intervals. Tensile strength loss in jute nets behaved in a similar matter, in which a sudden decrease of strength was revealed in the last two months of the experiment. According to a study from Saha *et al.*, (2012) jute fabrics, exposed to a 3 % NaCl aqueous solution for 120 days, were left with 15 % of their original tensile strength. Tensile strength for jute layouts in this study reduced by approx. 70% after a period of 84 days, comparable to the results from this study. The decrease of tensile strength was more pronounced even, possibly due to the additional component of the burial. Yet, although weight reduction between jute net layouts was the same after two months, tensile strength loss was not induced in **JC** layouts up until the third month, whereas tensile strength reduced half already after two months in **JT7** structures. According to these findings tensile strength reduction clearly was influenced by another factor than just weight loss. Oxygen consumption rate ranged in similar magnitudes for both jute net layouts, implying comparable aerobic microbial activity. Hence, OCR was not the influencing factor on the variance in tensile strength loss between the layouts. Aerobic microbial activity appeared to be rather independent from the mechanical properties for jute net layouts until the final stage of the experiment. Complementary to the tensile strength loss in **JC**, an increase of OCR was recorded. Nevertheless, other conformities among the parameters for jute net layouts were not identified. Tensile strength loss in coir net layouts followed, like sisal net layouts, the pattern of the weight loss. After eight weeks tensile performance of **CT7** layouts lowered 1.3x compared to the first month, alike the weight and, increased in the same magnitude as it lowered after twelve weeks for tensile strength and weight. Also, **CC** layouts dropped in weight and tensile strength simultaneously after three months, indicating correlating behavior between tensile strength and weight loss. The overall OCR was rather low in **coir** net textiles compared to the other layouts. The high lignin content in the coir fibers results in protection of the cellulose, thus protection from chemical and biological deterioration (Rajan *et al.*, 2005), which was supported by the findings of this study. Microorganisms are more susceptible to degrade fibers with higher cellulose and hemicellulose components and only few microorganisms are capable of decomposing lignin (Rajan *et al.*, 2005). Composition of cellulose, hemicellulose and lignin is comparable between **sisal** and **jute** fibers, potentially explaining the similar degradation behavior of these two layouts.

Generally, the increased variance in OCR might have led to misinterpretation of final results questionable, which though, is an inherent occurrence in biological investigations (Hicks *et al.*, 2020). Possible reason for the high variance in the tensile strength in **coir** net and **jute** net layouts might be the inconsistency of the thickness of yarns, therefore forces distribute differently throughout the samples among replicates. This assumption is supported by the low variance in **sisal** layouts, attributed to the very consistent net it provides. Weight loss appeared to be less affected by spreading, wherefore results are more reliable. Improvement of results can be achieved by using an increased sample size and thereby, achieve a more consistent pattern.

This study showed that, the biodegradation of fibers from natural derivates requires a certain time of response until the degradation process is induced. All layouts were rather stable in their physical properties along with aerobic microbial activity and declined significantly in performance after a threshold of two or three months. Furthermore, it was proven that, the chemical composition of the fibers was responsible for the degree of degradation of the different layouts, as the two opposing weave designs of a high-density **sisal** mesh appeared to degrade in similar manner as a low-density **jute** mesh. Moreover, this work showcased that textile substrates degrade more rapidly submerged in the marine environment than in terrestrial. **Sisal** fibers degrade within 24-36 months in contact with soil (The East Africa Sisal Company Ltd.). This study revealed, that if **sisal** would degrade at the same rate as the past three months, a full weight loss of less in twelve months would be achieved. Weight loss in **coir** textiles proceeds much slower than the given 36-48 months rate from literature (Greenfix). Yet, tensile strength was reduced by avg. 30 % after three months, whereas according to Sumi *et al.*, (2018) coir buried in sand lacked 63 % of tensile strength after one year, corresponding to the initial statement that saline environment catalyzes degradation. According to a study from Arshad & Mujahid, (2011) jute lost 40 % of its weight after three months. In the case of this study structures composed with **jute** nets only degraded by 15 % during that time period. Though, due to the wide grid of the jute net, weight decrease affected the interior coir mats directly, therefore it is not clear how much the jute net itself degraded, as it only took a small weight percentage of the overall weight of the sandwich structure. It was expected that the high resistance of **sisal** to saltwater would result in a superior performance of these layouts above the others with regard to biodegradation and that the enclosed net structure would decrease microbial attack. This study demonstrated that despite the high resistance of sisal fibers towards saline water, biodegradation was more pronounced than in **coir** net textiles and was more similar to **jute net** layouts, disproving with expectations. Predictions about the mats were not met. **Type 7** mat did not experience increased biodegradation compared to the **cocomat**. In fact, no distinction between the two types of nonwovens was discovered.

6.2 MESOCOSM

During the course of the experiments shoot integrity and number decreased in all treatments, wherefore it was examined in which setting shoots were the healthiest over time and survived the longest. Mortality was potentially caused by immoderate water temperature. Annual average water temperatures around the donor meadow (Culatra island) range between 18 °C – 20°C (Newton & Mudge, 2003) , approx. 8°C lower than the temperature in the tanks. Additionally, minimum light requirements for *Zostera marina,* which, according to Eriander, (2017), account for approx. 1875 lux, were only met at the southwest facing tanks. Though, differences among replicates were not associated with their location in the tanks. Another assumption is that, the damaged of the leaf puncturing was to severe, leaving shoots unable to recover. Leaves turned brown from the puncture on towards the top and subsequently the entire leave. Therefore, the measurement of leaf elongation could not be executed further after three weeks into the experiment. Repuncturing also failed, since leaves turned brown shortly after again. Hence, leaf elongation was excluded from the parameters.

Superior performance was observed in **sisal** layouts, in which shoots appeared to undergo slowest degradation along with even some recovery towards the end of the experiment. Mortality rate was lowest in these layouts, resulting in an increased leaf number. Furthermore, shoots developed the highest number of new leaves and even root segment elongation was observed in shoots, incorporated into **SC** fabrics, which, though was not statistically proven. On the contrary, **coir** layouts offered the lowest support for shoots, indicated by the inferior results of all parameters with **CT7** layouts performing slightly better than **CC** layouts. Shoots in **controls** did not appear to grow well either, leading to the assumption, that a mesh with a certain thread density, and thus supporting system, can result in better growth such as the sisal net. Despite these findings, fertilized shoots, which were not growing on a carrier fabric, featured lower deterioration in their morphological appearance than shoots growing on coir nets. Hence, the study demonstrated that the textile design, especially thread density, along with the material selection are vital factors in the development of textiles fostering shoot stabilization and growth, which was also showcased in a study from Keune, (2017). The coir grid possibly did not supply sufficient support for the shoots due to its lower thread density. Therefore, many leaves were lost from which the shoots could not recover and died eventually. Yet, as hydrodynamics were not mimicked in this experiment, the stabilizing function of the meshes was not analyzed empirically and hence, fertilized shoots possibly might behave inferior than coir net layouts outside laboratory conditions. Contrary to this study, findings from other research suggest that coarse weave meshes are more suitable for transplants of recruits and shoots as the rough surface of the mesh facilitates root anchoring (Irving *et al.*, 2010; Tanner *et al.*, 2014; O'Brien, 2019). Yet, this assumption is not applicable to this study as textile design along with function of the individual substrates (mesh, mat) differed among studies. The function of the mesh in this study was to provide enough support for the above ground parts of the as well as sediment stabilization and strength for transport in future applications in the marine environment. A surface for root entanglement was given by the mat. Thus, this work demonstrated that minor changes in design alter the functionality immediately and must be tailored carefully to the particular purpose such as rooting surface below ground or stabilization above ground of leaves and shoots.

Furthermore, material degradation might affect shoot evolution via the provision of compounds, that foster vegetation (Marczak *et al.*, 2020). The in this study proven earlier induced degradation process of the **sisal** fibers, resulted in earlier release of vegetation supporting compounds into the mesocosm, supporting shoots in the production of new leaves and maintaining the original shoot number as long as possible. **Coir** fibers are subject to slow degradation thus, nutrients might be released in lower concentrations compared to the **sisal** layouts and hence, the rate of newly developed leaves was the lowest in these layouts. Tanner *et al.*, (2014) claims that fast material degradation has adverse effect on shoot recruitment. Lose parts of the textile disturb the shoots and put them under physical pressure. Because this study was not executed in an environment exposed to hydrodynamical forces, this finding is not applicable to this series of experiments and thus had no influence the results. Nevertheless, the concern is valid and must be further investigated in future studies set beyond laboratory conditions.

It was recognized that roots did not entangle into the mats during the period of the experiment. As horizontal rhizome growth is rather slow (26 cm apex-1 yr-1(Marba *et al.*, 2004) it was not expected to observe interactions between the rhizomes and the mats. Additionally, shoot development behaved contrary in the mats. Combined with the sisal net,

ST7 performed inferior compared to **SC**, but, in combination with the coir net, **CT7** showed better results than **CC**. Hence, no distinction in performance related to the mats could be made. Highest wet weight loss was identified in **ST7** layouts as well as loss in root segment length. Therefore, wet weight loss was attributed to loss in segment length due to the higher wt.% of the roots than the leaves.

Most of the green leaves lost their integrity shortly after the start of the experiment and turned into a brownish color. This was caused by the transformation of chlorophyll into pheophytin, which is associated with external stressors such as increased temperature or light (Aramrueang *et al.*, 2019). Effective quantum yield decreased in shoots in all layouts, associated with the loss of chlorophyll-*a* and possibly with down-regulation of photosynthesis due to low irradiance conditions (Beer *et al.*, 1998). Shoots in **coir** layouts and **controls** possessed very low to absent effective quantum yield, respectively, indicating low photosynthetic activity. Despite the increased development of new leaves in **controls**, yield dropped abruptly after three weeks along with an analogous increase in mortality and loss in leaf number, implying that new leaves did not survive in the environmental conditions of the mesocosm and shoots could not recover. Highest effective quantum yield at the final stage of the trials was found in shoots growing on **ST7** layouts, even showing rates higher for some replicates than at the beginning of the experiment, leading to the assumption that some of the survived shoots were recovering and even thriving. Yet, an average decrease of effective quantum yield was also noted for **ST7** plants. Shoots incorporated into **SC** layouts featured some increased yield, however on average lower photosynthesis was detected than in **ST7** layouts. Still, rates were higher than in other treatments suggesting that the high survival rate as well as increased leaf production rate in **sisal** layouts had positive influence on effective quantum yield. **Fertilized** plants did not show any distinctive behavior from shoots incorporated into **sisal** layouts, indicating that the fertilizer did not foster the integrity of the plants to higher extent than the stabilization effect of the dense **sisal** mesh though higher than the wider **coir** mesh. In summary the relation of effective quantum yield with the development of new healthy leaves and the general mortality rate of the shoots is proven by the continuously pattern of shoots growing on **sisal** mesh performing superior in all three parameters, followed by **fertilized** shoots. Inferior performance was detected in shoots growing on **coir** mesh and lowest plant integrity was found to be in **controls**.

7 CONCLUSION

In summary the most robust set up against biodegradation were layouts composed of coir nets. Coconut fibers are proven to be very durable as well as the yarn thickness of the mesh resulted in the improvement of tensile strength properties compared to the individual fibers. It was discovered though that the retarded degradation of the material and the textile design offered no positive effect on maintenance of the integrity nor growth of *Zostera marina* shoots as performance of shoots planted without carrier substrate (controls) was similar. It was also demonstrated that fertilized shoots, planted without carrier substrate, maintained better integrity than shoots in coir meshes but worse than in sisal, emphasizing the importance of right material and design selection. Despite the highest degradation rate, sisal layouts possessed the highest initial and final tensile strength, resulting in less risk of failure during transport and out-planting of seagrasses into the marine environment. Additionally, a more rapid degradation might lead to nourishment of the shoots supporting growth. Moreover, shoots incorporated into sisal meshes were proven to thrive in some replicates and overall were in better state than shoots from other treatments.

Nevertheless, trials were conducted in controlled conditions for a short period of time and were not subjected to hydrodynamic forces. It is possible that the rapid biodegradation of the sisal mesh might be too pronounced over the long run, not giving shoots adequate time to root into the sediment floor. Further research in the translation of these findings into the open environment must be pursued.

Altogether, the null hypothesis was rejected as this work clearly depicted that a textile carrier substrate can have positive influence on *Zostera marina* shoot integrity and that the material and design of the substrate are vital factors to achieve successful restoration.

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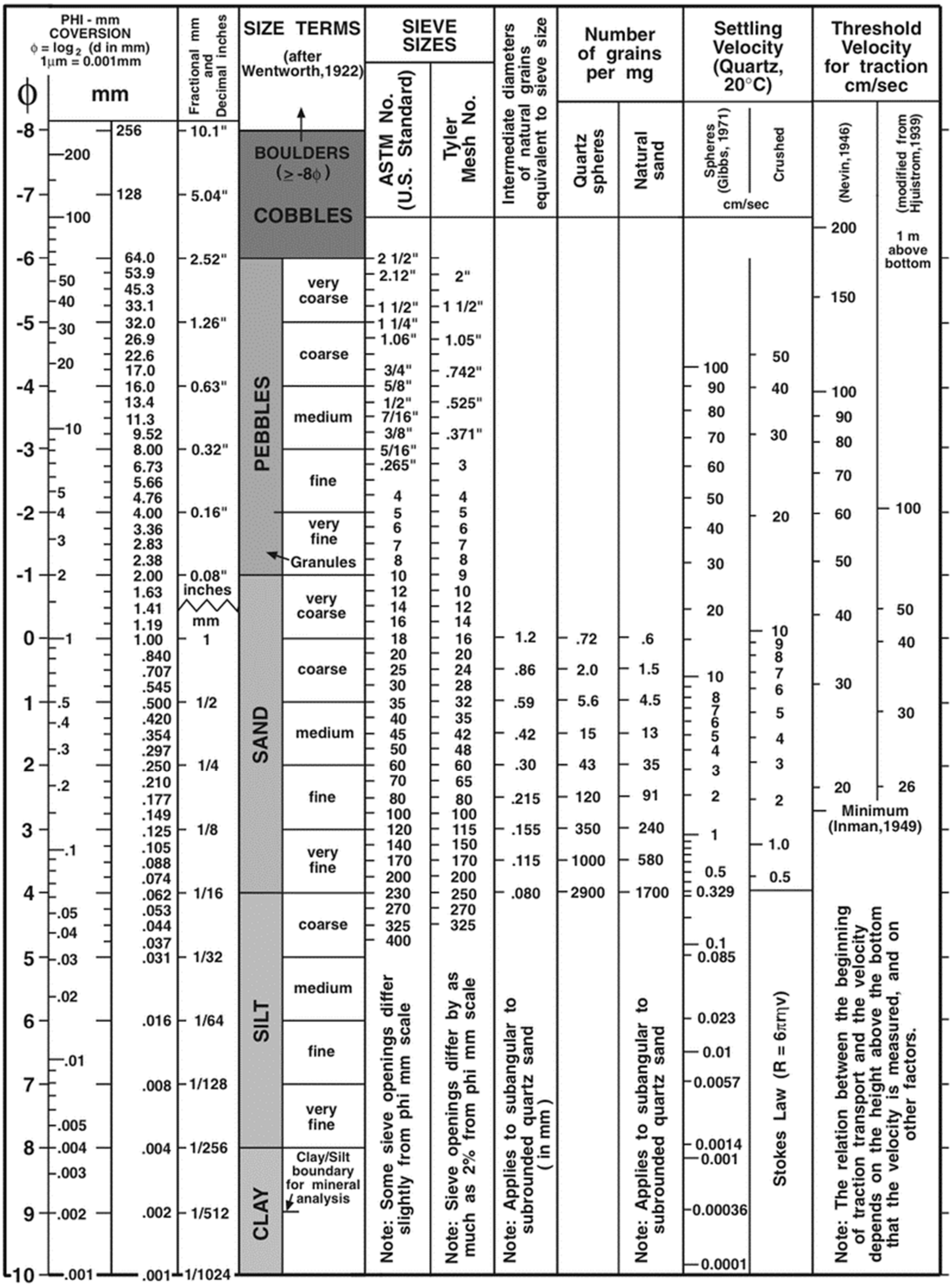
APPENDICES

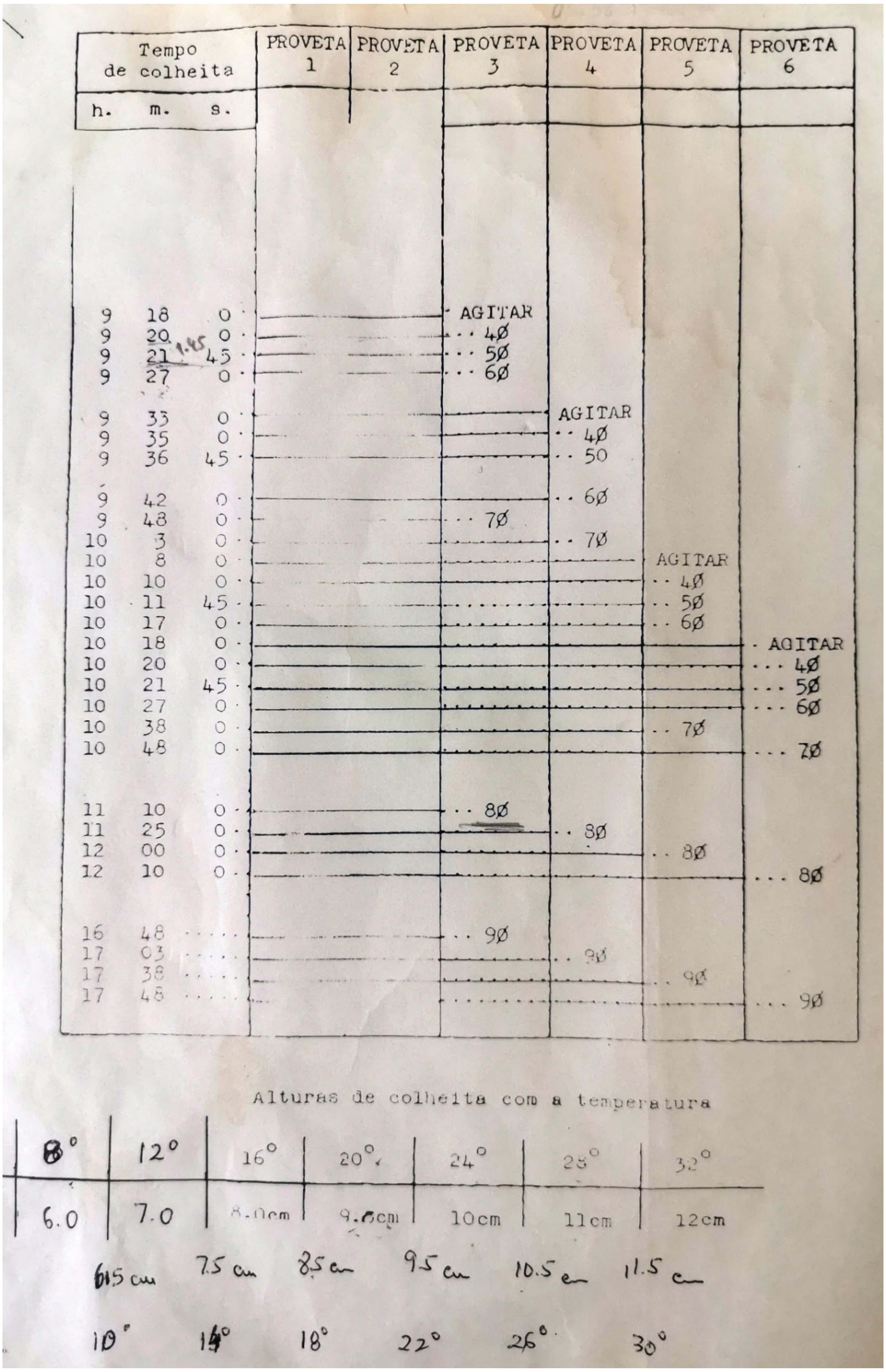
Appendix 1

Wentworth phi scale of sediment classification according to grain size



Appendix 2

Grain size analysis wet separation sampling intervals



Tempo de colheita h.	m.	s.	PROVETA 1	PROVETA 2	PROVETA 3	PROVETA 4	PROVETA 5	PROVETA 6
9	18	0			AGITAR			
9	20	0			40			
9	21 1.45	45			50			
9	27	0			60			
9	33	0				AGITAR		
9	35	0				40		
9	36	45				50		
9	42	0				60		
9	48	0			70			
10	3	0				70		
10	8	0					AGITAR	
10	10	0					40	
10	11	45					50	
10	17	0					60	
10	18	0						AGITAR
10	20	0						40
10	21	45						50
10	27	0						60
10	38	0					70	
10	48	0						70
11	10	0			80			
11	25	0				80		
12	00	0					80	
12	10	0						80
16	48				90			
17	03					90		
17	38						90	
17	48							90

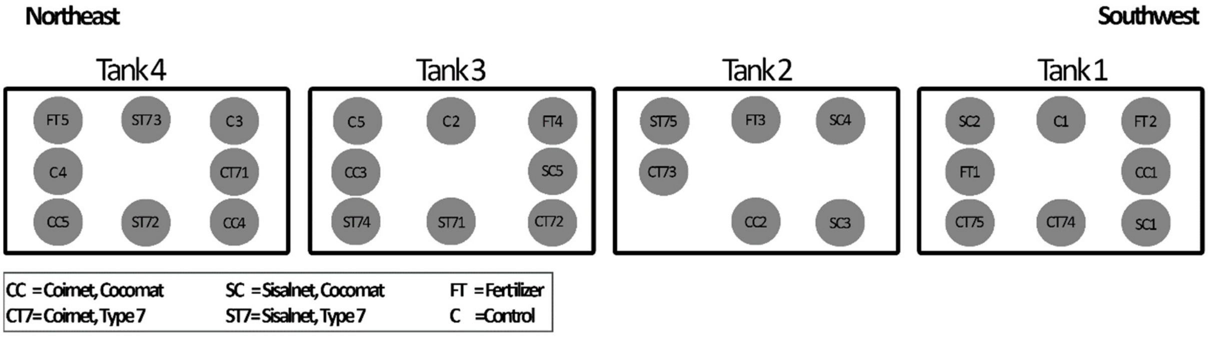
Alturas de colheita com a temperatura

8°	12°	16°	20°	24°	28°	32°
6.0	7.0	8.0cm	9.0cm	10cm	11cm	12cm

6.5 cm	7.5 cm	8.5 cm	9.5 cm	10.5 cm	11.5 cm
10°	14°	18°	22°	26°	30°

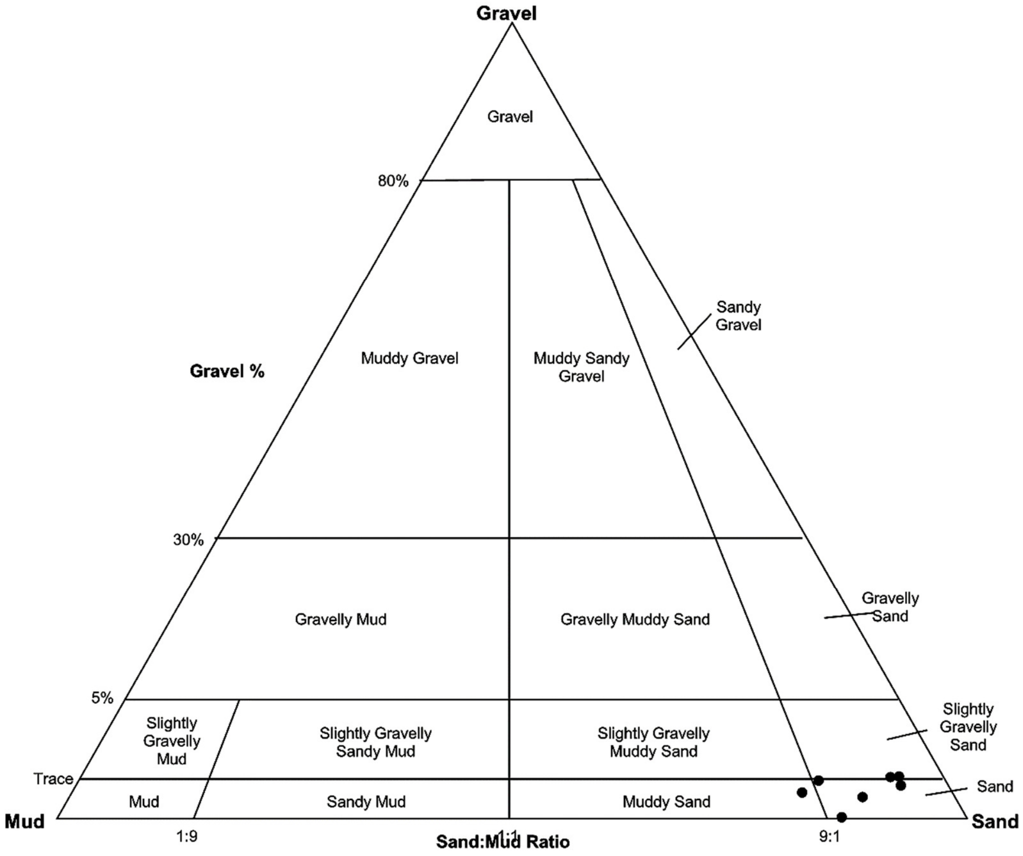
Appendix 3

Plan mesocosm experiment: Position of replicates in the tanks



Appendix 4

Folk and Ward triangle. Results of grain size analysis from burial site



Appendix 5

Sharpio-Wilk normality test results

***** =significant

Identification	Parameter	w-value	p-value	Significance
CC	Weight loss	0.974	0.550	-
CC	Tensile strength loss	0.969	0.404	-
CC	OCR	0.753	0.000	*
CT7	Weight loss	0.972	0.508	-
CT7	Tensile strength loss	0.938	0.046	*
CT7	OCR	0.675	0.000	*
JC	Weight loss	0.727	0.000	*
JC	Tensile strength loss	0.955	0.163	-
JC	OCR	0.694	0.000	*
JT7	Weight loss	0.800	0.000	*
JT7	Tensile strength loss	0.962	0.267	-
JT7	OCR	0.745	0.000	*
SC	Weight loss	0.831	0.000	*
SC	Tensile strength loss	0.967	0.358	-
SC	OCR	0.733	0.000	*
ST7	Weight loss	0.815	0.000	*
ST7	Tensile strength loss	0.972	0.486	-
ST7	OCR	0.648	0.000	*

Identification	Parameter	w-value	p-value	Significance
CC	Survival rate	0.730	0.000	*
CC	Leaf number	0.900	0.018	*
CC	New leaf number	0.502	0.000	*
CC	Wet weight loss	0.959	0.804	-
CC	Root segment elongation	0.986	0.963	-
CC	Effective quantum yield	0.749	0.000	*
CT7	Survival rate	0.727	0.000	*
CT7	Leaf number	0.909	0.029	*
CT7	New leaf number	0.637	0.000	*
CT7	Wet weight loss	0.888	0.347	-
CT7	Root segment elongation	0.960	0.805	-
CT7	Effective quantum yield	0.723	0.000	*
SC	Survival rate	0.547	0.000	*
SC	Leaf number	0.910	0.031	*
SC	New leaf number	0.725	0.000	*
SC	Wet weight loss	0.917	0.511	-
SC	Root segment elongation	0.828	0.136	-
SC	Effective quantum yield	0.736	0.000	*
ST7	Survival rate	0.659	0.000	*
ST7	Leaf number	0.908	0.028	*
ST7	New leaf number	0.702	0.000	*
ST7	Wet weight loss	0.800	0.081	-
ST7	Root segment elongation	0.928	0.586	-
ST7	Effective quantum yield	0.705	0.000	*

Control	Survival rate	0.649	0.000	*
Control	Leaf number	0.921	0.054	-
Control	New leaf number	0.574	0.000	*
Control	Wet weight loss	0.961	0.814	-
Control	Root segment elongation	0.915	0.497	-
Control	Effective quantum yield	0.750	0.000	*
Fertilizer	Survival rate	0.626	0.000	*
Fertilizer	Leaf number	0.915	0.040	*
Fertilizer	New leaf number	0.610	0.000	*
Fertilizer	Wet weight loss	0.881	0.315	-
Fertilizer	Root segment elongation	0.941	0.672	-
Fertilizer	Effective quantum yield	0.729	0.000	*

Appendix 6

Spearman Rank correlation Trend detection of the burial experiments with parameters: Weight loss, tensile strength loss, oxygen consumption rate

Parameter	Layout	ρ	P	Classification	Significance
Weight loss					
	CC	-0.463	5.077e-3	moderate	
	CT7	-0.552	5.797e-4	moderate	
	JC	-0.871	1.005e-11	very strong	
	JT7	-0.638	3.627e-5	strong	
	SC	-0.854	6.804e-11	very strong	
	ST7	-0.927	1.096e-15	very strong	
Tensile Strength					
	CC	-0.438	8.416e-3	moderate	
	CT7	-0.175	3.135e-1	very weak	
	JC	-0.555	5.256e-4	moderate	
	JT7	-0.663	1.400e-5	strong	
	SC	-0.916	1.087e-14	very strong	
	ST7	-0.850	1.027e-10	very strong	
OCR					
	CC	-0.535	9.147e-4	moderate	
	CT7	-0.430	9.914e-3	moderate	
	JC	-0.682	6.232e-6	strong	
	JT7	-0.831	6.435e-10	very strong	
	SC	-0.758	1.308e-7	strong	
	ST7	-0.316	6.413e-2	weak	

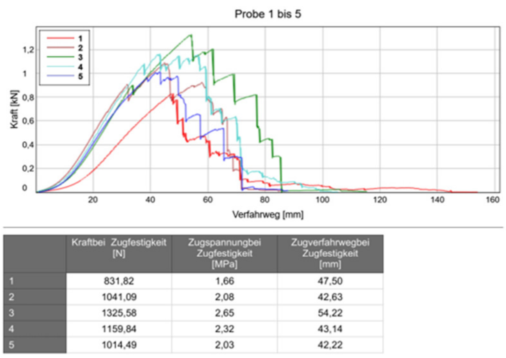
Appendix 7

Profile tensile strength test INSTRON

Table 9. Legend - Translation of graph labels

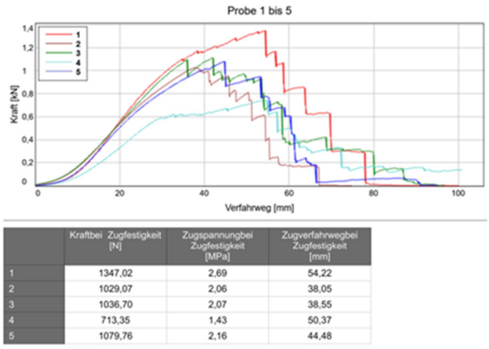
German	English
Kraft	Force
Verfahrensweg	Procedural path
Kraft bei Zugfestigkeit	Tensile strength
Zugspannung bei Zugfestigkeit	Tension at force at break
Zugverfahrensweg bei Zugfestikeit	Proceduaral path at force at break

CC Control



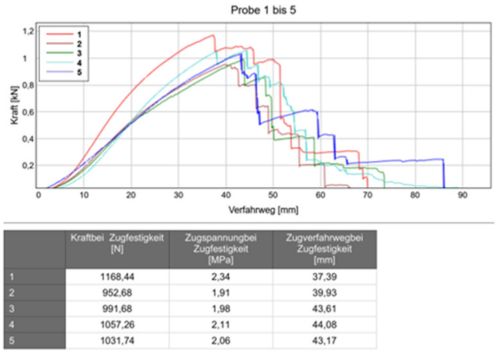
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	831,82	1,66	47,50
2	1041,09	2,08	42,63
3	1325,58	2,65	54,22
4	1159,84	2,32	43,14
5	1014,49	2,03	42,22

CC 1



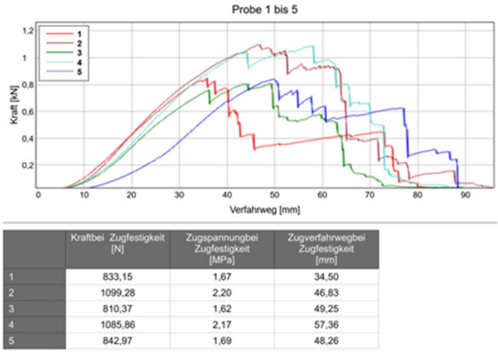
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	1347,02	2,69	54,22
2	1029,07	2,06	38,05
3	1036,70	2,07	38,55
4	713,35	1,43	50,37
5	1079,76	2,16	44,48

CC 2



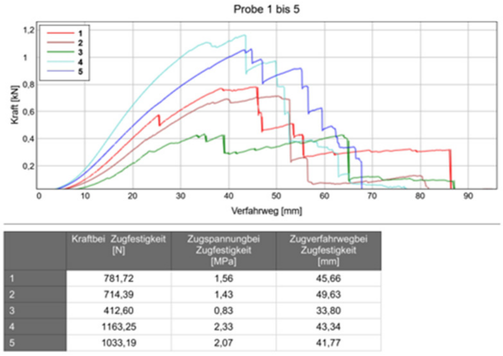
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	1168,44	2,34	37,39
2	952,68	1,91	39,93
3	991,68	1,98	43,61
4	1057,26	2,11	44,08
5	1031,74	2,06	43,17

CC 3



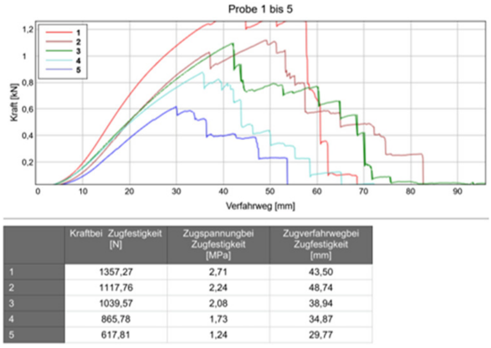
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	833,15	1,67	34,50
2	1099,28	2,20	46,83
3	810,37	1,62	49,25
4	1085,86	2,17	57,36
5	842,97	1,69	48,26

CC 4



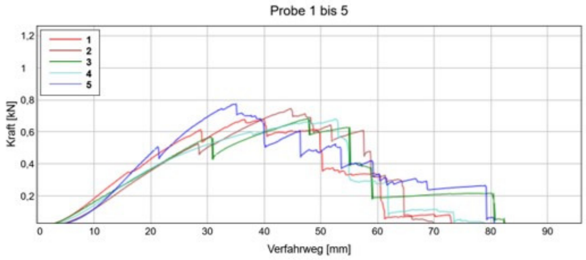
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	781,72	1,56	45,66
2	714,39	1,43	49,63
3	412,60	0,83	33,80
4	1163,25	2,33	43,34
5	1033,19	2,07	41,77

CC 5



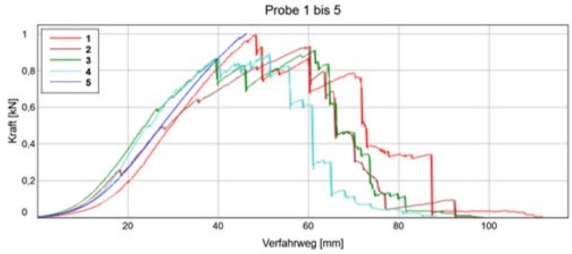
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	1357,27	2,71	43,50
2	1117,76	2,24	48,74
3	1039,57	2,08	38,94
4	865,78	1,73	34,87
5	617,81	1,24	29,77

CC 6



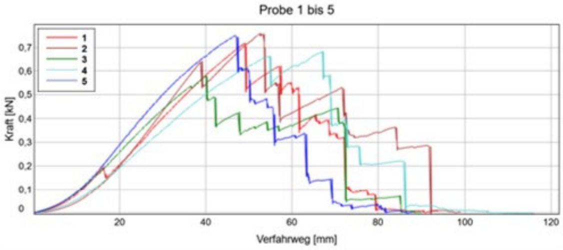
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	656,51	1,31	36,89
2	726,12	1,45	42,96
3	683,17	1,37	47,67
4	657,99	1,32	48,00
5	772,73	1,55	34,47

CT7 Control



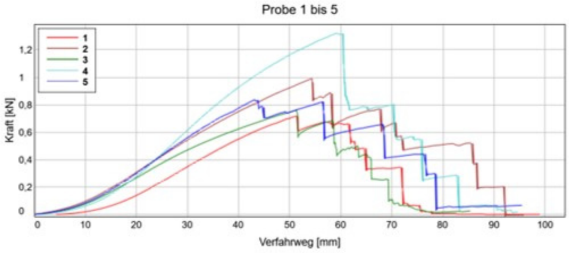
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	958,42	1,92	46,10
2	900,87	1,80	56,37
3	910,09	1,82	61,35
4	859,44	1,72	48,52
5 🚫	1000,00	2,00	46,14

CT7 1



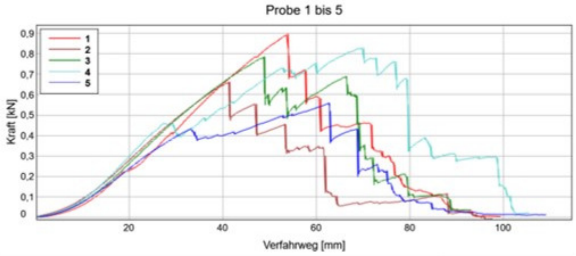
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	674,56	1,35	45,87
2	715,58	1,43	49,43
3	534,82	1,07	37,14
4	681,62	1,36	66,58
5	715,12	1,43	43,70

CT7 2



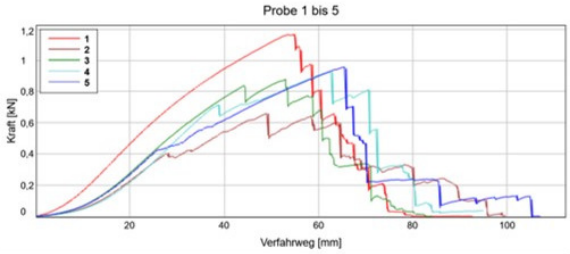
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	719,88	1,44	47,08
2	992,80	1,99	54,32
3	760,54	1,52	51,16
4	1320,05	2,64	58,68
5	822,88	1,65	42,34

CT7 3



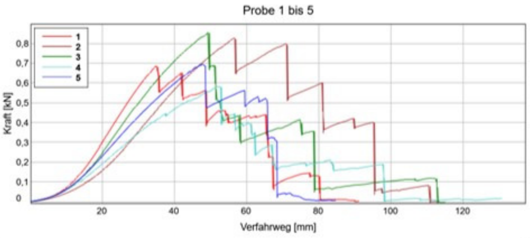
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	896,66	1,79	53,07
2	628,89	1,26	38,50
3	784,62	1,57	48,76
4	829,15	1,66	69,72
5	558,40	1,12	62,42

CT7 4



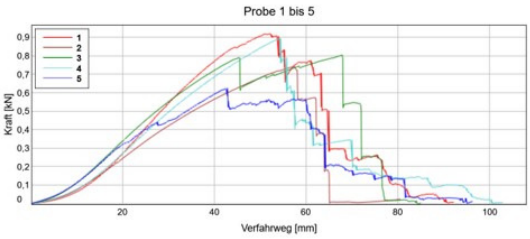
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	1168,61	2,34	54,73
2	662,31	1,32	48,97
3	876,67	1,75	52,70
4	927,02	1,85	62,37
5	958,39	1,92	65,30

CT7 5



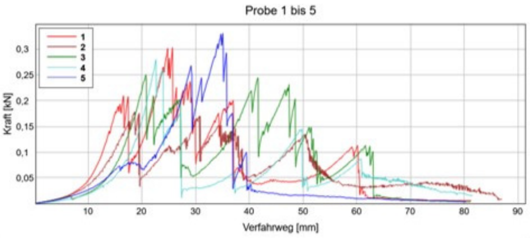
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	686,64	1,37	34,98
2	829,49	1,66	56,59
3	855,68	1,71	49,41
4	555,74	1,11	48,70
5	658,86	1,32	44,34

CT7 6



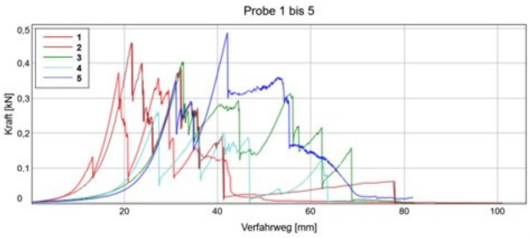
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	921,09	1,84	52,09
2	742,79	1,49	57,27
3	803,39	1,61	67,72
4	893,09	1,79	54,05
5	624,05	1,25	42,67

JC Control



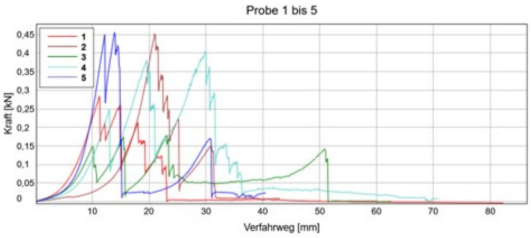
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	258,61	0,52	24,95
2	157,18	0,31	17,37
3	185,80	0,37	21,54
4	272,87	0,55	22,07
5	236,65	0,47	31,91

JC 1



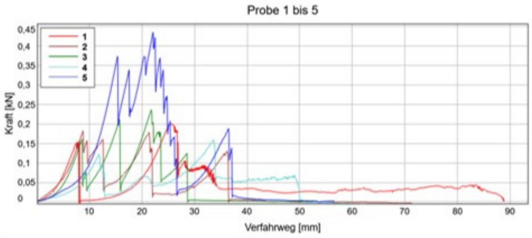
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	325,77	0,65	26,70
2	299,97	0,60	21,74
3	394,55	0,79	31,87
4	230,95	0,46	25,37
5	317,08	0,63	41,84

JC 2



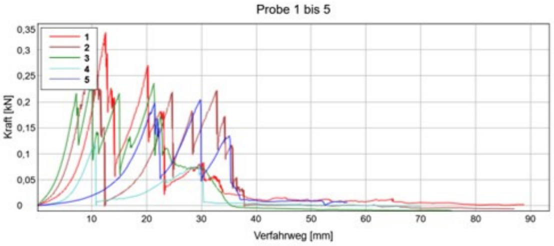
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	181,72	0,36	12,58
2	435,09	0,87	20,60
3	145,69	0,29	21,81
4	350,21	0,70	28,20
5	449,37	0,90	12,07

JC 3



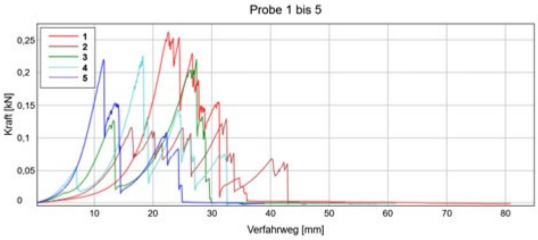
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	198,95	0,40	25,21
2	122,43	0,24	19,10
3	194,42	0,39	20,65
4	124,74	0,25	31,73
5	365,22	0,73	20,16

JC 4



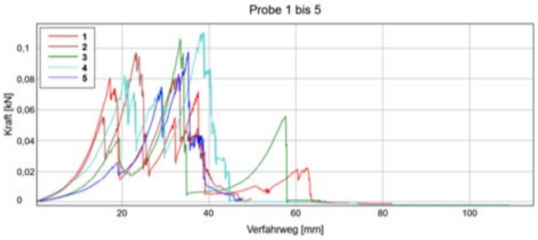
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	277,22	0,55	12,67
2	268,80	0,54	9,34
3	161,91	0,32	19,12
4	87,77	0,18	9,10
5	168,81	0,34	28,03

JC 5



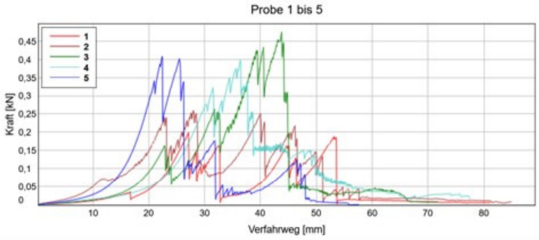
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	226,74	0,45	23,50
2	58,40	0,12	27,30
3	174,54	0,35	24,83
4	196,71	0,39	17,24
5	201,67	0,40	10,94

JC 6



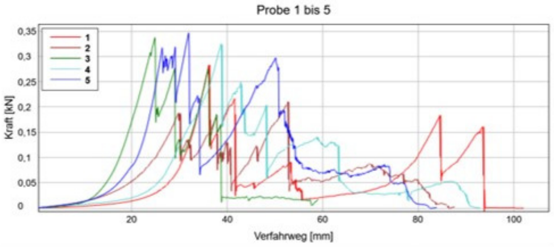
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	68,78	0,14	15,84
2	89,31	0,18	22,20
3	77,29	0,15	30,40
4	98,97	0,20	37,00
5	70,64	0,14	31,17

JT7 Control



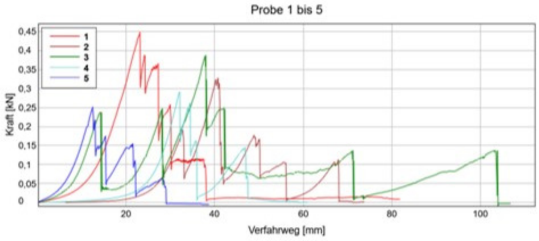
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	100,56	0,20	48,67
2	173,55	0,35	24,91
3	419,05	0,84	39,90
4	346,01	0,69	34,08
5	227,30	0,45	22,28

JT7 1



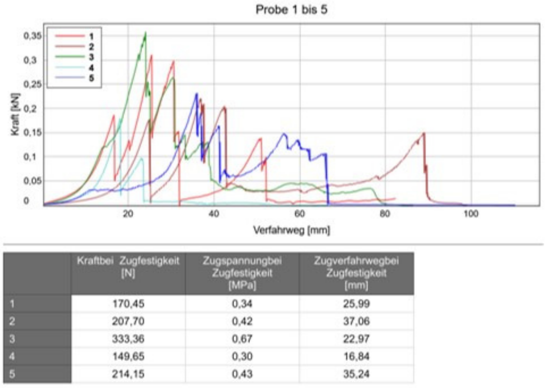
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	283,10	0,57	35,04
2	165,48	0,33	49,43
3	320,26	0,64	23,70
4	303,80	0,61	37,77
5	281,84	0,56	28,24

JT7 2



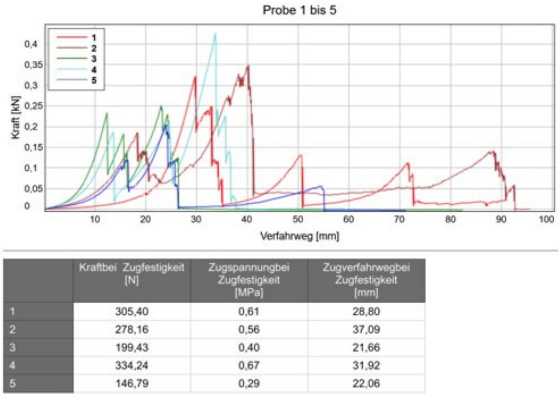
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	442,81	0,89	22,87
2	253,87	0,51	32,57
3	336,24	0,67	36,76
4	276,50	0,55	30,57
5	243,93	0,49	12,17

JT7 3



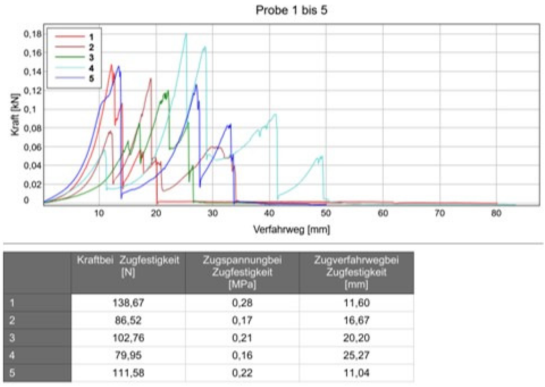
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	170,45	0,34	25,99
2	207,70	0,42	37,06
3	333,36	0,67	22,97
4	149,65	0,30	16,84
5	214,15	0,43	35,24

JT7 4



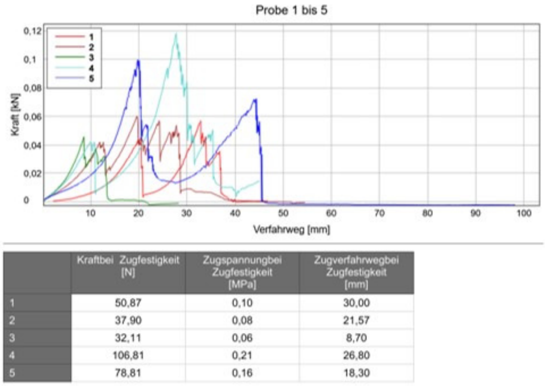
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	305,40	0,61	28,80
2	278,16	0,56	37,09
3	199,43	0,40	21,66
4	334,24	0,67	31,92
5	146,79	0,29	22,06

JT7 5



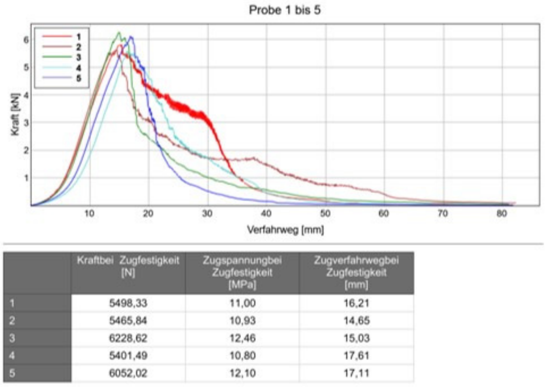
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	138,67	0,28	11,60
2	86,52	0,17	16,67
3	102,76	0,21	20,20
4	79,95	0,16	25,27
5	111,58	0,22	11,04

JT7 6



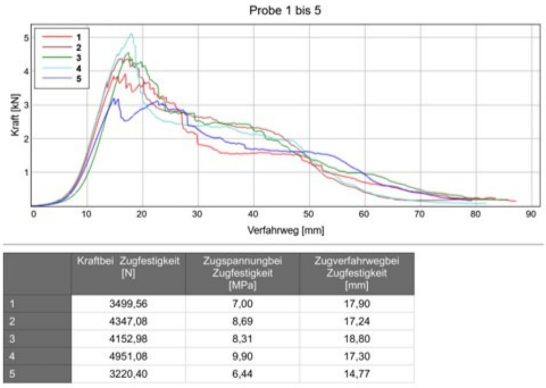
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	50,87	0,10	30,00
2	37,90	0,08	21,57
3	32,11	0,06	8,70
4	106,81	0,21	26,80
5	78,81	0,16	18,30

SC Control



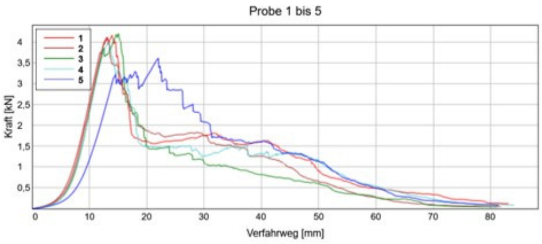
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	5498,33	11,00	16,21
2	5465,84	10,93	14,65
3	6228,62	12,46	15,03
4	5401,49	10,80	17,61
5	6052,02	12,10	17,11

SC 1



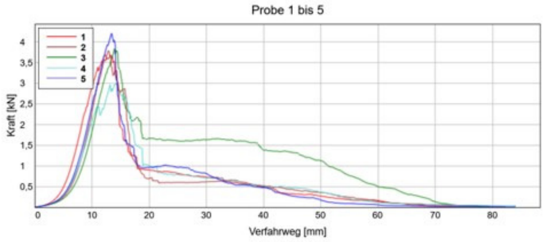
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	3499,56	7,00	17,90
2	4347,08	8,69	17,24
3	4152,98	8,31	18,80
4	4951,08	9,90	17,30
5	3220,40	6,44	14,77

SC 2



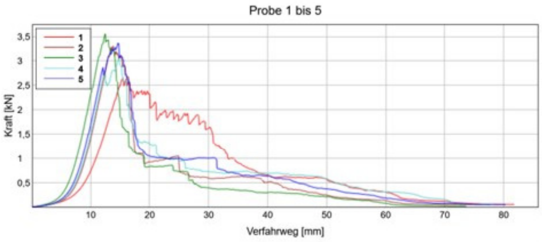
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	4141,87	8,28	13,83
2	3727,05	7,45	13,50
3	4069,74	8,14	14,30
4	3667,32	7,33	13,93
5	3162,65	6,33	19,93

SC 3



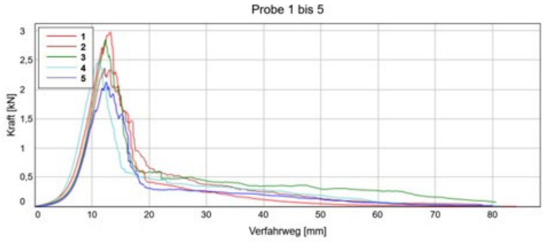
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	3567,61	7,14	12,50
2	3675,97	7,35	13,19
3	3778,96	7,56	14,41
4	2936,89	5,87	13,80
5	4134,95	8,27	13,27

SC 4



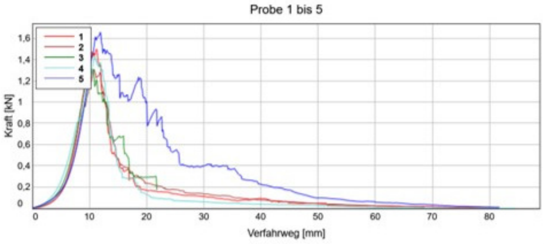
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	2308,48	4,62	17,54
2	3205,26	6,41	14,20
3	3431,01	6,86	12,83
4	2910,22	5,82	14,29
5	3221,96	6,44	14,20

SC 5



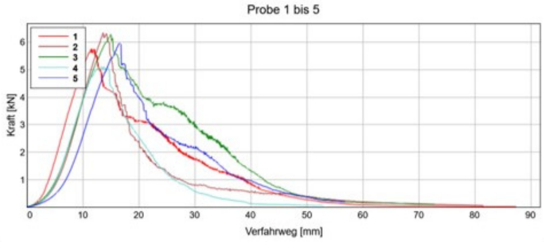
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	2898,56	5,80	12,82
2	2292,38	4,58	13,14
3	2640,77	5,28	12,65
4	2480,97	4,96	11,20
5	1995,83	3,99	12,65

SC 6



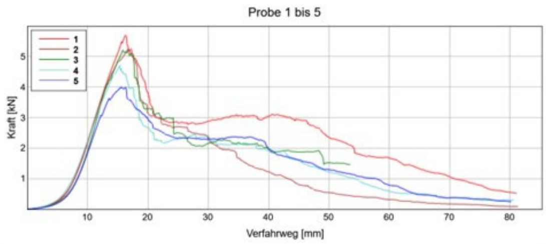
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	1439,06	2,88	10,80
2	1225,93	2,45	11,24
3	1162,05	2,32	10,99
4	1421,91	2,84	10,90
5	1468,46	2,94	13,22

ST7 Control



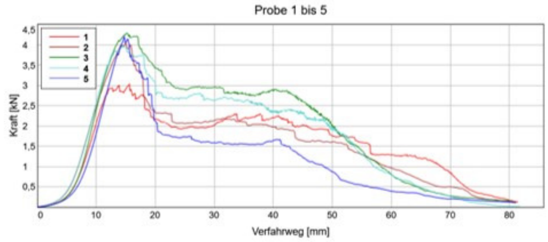
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	5658,28	11,32	12,08
2	6304,92	12,61	14,11
3	6118,77	12,24	15,19
4	5052,08	10,10	13,50
5	5977,89	11,96	16,67

ST7 1



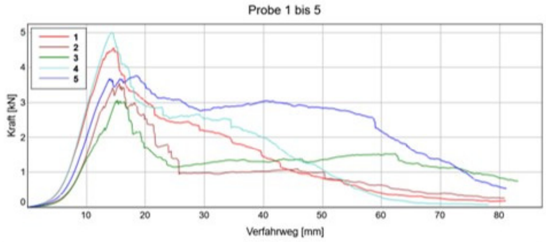
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	5386,19	10,77	16,44
2	5171,68	10,34	16,44
3	5158,44	10,32	16,58
4	4470,66	8,94	15,56
5	3950,24	7,90	16,03

ST7 2



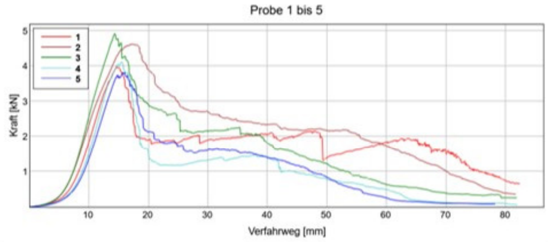
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	2937,20	5,87	15,02
2	4029,19	8,06	14,90
3	4194,70	8,39	15,58
4	3819,08	7,64	15,38
5	3951,04	7,90	15,59

ST7 3



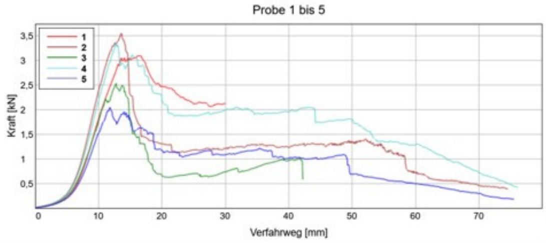
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	4466,21	8,93	14,81
2	3334,06	6,67	15,40
3	3030,42	6,06	15,73
4	4834,63	9,67	14,68
5	3766,23	7,53	18,21

ST7 4



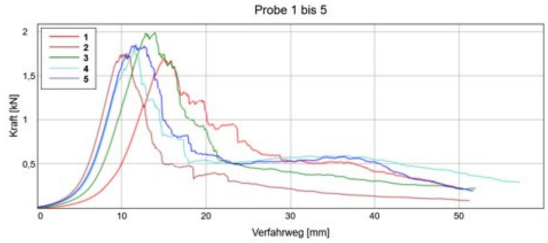
	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	3967,07	7,93	15,00
2	4621,25	9,24	16,95
3	4616,28	9,23	15,15
4	4076,82	8,15	15,25
5	3811,59	7,62	15,64

ST7 5



	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	3073,63	6,15	16,04
2	3454,44	6,91	13,27
3	2438,88	4,88	13,00
4	2961,65	5,92	14,69
5	1950,93	3,90	13,99

ST7 6



	Kraftbei Zugfestigkeit [N]	Zugspannungbei Zugfestigkeit [MPa]	Zugverfahrwegbei Zugfestigkeit [mm]
1	1595,00	3,19	15,84
2	1742,68	3,49	10,50
3	1988,00	3,98	13,94
4	1734,81	3,47	11,71
5	1788,16	3,58	12,07

Appendix 8

PERMANOVA Results

Relative weight loss of textile substrates

```
PERMANOVA

Permutational MANOVA

Resemblance worksheet
Name: Resem3
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name            Abbrev.   Type    Levels
Layout          La        Fixed        6
Time Interval   Ti        Fixed        7

PERMANOVA table of results
                                                                Unique
Source    df       SS          MS      Pseudo-F    P(perm)     perms     P(MC)
La         5   56,788      11,358        124,12      0,001       999     0,001
Ti         6   95,055      15,843        173,13      0,001       999     0,001
LaxTi     30   41,784      1,3928        15,221      0,001       997     0,001
Res      168   15,373   9,1505E-2
Total    209      209

Details of the expected mean squares (EMS) for the model
Source    EMS
La        1*V(Res) + 35*S(La)
Ti        1*V(Res) + 30*S(Ti)
LaxTi     1*V(Res) + 5*S(LaxTi)
Res       1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source    Numerator    Denominator    Num.df    Den.df
La        1*La         1*Res               5       168
Ti        1*Ti         1*Res               6       168
LaxTi     1*LaxTi      1*Res              30       168

Estimates of components of variation
Source         Estimate       Sq.root
S(La)           0,32189       0,56735
S(Ti)           0,52504       0,72459
S(LaxTi)        0,26026       0,51015
V(Res)        9,1505E-2        0,3025
```

Tensile strength loss of textile substrates

PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem4
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors

Name	Abbrev.	Type	Levels
Layout	La	Fixed	6
Time Interval	Ti	Fixed	7

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms	P(MC)
La	5	163,76	32,753	1066,8	0,001	999	0,001
Ti	6	15,62	2,6033	84,793	0,001	998	0,001
LaxTi	30	24,459	0,8153	26,555	0,001	997	0,001
Res	168	5,1579	3,0702E-2				
Total	209	209					

Details of the expected mean squares (EMS) for the model

Source	EMS
La	1*V(Res) + 35*S(La)
Ti	1*V(Res) + 30*S(Ti)
LaxTi	1*V(Res) + 5*S(LaxTi)
Res	1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares

Source	Numerator	Denominator	Num.df	Den.df
La	1*La	1*Res	5	168
Ti	1*Ti	1*Res	6	168
LaxTi	1*LaxTi	1*Res	30	168

Estimates of components of variation

Source	Estimate	Sq.root
S(La)	0,93491	0,96691
S(Ti)	8,5754E-2	0,29284
S(LaxTi)	0,15692	0,39613
V(Res)	3,0702E-2	0,17522

Oxygen consumption rate of textile substrates

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem2
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name            Abbrev.   Type    Levels
Layout          La        Fixed       6
Time Interval   Ti        Fixed       7

PERMANOVA table of results
                                                      Unique
Source    df      SS        MS     Pseudo-F   P(perm)   perms    P(MC)
La         5    22,43     4,4861     7,1001     0,001     999    0,001
Ti         6    43,12     7,1866     11,374     0,001     999    0,001
LaxTi     30   37,302     1,2434     1,9679     0,007     999    0,002
Res      168   106,15    0,63183
Total    209      209

Details of the expected mean squares (EMS) for the model
Source    EMS
La        1*V(Res) + 35*S(La)
Ti        1*V(Res) + 30*S(Ti)
LaxTi     1*V(Res) + 5*S(LaxTi)
Res       1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source    Numerator    Denominator    Num.df    Den.df
La        1*La         1*Res               5       168
Ti        1*Ti         1*Res               6       168
LaxTi     1*LaxTi      1*Res              30       168

Estimates of components of variation
Source       Estimate    Sq.root
S(La)         0,11012    0,33184
S(Ti)         0,21849    0,46743
S(LaxTi)      0,12231    0,34973
V(Res)        0,63183    0,79488
```

PERMANOVA post-hoc results

Relative weight loss of textile substrates in factor 'Layout'

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem3
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                 Abbrev.        Type        Levels
Layout               La             Fixed            6
Time Interval        Ti             Fixed            7

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Layout'

Within level '0' of factor 'Time Interval'

                  Unique
Groups                 t                       P(perm)
                   perms                       P(MC)
CC, CT7           Denominator is 0

CC, JC            Denominator is 0

CC, JT7           Denominator is 0

CC, SC            Denominator is 0

CC, ST7           Denominator is 0

CT7, JC           Denominator is 0

CT7, JT7          Denominator is 0

CT7, SC           Denominator is 0

CT7, ST7          Denominator is 0

JC, JT7           Denominator is 0

JC, SC            Denominator is 0

JC, ST7           Denominator is 0

JT7, SC           Denominator is 0

JT7, ST7          Denominator is 0

SC, ST7           Denominator is 0


Denominators
Groups            Denominator          Den.df
CC, CT7           1*Res                     0
CC, JC            1*Res                     0
CC, JT7           1*Res                     0
CC, SC            1*Res                     0
CC, ST7           1*Res                     0
CT7, JC           1*Res                     0
CT7, JT7          1*Res                     0
CT7, SC           1*Res                     0
CT7, ST7          1*Res                     0
JC, JT7           1*Res                     0
JC, SC            1*Res                     0
JC, ST7           1*Res                     0
JT7, SC           1*Res                     0
JT7, ST7          1*Res                     0
SC, ST7           1*Res                     0

Average Distance between/within groups
         CC     CT7      JC     JT7      SC     ST7
CC        0
CT7       0       0
JC        0       0       0
JT7       0       0       0       0
SC        0       0       0       0       0
ST7       0       0       0       0       0       0

Within level '1' of factor 'Time Interval'
                                                      Unique

Groups                 t              P(perm)          perms
                  P(MC)
CC, CT7           1,1093E-2             0,992            125
                  0,993
CC, JC              2,0579              0,098            126
                  0,084
CC, JT7             1,0594              0,307            126
                  0,309
CC, SC              7,3055              0,008            126
                  0,001
CC, ST7             10,034              0,011            126
                  0,001
CT7, JC            0,87997              0,435            126
                   0,41
CT7, JT7           0,50195              0,646            126
                  0,618
CT7, SC             5,3001              0,007            126
                  0,001
CT7, ST7            4,0018              0,027            126
                  0,003
```

```
Within level '3' of factor 'Time Interval'
                                                  Unique
Groups                 t          P(perm)          perms        P(MC)
CC, CT7           3,6246            0,028            126        0,009
CC, JC            7,4048            0,008            126        0,001
CC, JT7           1,6628            0,108            126        0,138
CC, SC            7,8567            0,005            126        0,001
CC, ST7           9,4296            0,008            126        0,001
CT7, JC           1,7002            0,076            126        0,131
CT7, JT7         0,11531            0,931            126        0,898
CT7, SC           5,5115            0,013            126        0,001
CT7, ST7          5,6768            0,009            126        0,001
JC, JT7          0,83884            0,507            126        0,397
JC, SC            5,1916            0,007            126        0,001
JC, ST7           5,7045            0,005            126        0,001
JT7, SC           3,9752            0,017            126        0,007
JT7, ST7          3,2973            0,038            126        0,014
SC, ST7           1,5707            0,154            125        0,156

Denominators
Groups            Denominator          Den.df
CC, CT7           1*Res                     8
CC, JC            1*Res                     8
CC, JT7           1*Res                     8
CC, SC            1*Res                     8
CC, ST7           1*Res                     8
CT7, JC           1*Res                     8
CT7, JT7          1*Res                     8
CT7, SC           1*Res                     8
CT7, ST7          1*Res                     8
JC, JT7           1*Res                     8
JC, SC            1*Res                     8
JC, ST7           1*Res                     8
JT7, SC           1*Res                     8
JT7, ST7          1*Res                     8
SC, ST7           1*Res                     8

Average Distance between/within groups
              CC             CT7              JC             JT7             SC
             ST7
CC        0,1556

CT7      0,34101         0,18123

JC       0,46164         0,14011       6,4999E-2

JT7      0,32726         0,31258          0,3648          0,4226

SC        1,2224         0,88929         0,76078         0,93012        0,40211

ST7      0,95984         0,62671          0,4982         0,68297        0,35188
         0,22119

Within level '4' of factor 'Time Interval'
                                                  Unique
Groups                 t          P(perm)          perms        P(MC)
CC, CT7           3,5111            0,009            126        0,009
CC, JC            3,2295            0,014            126        0,016
CC, JT7           1,5891            0,113            126        0,154
CC, SC             6,444            0,013            126        0,001
CC, ST7           8,4386             0,01            126        0,001
CT7, JC          0,25099            0,802            126        0,811
CT7, JT7         0,32844            0,808            126        0,766
CT7, SC           4,2352            0,008            126        0,004
CT7, ST7          3,9375            0,018            125        0,003
JC, JT7          0,43754            0,783            125        0,675
JC, SC            4,4015            0,007            126        0,006
JC, ST7           4,2125            0,015            126        0,002
JT7, SC           2,3136            0,063            126        0,049
JT7, ST7          1,3993            0,168            125        0,201
SC, ST7           1,7598            0,094            126        0,105

Denominators
Groups            Denominator          Den.df
CC, CT7           1*Res                     8
CC, JC            1*Res                     8
CC, JT7           1*Res                     8
CC, SC            1*Res                     8
CC, ST7           1*Res                     8
CT7, JC           1*Res                     8
CT7, JT7          1*Res                     8
CT7, SC           1*Res                     8
CT7, ST7          1*Res                     8
JC, JT7           1*Res                     8
JC, SC            1*Res                     8
JC, ST7           1*Res                     8
JT7, SC           1*Res                     8
JT7, ST7          1*Res                     8
SC, ST7           1*Res                     8

Average Distance between/within groups
              CC             CT7              JC             JT7             SC
ST7
CC       0,11415
CT7      0,33336         0,23586
JC       0,30759         0,19875         0,23502
JT7      0,51711         0,41969         0,41117         0,66835
SC        1,1564         0,82308         0,85318         0,85491        0,45916
ST7       0,8132         0,48189         0,51061         0,61762        0,40019
         0,24384

Within level '5' of factor 'Time Interval'
                                                  Unique
Groups                 t          P(perm)          perms        P(MC)
CC, CT7           2,8007            0,031            126        0,023
CC, JC            10,758             0,01            126        0,001
CC, JT7           5,4802            0,011            126        0,003
CC, SC            15,712             0,01            126        0,001
CC, ST7           14,855             0,01            125        0,001
CT7, JC           2,8037            0,038            126        0,019
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JC, JT7            0,62321          0,575          126
                   0,564
JC, SC              6,0735          0,007          126
                   0,001
JC, ST7             6,1607           0,01          126
                   0,001
JT7, SC             6,2497          0,012          126
                   0,001
JT7, ST7            6,1735          0,008          126
                   0,001
SC, ST7             3,0682          0,043          126
                   0,024

Denominators
Groups             Denominator          Den.df
CC, CT7            1*Res                   8
CC, JC             1*Res                   8
CC, JT7            1*Res                   8
CC, SC             1*Res                   8
CC, ST7            1*Res                   8
CT7, JC            1*Res                   8
CT7, JT7           1*Res                   8
CT7, SC            1*Res                   8
CT7, ST7           1*Res                   8
JC, JT7            1*Res                   8
JC, SC             1*Res                   8
JC, ST7            1*Res                   8
JT7, SC            1*Res                   8
JT7, ST7           1*Res                   8
SC, ST7            1*Res                   8

Average Distance between/within groups
             CC                 CT7                JC
JT7         SC                  ST7
CC      8,8383E-2

CT7       0,22644             0,35352

JC        0,15994             0,29337            0,15082

JT7       0,14805              0,2754            0,14415
        0,18231
SC         1,0451              1,0435            0,91151
        0,96598               0,36274
ST7       0,59222             0,59564            0,45859
        0,51306                 0,48             0,13307

Within level '2' of factor 'Time Interval'
                                                   Unique
Groups                 t           P(perm)          perms
                   P(MC)
CC, CT7             4,414           0,008            126
                   0,002
CC, JC             4,3291           0,005            126
                   0,003
CC, JT7            2,5381            0,05            126
                   0,034
CC, SC             8,7598            0,01            126
                   0,001
CC, ST7            9,8863            0,01            126
                   0,001
CT7, JC            1,5382           0,167            126
                   0,165
CT7, JT7           3,5248           0,005            126
                   0,006
CT7, SC            4,4674            0,01            126
                   0,003
CT7, ST7           3,5431            0,02            125
                   0,003
JC, JT7            3,0182           0,046            126
                   0,016
JC, SC             6,3482           0,008            126
                   0,001
JC, ST7            6,2007           0,006            126
                   0,002
JT7, SC            8,1596           0,012            126
                   0,001
JT7, ST7            9,196           0,009            126
                   0,001
SC, ST7            1,7192           0,114            126
                   0,135

Denominators
Groups             Denominator          Den.df
CC, CT7            1*Res                   8
CC, JC             1*Res                   8
CC, JT7            1*Res                   8
CC, SC             1*Res                   8
CC, ST7            1*Res                   8
CT7, JC            1*Res                   8
CT7, JT7           1*Res                   8
CT7, SC            1*Res                   8
CT7, ST7           1*Res                   8
JC, JT7            1*Res                   8
JC, SC             1*Res                   8
JC, ST7            1*Res                   8
JT7, SC            1*Res                   8
JT7, ST7           1*Res                   8
SC, ST7            1*Res                   8

Average Distance between/within groups
             CC                 CT7                JC
JT7         SC                  ST7
CC      9,2731E-2

CT7       0,42959             0,25451

JC         0,2682             0,21914            0,14232

JT7       0,10805             0,32934            0,17558
        4,6664E-2
SC         1,1107             0,68116            0,84255
1,0105  0,33039
ST7       0,85961             0,43018            0,59141
0,75937 0,30266               0,21913
```

```
CT7, JT7          2,1443        0,053          126          0,056
CT7, SC           9,3063        0,011          126          0,001
CT7, ST7          6,9714        0,007          126          0,002
JC, JT7          0,13556        0,891          126          0,907
JC, SC            10,393        0,007          126          0,002
JC, ST7           7,9917        0,013          126          0,001
JT7, SC           6,9037        0,008          126          0,001
JT7, ST7          4,2668        0,004          126          0,003
SC, ST7           4,0536        0,006          126          0,002

Denominators
Groups            Denominator           Den.df
CC, CT7           1*Res                    8
CC, JC            1*Res                    8
CC, JT7           1*Res                    8
CC, SC            1*Res                    8
CC, ST7           1*Res                    8
CT7, JC           1*Res                    8
CT7, JT7          1*Res                    8
CT7, SC           1*Res                    8
CT7, ST7          1*Res                    8
JC, JT7           1*Res                    8
JC, SC            1*Res                    8
JC, ST7           1*Res                    8
JT7, SC           1*Res                    8
JT7, ST7          1*Res                    8
SC, ST7           1*Res                    8

Average Distance between/within groups
            CC              CT7              JC              JT7              SC
ST7
CC       0,1875
CT7     0,45651          0,38266
JC      0,86802          0,43641          0,11432
JT7     0,88864          0,50702          0,24077          0,39543
SC       2,2041           1,7561           1,3361           1,3155          0,32961
ST7      1,6068           1,1587          0,73877          0,71815          0,59736
        0,22809

Within level '6' of factor 'Time Interval'
                                                          Unique
Groups                t           P(perm)                  perms        P(MC)
CC, CT7           0,99174           0,35                    126         0,371
CC, JC             7,1841          0,005                    126         0,001
CC, JT7            16,692          0,006                    126         0,001
CC, SC             7,8218          0,007                    126         0,001
CC, ST7            23,187          0,007                    126         0,001
CT7, JC            6,0443          0,007                    126         0,001
CT7, JT7           9,8277          0,008                    125         0,001
CT7, SC            7,2535          0,008                    125         0,001
CT7, ST7           14,496          0,013                    126         0,001
JC, JT7           0,59349          0,579                    126         0,547
JC, SC             3,1018          0,018                    126         0,017
JC, ST7            2,2996          0,073                    125         0,063
JT7, SC            3,8735          0,011                    126         0,006
JT7, ST7           5,5853          0,005                    126         0,003
SC, ST7            2,0806          0,086                    126         0,072

Denominators
Groups            Denominator           Den.df
CC, CT7           1*Res                    8
CC, JC            1*Res                    8
CC, JT7           1*Res                    8
CC, SC            1*Res                    8
CC, ST7           1*Res                    8
CT7, JC           1*Res                    8
CT7, JT7          1*Res                    8
CT7, SC           1*Res                    8
CT7, ST7          1*Res                    8
JC, JT7           1*Res                    8
JC, SC            1*Res                    8
JC, ST7           1*Res                    8
JT7, SC           1*Res                    8
JT7, ST7          1*Res                    8
SC, ST7           1*Res                    8

Average Distance between/within groups
            CC              CT7              JC              JT7              SC
ST7
CC      8,0381E-2
CT7      0,27349         0,42049
JC        2,2202          2,0685          0,86545
JT7       2,0248          1,8731          0,57005          0,31673
SC        4,1046          3,9529           1,9152           2,0799          1,4635
ST7       2,9839          2,8322          0,84469          0,95911          1,2221
        0,31735
```

Relative weight loss of textile substrates in factor ‘Time Interval’

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem3
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                       Abbrev.           Type          Levels
Layout                     La                Fixed              6
Time Interval              Ti                Fixed              7

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Time Interval'

Within level 'CC' of factor 'Layout'
                                                            Unique
Groups               t                   P(perm)             perms          P(MC)
0, 1            7,6656                     0,008                16          0,001
0, 2            7,6766                     0,006                16          0,001
0, 3            6,1098                     0,006                16          0,001
0, 4            1,6774                     0,195                16          0,138
0, 5         5,4405E-2                         1                16          0,962
0, 6            3,5521                      0,01                16          0,009
1, 2           0,18102                     0,911               126          0,855
1, 3            1,5044                      0,16               126           0,18
1, 4              3,44                     0,028               126          0,005
1, 5            3,2264                     0,017               126          0,016
1, 6            8,0609                     0,006               125          0,001
2, 3            1,3643                     0,211               126           0,22
2, 4            3,5565                      0,02               126           0,01
2, 5            3,3177                     0,005               126          0,011
2, 6            8,1083                     0,012               126          0,001
3, 4            3,9719                     0,008               126          0,005
3, 5            3,8537                     0,009               126          0,007
3, 6            7,0593                     0,014               126          0,001
4, 5           0,81371                     0,466               126          0,435
4, 6            3,4361                     0,004               126          0,012
5, 6            1,4528                     0,213               126          0,196

Denominators
Groups          Denominator             Den.df
0, 1            1*Res                        8
0, 2            1*Res                        8
0, 3            1*Res                        8
0, 4            1*Res                        8
0, 5            1*Res                        8
0, 6            1*Res                        8
1, 2            1*Res                        8
1, 3            1*Res                        8
1, 4            1*Res                        8
1, 5            1*Res                        8
1, 6            1*Res                        8
2, 3            1*Res                        8
2, 4            1*Res                        8
2, 5            1*Res                        8
2, 6            1*Res                        8
3, 4            1*Res                        8
3, 5            1*Res                        8
3, 6            1*Res                        8
4, 5            1*Res                        8
4, 6            1*Res                        8
5, 6            1*Res                        8

Average Distance between/within groups
           0                     1                      2                    3
          4                     5                      6
0          0

1       0,25185             8,8383E-2

2        0,2604             7,6598E-2              9,2731E-2

3       0,35153               0,13287                0,12932
0,1556
4     8,5601E-2               0,18412                0,19269
      0,28185               0,11415
5       0,10491               0,24807                0,25662
      0,34774               0,13651               0,1875

Denominators
Groups          Denominator             Den.df
0, 1            1*Res                        8
0, 2            1*Res                        8
0, 3            1*Res                        8
0, 4            1*Res                        8
0, 5            1*Res                        8
0, 6            1*Res                        8
1, 2            1*Res                        8
1, 3            1*Res                        8
1, 4            1*Res                        8
1, 5            1*Res                        8
1, 6            1*Res                        8
2, 3            1*Res                        8
2, 4            1*Res                        8
2, 5            1*Res                        8
2, 6            1*Res                        8
3, 4            1*Res                        8
3, 5            1*Res                        8
3, 6            1*Res                        8
4, 5            1*Res                        8
4, 6            1*Res                        8
5, 6            1*Res                        8

Average Distance between/within groups
         0                       1                     2                     3                     4
        5                       6
0        0

1      0,13241                 0,15082

2    9,1613E-2                 0,16245               0,14232

3      0,11011                 0,22834               0,11897             6,4999E-2

4      0,23931                 0,35579                0,2491               0,17461               0,23502

5      0,86424                 0,98246               0,85644               0,75413               0,63065
     0,11432
6       2,3263                  2,4446                2,3185                2,2162                2,0927
      1,4621                 0,86545

Within level 'JT7' of factor 'Layout'
                                                            Unique
Groups               t              P(perm)              perms          P(MC)
0, 1            2,5736                0,008                 16          0,032
0, 2            7,9168                0,007                 16          0,001
0, 3            0,2277                0,964                 16          0,816
0, 4            1,3446                0,291                 16          0,235
0, 5            6,0401                0,007                 16          0,001
0, 6            18,126                0,005                 16          0,001
1, 2           0,17893                0,898                126          0,854
1, 3           0,69496                0,672                126          0,477
1, 4            1,9374                0,046                126          0,084
1, 5            6,5632                0,012                126          0,001
1, 6            17,018                0,011                126          0,001
2, 3           0,66796                0,823                126          0,532
2, 4            1,9459                0,048                125          0,096
2, 5            7,0663                0,009                126          0,001
2, 6            19,206                0,014                117          0,001
3, 4             1,242                0,269                126          0,255
3, 5            4,0146                0,023                126          0,009
3, 6            10,181                0,008                126          0,001
4, 5            1,7564                0,122                126          0,118
4, 6            6,1488                0,009                126          0,001
5, 6            6,6337                0,006                126          0,001

Denominators
Groups          Denominator             Den.df
0, 1            1*Res                        8
0, 2            1*Res                        8
0, 3            1*Res                        8
0, 4            1*Res                        8
0, 5            1*Res                        8
0, 6            1*Res                        8
1, 2            1*Res                        8
1, 3            1*Res                        8
1, 4            1*Res                        8
1, 5            1*Res                        8
1, 6            1*Res                        8
2, 3            1*Res                        8
2, 4            1*Res                        8
2, 5            1*Res                        8
2, 6            1*Res                        8
3, 4            1*Res                        8
3, 5            1*Res                        8
3, 6            1*Res                        8
4, 5            1*Res                        8
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6       0,10614                 0,358                   0,36655
        0,45767                 0,17582                 0,16217
        8,0381E-2

Within level 'CT7' of factor 'Layout'
                                                        Unique
Groups          t               P(perm)                 perms           P(MC)
0, 1            1,7978          0,124                   16              0,113
0, 2            1,8547          0,135                   16              0,086
0, 3            0,25672         0,963                   16              0,807
0, 4            3,0885          0,01                    16              0,017
0, 5            3,0834          0,013                   16              0,018
0, 6            1,7188          0,126                   16              0,117
1, 2            2,5203          0,039                   126             0,035
1, 3            1,4809          0,17                    126             0,196
1, 4            3,1472          0,03                    126             0,015
1, 5            3,4666          0,033                   126             0,012
1, 6            2,4828          0,05                    126             0,038
2, 3            1,617           0,175                   126             0,154
2, 4            0,75638         0,46                    126             0,479
2, 5            1,6131          0,183                   126             0,154
2, 6            0,50497         0,625                   126             0,63
3, 4            2,5305          0,039                   126             0,036
3, 5            2,875           0,013                   126             0,036
3, 6            1,6615          0,172                   126             0,131
4, 5            1,0782          0,315                   126             0,329
4, 6            3,3873E-2       0,971                   126             0,973
5, 6            0,89625         0,405                   126             0,393

Denominators
Groups          Denominator             Den.df
0, 1            1*Res                   8
0, 2            1*Res                   8
0, 3            1*Res                   8
0, 4            1*Res                   8
0, 5            1*Res                   8
0, 6            1*Res                   8
1, 2            1*Res                   8
1, 3            1*Res                   8
1, 4            1*Res                   8
1, 5            1*Res                   8
1, 6            1*Res                   8
2, 3            1*Res                   8
2, 4            1*Res                   8
2, 5            1*Res                   8
2, 6            1*Res                   8
3, 4            1*Res                   8
3, 5            1*Res                   8
3, 6            1*Res                   8
4, 5            1*Res                   8
4, 6            1*Res                   8
5, 6            1*Res                   8

Average Distance between/within groups
        0               1               2               3
4       5               6
0       0

1       0,35756         0,35352

2       0,21689         0,47223         0,25451

3       0,11118         0,34994         0,243           0,18123

4       0,26369         0,54653         0,21505         0,2862
        0,23586
5       0,44426         0,70803         0,34072         0,46266
        0,30452         0,38266
6       0,32262         0,56323         0,29501         0,34539
        0,28393         0,36642         0,42049

Within level 'JC' of factor 'Layout'
                                                        Unique
Groups          t               P(perm)                 perms           P(MC)
0, 1            2,1109          0,054                   16              0,085
0, 2            0,15041         0,841                   16              0,88
0, 3            4,5864          0,01                    16              0,002
0, 4            2,7736          0,051                   16              0,032
0, 5            21,098          0,006                   16              0,001
0, 6            7,563           0,008                   16              0,001
1, 2            1,6513          0,138                   126             0,135
1, 3            3,7472          0,009                   126             0,007
1, 4            3,4785          0,015                   126             0,011
1, 5            14,159          0,007                   126             0,001
1, 6            7,8188          0,009                   126             0,001
2, 3            1,7909          0,091                   126             0,117
2, 4            2,2832          0,062                   126             0,046
2, 5            12,962          0,013                   126             0,001
2, 6            7,4329          0,009                   126             0,001
3, 4            1,41            0,2                     126             0,188
3, 5            15,883          0,009                   126             0,001
3, 6            7,1832          0,009                   126             0,001
4, 5            6,734           0,009                   126             0,002
4, 6            6,5621          0,005                   126             0,001
5, 6            4,7117          0,009                   126             0,004
```

```
4, 6            1*Res                   8
5, 6            1*Res                   8

Average Distance between/within groups
        0               1               2               3               4
        5               6
0       0

1       0,1727          0,18231

2       0,16016         0,11526         4,6664E-2

3       0,29873         0,28381         0,25488         0,4226

4       0,4753          0,5869          0,5714          0,59378         0,66835

5       0,88486         1,0576          1,045           0,94587         0,70242
        0,39543
6       2,1309          2,3036          2,2911          2,1714          1,7761
        1,246           0,31673

Within level 'SC' of factor 'Layout'
                                                        Unique
Groups          t               P(perm)                 perms           P(MC)
0, 1            5,6973          0,014                   16              0,001
0, 2            6,9598          0,008                   16              0,001
0, 3            6,0244          0,012                   16              0,001
0, 4            6,2248          0,006                   16              0,001
0, 5            18,057          0,012                   16              0,001
0, 6            8,0371          0,01                    16              0,001
1, 2            0,30804         0,774                   126             0,787
1, 3            0,38669         0,694                   126             0,704
1, 4            1,3143          0,272                   126             0,229
1, 5            7,6047          0,004                   126             0,001
1, 6            6,3041          0,008                   126             0,001
2, 3            0,10857         0,909                   126             0,92
2, 4            1,1095          0,294                   126             0,291
2, 5            7,8236          0,009                   126             0,001
2, 6            6,2464          0,007                   126             0,002
3, 4            0,95239         0,379                   126             0,366
3, 5            7,0318          0,009                   126             0,001
3, 6            6,1452          0,011                   126             0,001
4, 5            5,2304          0,009                   126             0,002
4, 6            5,6569          0,006                   126             0,002
5, 6            3,7375          0,009                   126             0,013

Denominators
Groups          Denominator             Den.df
0, 1            1*Res                   8
0, 2            1*Res                   8
0, 3            1*Res                   8
0, 4            1*Res                   8
0, 5            1*Res                   8
0, 6            1*Res                   8
1, 2            1*Res                   8
1, 3            1*Res                   8
1, 4            1*Res                   8
1, 5            1*Res                   8
1, 6            1*Res                   8
2, 3            1*Res                   8
2, 4            1*Res                   8
2, 5            1*Res                   8
2, 6            1*Res                   8
3, 4            1*Res                   8
3, 5            1*Res                   8
3, 6            1*Res                   8
4, 5            1*Res                   8
4, 6            1*Res                   8
5, 6            1*Res                   8

Average Distance between/within groups
        0               1               2               3               4
        5               6
0       0

1       0,79328         0,36274

2       0,85034         0,29667         0,33039

3       0,8709          0,3229          0,3067          0,40211

4       1,0868          0,40361         0,37898         0,3941          0,45916

5       2,2004          1,4071          1,35            1,3295          1,1136
        0,32961
6       4,2108          3,4175          3,3604          3,3399          3,124
        2,0104          1,4635

Within level 'ST7' of factor 'Layout'
                                                        Unique
Groups          t               P(perm)                 perms           P(MC)
0, 1            6,9417          0,005                   16              0,001
0, 2            7,4845          0,009                   16              0,001
0, 3            7,2444          0,009                   16              0,001
0, 4            8,5507          0,017                   16              0,001
0, 5            19,344          0,009                   16              0,001
0, 6            24,687          0,009                   16              0,001
1, 2            2,7572          0,036                   126             0,022
1, 3            2,7557          0,03                    126             0,027
1, 4            4,0387          0,017                   126             0,004
1, 5            13,113          0,012                   126             0,001
1, 6            20,454          0,009                   126             0,001
2, 3            7,8443E-2       0,927                   126             0,939
2, 4            1,221           0,237                   125             0,245
2, 5            8,7115          0,012                   126             0,001
2, 6            16,764          0,007                   126             0,001
3, 4            1,1186          0,334                   126             0,304
3, 5            8,4313          0,01                    126             0,001
3, 6            16,465          0,01                    126             0,001
4, 5            7,1552          0,011                   125             0,001
4, 6            15,396          0,011                   126             0,001
5, 6            9,9057          0,005                   126             0,001

Denominators
Groups          Denominator             Den.df
0, 1            1*Res                   8
0, 2            1*Res                   8
0, 3            1*Res                   8
0, 4            1*Res                   8
0, 5            1*Res                   8
```

```
0, 6          1*Res                 8
1, 2          1*Res                 8
1, 3          1*Res                 8
1, 4          1*Res                 8
1, 5          1*Res                 8
1, 6          1*Res                 8
2, 3          1*Res                 8
2, 4          1*Res                 8
2, 5          1*Res                 8
2, 6          1*Res                 8
3, 4          1*Res                 8
3, 5          1*Res                 8
3, 6          1*Res                 8
4, 5          1*Res                 8
4, 6          1*Res                 8
5, 6          1*Res                 8

Average Distance between/within groups
        0               1              2              3              4
        5               6
0       0

1     0,34036         0,13307

2     0,59921         0,27079        0,21913

3     0,60831         0,29013        0,19297        0,22119

4     0,74353         0,40507        0,23066        0,22504        0,24384

5      1,603          1,2626          1,0038         0,9947        0,85948
      0,22809
6      3,09           2,7496          2,4908         2,4817         2,3465
       1,487          0,31735
```

PERMANOVA post-hoc results of tensile strength loss of textile substrates in factor ‘Layout’

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem4
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                  Abbrev.         Type        Levels
Layout                La              Fixed          6
Time Interval         Ti              Fixed          7

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Layout'

Within level '0' of factor 'Time Interval'
                                                  Unique
Groups              t          P(perm)            perms         P(MC)
CC, CT7           1,9511        0,065              126          0,097
CC, JC            10,059        0,014              126          0,001
CC, JT7           8,2051        0,012              126          0,001
CC, SC            24,573        0,005              126          0,001
CC, ST7           20,253        0,008              126          0,001
CT7, JC           25,163        0,005              126          0,001
CT7, JT7           10,99        0,011              126          0,001
CT7, SC           28,071        0,004              126          0,001
CT7, ST7          22,292        0,006              126          0,001
JC, JT7          0,50376        0,643              126          0,604
JC, SC            31,973        0,008              126          0,001
JC, ST7           25,366        0,009              126          0,001
JT7, SC           30,372        0,009              126          0,001
JT7, ST7          24,521        0,007              126          0,001
SC, ST7          0,33465         0,75              126          0,748

Denominators
Groups            Denominator           Den.df
CC, CT7           1*Res                    8
CC, JC            1*Res                    8
CC, JT7           1*Res                    8
CC, SC            1*Res                    8
CC, ST7           1*Res                    8
CT7, JC           1*Res                    8
CT7, JT7          1*Res                    8
CT7, SC           1*Res                    8
CT7, ST7          1*Res                    8
JC, JT7           1*Res                    8
JC, SC            1*Res                    8
JC, ST7           1*Res                    8
JT7, SC           1*Res                    8
JT7, ST7          1*Res                    8
SC, ST7           1*Res                    8

Average Distance between/within groups
             CC               CT7                 JC                  JT7
             SC              ST7
CC        0,13412
```

```
Within level '3' of factor 'Time Interval'
                                                  Unique
Groups              t          P(perm)            perms         P(MC)
CC, CT7           2,1515        0,088              126          0,069
CC, JC            9,3444        0,005              126          0,001
CC, JT7           9,9534        0,007              126          0,001
CC, SC            13,044        0,008              126          0,001
CC, ST7           8,5724        0,008              124          0,001
CT7, JC           6,9854        0,006              126          0,001
CT7, JT7          7,4128        0,012              126          0,001
CT7, SC           14,027        0,007              126          0,001
CT7, ST7          9,1464        0,011              126          0,001
JC, JT7          0,25541        0,755              125          0,815
JC, SC            17,068        0,006              126          0,001
JC, ST7           10,805        0,012              126          0,001
JT7, SC            17,2         0,009              126          0,001
JT7, ST7          10,807        0,009              126          0,001
SC, ST7          0,68477         0,49              126          0,502

Denominators
Groups            Denominator           Den.df
CC, CT7           1*Res                    8
CC, JC            1*Res                    8
CC, JT7           1*Res                    8
CC, SC            1*Res                    8
CC, ST7           1*Res                    8
CT7, JC           1*Res                    8
CT7, JT7          1*Res                    8
CT7, SC           1*Res                    8
CT7, ST7          1*Res                    8
JC, JT7           1*Res                    8
JC, SC            1*Res                    8
JC, ST7           1*Res                    8
JT7, SC           1*Res                    8
JT7, ST7          1*Res                    8
SC, ST7           1*Res                    8

Average Distance between/within groups
             CC               CT7                 JC                  JT7
             SC               ST7
CC       9,8326E-2

CT7       0,12583           0,1038

JC         0,434            0,3187            6,6273E-2

JT7       0,42577          0,31047            5,0728E-2           4,8672E-2

SC         1,5891           1,7044              2,0231              2,0149
          0,3087
ST7        1,7474           1,8627              2,1814              2,1732
         0,40638           0,56123

Within level '4' of factor 'Time Interval'
                                                  Unique
Groups              t          P(perm)            perms         P(MC)
CC, CT7          0,63415        0,546              126          0,562
CC, JC            4,6349        0,005              126          0,003
CC, JT7           4,2005        0,011              126          0,004
CC, SC            9,3394        0,012              126          0,001
CC, ST7           15,918        0,006              126          0,001
CT7, JC            8,189        0,007              126          0,001
CT7, JT7          7,5452        0,007              126          0,001
CT7, SC           9,9183        0,008              126          0,001
CT7, ST7          17,628        0,007              125          0,001
JC, JT7            1,203        0,252              126          0,259
JC, SC            14,222        0,008              126          0,001
```

CT7	0,11531	2,6866E-2				
JC	0,50454	0,40815	3,6013E-2			
JT7	0,48615	0,38976	6,3583E-2	9,5829E-2		
SC	2,7553	2,8517	3,2599	3,2415	0,26524	
ST7	2,8105	2,9068	3,315	3,2966	0,28171	0,35116

Within level '1' of factor 'Time Interval'

Groups	t	P(perm)	Unique perms	P(MC)
CC, CT7	3,4384	0,027	91	0,009
CC, JC	6,9941	0,01	126	0,003
CC, JT7	7,397	0,007	91	0,001
CC, SC	9,2291	0,011	126	0,001
CC, ST7	13,223	0,012	126	0,001
CT7, JC	13,729	0,011	91	0,001
CT7, JT7	33,952	0,009	66	0,001
CT7, SC	10,831	0,009	91	0,001
CT7, ST7	15,413	0,01	91	0,001
JC, JT7	0,70504	0,54	91	0,498
JC, SC	12,025	0,008	125	0,001
JC, ST7	16,759	0,007	126	0,001
JT7, SC	12,127	0,01	91	0,001
JT7, ST7	16,904	0,015	91	0,001
SC, ST7	1,9417	0,072	126	0,075

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, JC	1*Res	8
CC, JT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CT7, JC	1*Res	8
CT7, JT7	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
JC, JT7	1*Res	8
JC, SC	1*Res	8
JC, ST7	1*Res	8
JT7, SC	1*Res	8
JT7, ST7	1*Res	8
SC, ST7	1*Res	8

Average Distance between/within groups

	CC	CT7	JC	JT7	SC	ST7
CC	0,15604					
CT7	0,20588	1,3679E-2				
JC	0,43065	0,22496	4,1791E-2			
JT7	0,44204	0,23635	2,7713E-2	1,1548E-2		
SC	1,7717	1,9774	2,2024	2,2138	0,51013	
ST7	2,2413	2,447	2,6719	2,6833	0,56808	0,423

Within level '2' of factor 'Time Interval'

Groups	t	P(perm)	Unique perms	P(MC)
CC, CT7	1,0137	0,385	126	0,354
CC, JC	9,9553	0,011	125	0,001
CC, JT7	14,071	0,009	126	0,001
CC, SC	15,229	0,014	126	0,001
CC, ST7	41,188	0,012	91	0,001
CT7, JC	4,8266	0,01	126	0,002
CT7, JT7	5,3	0,009	126	0,001
CT7, SC	13,744	0,008	126	0,001
CT7, ST7	24,395	0,01	91	0,001
JC, JT7	2,3862E-2	0,957	126	0,978
JC, SC	18,552	0,007	126	0,001
JC, ST7	41,657	0,011	91	0,001
JT7, SC	19,322	0,011	126	0,001
JT7, ST7	51,345	0,008	91	0,001
SC, ST7	1,2725	0,261	91	0,241

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, JC	1*Res	8
CC, JT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CT7, JC	1*Res	8
CT7, JT7	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
JC, JT7	1*Res	8
JC, SC	1*Res	8
JC, ST7	1*Res	8
JT7, SC	1*Res	8
JT7, ST7	1*Res	8
SC, ST7	1*Res	8

Average Distance between/within groups

	CC	CT7	JC	JT7	SC	ST7
CC	5,8851E-2					
CT7	0,13751	0,1696				
JC	0,4309	0,36157	0,1019			
JT7	0,43194	0,3626	7,5381E-2	5,6842E-2		
SC	1,6062	1,6755	2,0371	2,0381	0,2795	
ST7	1,7454	1,8148	2,1763	2,1774	0,203	9,8191E-2

JC, ST7	23,344	0,008	126	0,001
JT7, SC	13,932	0,006	126	0,001
JT7, ST7	23,023	0,003	126	0,001
SC, ST7	4,6632	0,005	126	0,002

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, JC	1*Res	8
CC, JT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CT7, JC	1*Res	8
CT7, JT7	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
JC, JT7	1*Res	8
JC, SC	1*Res	8
JC, ST7	1*Res	8
JT7, SC	1*Res	8
JT7, ST7	1*Res	8
SC, ST7	1*Res	8

Average Distance between/within groups

	CC	CT7	JC	JT7	SC	ST7
CC	0,21548					
CT7	0,1576	0,12956				
JC	0,37182	0,42957	5,7512E-2			
JT7	0,33636	0,39412	5,6141E-2	5,693E-2		
SC	1,2989	1,2412	1,6708	1,6353	0,3027	
ST7	2,0112	1,9534	2,383	2,3475	0,71224	0,26857

Within level '5' of factor 'Time Interval'

Groups	t	P(perm)	Unique perms	P(MC)
CC, CT7	2,0777	0,089	126	0,082
CC, JC	6,4438	0,011	90	0,001
CC, JT7	7,2029	0,011	126	0,001
CC, SC	7,4218	0,007	126	0,001
CC, ST7	6,1198	0,006	126	0,002
CT7, JC	9,1875	0,011	91	0,001
CT7, JT7	10,815	0,007	126	0,001
CT7, SC	10,704	0,008	126	0,001
CT7, ST7	7,6723	0,007	126	0,001
JC, JT7	7,1793	0,008	91	0,001
JC, SC	14,753	0,007	91	0,001
JC, ST7	9,8123	0,008	90	0,001
JT7, SC	15,362	0,011	126	0,001
JT7, ST7	10,173	0,011	126	0,001
SC, ST7	1,034	0,339	126	0,342

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, JC	1*Res	8
CC, JT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CT7, JC	1*Res	8
CT7, JT7	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
JC, JT7	1*Res	8
JC, SC	1*Res	8
JC, ST7	1*Res	8
JT7, SC	1*Res	8
JT7, ST7	1*Res	8
SC, ST7	1*Res	8

Average Distance between/within groups

	CC	CT7	JC	JT7	SC	ST7
CC	0,20492					
CT7	0,19363	9,122E-2				
JC	0,47377	0,30663	1,2947E-2			
JT7	0,53023	0,36309	5,6459E-2	1,687E-2		
SC	0,86546	1,0326	1,3392	1,3957	0,25499	
ST7	1,0515	1,2186	1,5252	1,5817	0,34025	0,43115

Within level '6' of factor 'Time Interval'

Groups	t	P(perm)	Unique perms	P(MC)
CC, CT7	1,6836	0,146	123	0,126
CC, JC	27,001	0,006	126	0,001
CC, JT7	24,366	0,009	126	0,001
CC, SC	9,7429	0,005	126	0,001
CC, ST7	4,2143	0,01	126	0,005
CT7, JC	13,272	0,012	126	0,001
CT7, JT7	13,275	0,01	116	0,001
CT7, SC	6,649	0,011	126	0,001
CT7, ST7	3,641	0,029	125	0,008
JC, JT7	1,3062	0,212	126	0,218
JC, SC	20,177	0,011	126	0,001
JC, ST7	7,2459	0,011	126	0,001
JT7, SC	20,082	0,009	126	0,001
JT7, ST7	7,3278	0,012	126	0,001
SC, ST7	1,0542	0,339	126	0,313

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, JC	1*Res	8
CC, JT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CT7, JC	1*Res	8
CT7, JT7	1*Res	8

```
CT7, SC          1*Res                    8
CT7, ST7         1*Res                    8
JC, JT7          1*Res                    8
JC, SC           1*Res                    8
JC, ST7          1*Res                    8
JT7, SC          1*Res                    8
JT7, ST7         1*Res                    8
SC, ST7          1*Res                    8

Average Distance between/within groups
              CC                  CT7                  JC                  JT7
              SC                  ST7
CC       3,5442E-2

CT7      7,7012E-2           8,8127E-2

JC         0,36593             0,42377           9,3587E-3

JT7        0,37759             0,43543           1,8706E-2           2,2531E-2

SC         0,38139             0,32356             0,74732             0,75898
         9,7784E-2
ST7        0,51532             0,46947             0,88125             0,89291
           0,26542           0,30158
```

PERMANOVA post-hoc results of tensile strength loss of textile substrates in factor ‘Time Interval’

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem4
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                     Abbrev.          Type          Levels
Layout                   La               Fixed            6
Time Interval            Ti               Fixed            7

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Time Interval'

Within level 'CC' of factor 'Layout'
                                                      Unique
Groups           t              P(perm)               perms          P(MC)
0, 1          0,25733            0,789                 126           0,828
0, 2          0,38151            0,746                 126           0,719
0, 3           1,3431            0,244                 126           0,224
0, 4           1,6438             0,15                 126           0,139
0, 5          0,50452            0,651                 126           0,637
0, 6           4,4276            0,006                 126           0,003
1, 2        7,6551E-3                1                 126           0,994
1, 3          0,89233            0,391                 126           0,416
1, 4           1,3342            0,251                 126             0,2
1, 5          0,26019            0,803                 126           0,779
1, 6            3,318            0,028                 125            0,01
2, 3           1,4237            0,173                 126           0,201
2, 4           1,6154            0,138                 126           0,133
2, 5          0,31513            0,745                 126           0,754
2, 6           7,9707             0,01                 126           0,001
3, 4          0,77631            0,467                 126           0,481
3, 5          0,46694            0,609                 126           0,653
3, 6            3,431            0,008                 126           0,006
4, 5          0,99149            0,374                 126           0,358
4, 6          0,91887            0,367                 126           0,397
5, 6           2,3866            0,061                 126           0,058

Denominators
Groups        Denominator               Den.df
0, 1          1*Res                       8
0, 2          1*Res                       8
0, 3          1*Res                       8
0, 4          1*Res                       8
0, 5          1*Res                       8
0, 6          1*Res                       8
1, 2          1*Res                       8
1, 3          1*Res                       8
1, 4          1*Res                       8
1, 5          1*Res                       8
1, 6          1*Res                       8
2, 3          1*Res                       8
2, 4          1*Res                       8
2, 5          1*Res                       8
2, 6          1*Res                       8
3, 4          1*Res                       8
3, 5          1*Res                       8
3, 6          1*Res                       8
4, 5          1*Res                       8
4, 6          1*Res                       8
5, 6          1*Res                       8

Average Distance between/within groups
          0                  1                  2                  3
          4                  5                  6
0     0,13412

1     0,12172            0,15604

2   8,6961E-2          9,7388E-2          5,8851E-2
```

```
Denominators
Groups        Denominator               Den.df
0, 1          1*Res                       8
0, 2          1*Res                       8
0, 3          1*Res                       8
0, 4          1*Res                       8
0, 5          1*Res                       8
0, 6          1*Res                       8
1, 2          1*Res                       8
1, 3          1*Res                       8
1, 4          1*Res                       8
1, 5          1*Res                       8
1, 6          1*Res                       8
2, 3          1*Res                       8
2, 4          1*Res                       8
2, 5          1*Res                       8
2, 6          1*Res                       8
3, 4          1*Res                       8
3, 5          1*Res                       8
3, 6          1*Res                       8
4, 5          1*Res                       8
4, 6          1*Res                       8
5, 6          1*Res                       8

Average Distance between/within groups
          0                  1                  2                  3
          4                  5                  6
0   9,5829E-2

1    6,607E-2          1,1548E-2

2   7,3703E-2          3,5419E-2          5,6842E-2

3   6,5873E-2          5,6196E-2          6,7287E-2          4,8672E-2

4   6,7542E-2          3,7367E-2           5,464E-2          4,9876E-2
     5,693E-2
5   9,0866E-2            0,11278             0,1224          6,5804E-2
    8,8146E-2           1,687E-2
6     0,11395            0,13799            0,14761          9,1019E-2
      0,11336          2,7639E-2          2,2531E-2

Within level 'SC' of factor 'Layout'
                                                      Unique
Groups           t              P(perm)               perms          P(MC)
0, 1           4,8093            0,006                 126           0,004
0, 2           8,0929            0,009                 126           0,001
0, 3            8,133            0,013                 126           0,001
0, 4           10,461             0,01                 126           0,001
0, 5           14,243            0,012                 126           0,001
0, 6           24,119            0,008                 126           0,001
1, 2          0,79196            0,501                 126            0,47
1, 3           1,1381            0,251                 126           0,296
1, 4           2,7921            0,023                 126           0,023
1, 5           4,5683            0,009                 126           0,005
1, 6           8,5551            0,007                 126           0,001
2, 3          0,51504            0,603                 126           0,627
2, 4           2,8207            0,044                 126            0,03
2, 5           5,5676            0,015                 126           0,002
2, 6           13,017             0,01                 126           0,001
3, 4           2,1854            0,081                 126           0,071
3, 5           4,6625            0,008                 126           0,002
3, 6           11,099            0,008                 126           0,001
4, 5           2,2316            0,067                 126           0,051
4, 6           8,1586            0,008                 126           0,001
5, 6           6,7639            0,008                 126           0,002

Denominators
Groups        Denominator               Den.df
0, 1          1*Res                       8
0, 2          1*Res                       8
0, 3          1*Res                       8
0, 4          1*Res                       8
0, 5          1*Res                       8
0, 6          1*Res                       8
1, 2          1*Res                       8
1, 3          1*Res                       8
1, 4          1*Res                       8
1, 5          1*Res                       8
1, 6          1*Res                       8
2, 3          1*Res                       8
2, 4          1*Res                       8
```

3	0,12057	0,12809	9,4677E-2	9,8326E-2			
4	0,18919	0,18655	0,16502	0,1503	0,21548		
5	0,14599	0,15172	0,12662	0,1401	0,19359	0,20492	
6	0,2222	0,20583	0,20196	0,13919	0,14327	0,19712	3,5442E-2

Within level 'CT7' of factor 'Layout'

Groups	t	P(perm)	Unique perms	P(MC)
0, 1	11,689	0,013	91	0,001
0, 2	0,10377	0,95	126	0,92
0, 3	2,6387	0,016	125	0,038
0, 4	8,2993E-2	0,906	124	0,944
0, 5	3,3457	0,01	126	0,009
0, 6	2,0482	0,08	125	0,07
1, 2	2,0875	0,008	91	0,061
1, 3	0,7186	0,473	91	0,482
1, 4	2,7559	0,036	90	0,019
1, 5	0,41757	0,768	91	0,7
1, 6	1,8978	0,116	91	0,098
2, 3	1,4522	0,181	126	0,184
2, 4	3,3958E-2	0,982	126	0,971
2, 5	1,6749	0,122	126	0,129
2, 6	1,0356	0,396	126	0,323
3, 4	1,7416	0,11	126	0,126
3, 5	0,2642	0,817	126	0,796
3, 6	0,69196	0,487	125	0,499
4, 5	2,0452	0,065	126	0,073
4, 6	1,2517	0,263	126	0,258
5, 6	1,0289	0,345	126	0,331

Denominators

Groups	Denominator	Den.df
0, 1	1*Res	8
0, 2	1*Res	8
0, 3	1*Res	8
0, 4	1*Res	8
0, 5	1*Res	8
0, 6	1*Res	8
1, 2	1*Res	8
1, 3	1*Res	8
1, 4	1*Res	8
1, 5	1*Res	8
1, 6	1*Res	8
2, 3	1*Res	8
2, 4	1*Res	8
2, 5	1*Res	8
2, 6	1*Res	8
3, 4	1*Res	8
3, 5	1*Res	8
3, 6	1*Res	8
4, 5	1*Res	8
4, 6	1*Res	8
5, 6	1*Res	8

Average Distance between/within groups

	0	1	2	3	4	5	6
0	2,6866E-2						
1	0,12906	1,3679E-2					
2	0,10907	0,13587	0,1696				
3	0,10369	7,4519E-2	0,13997	0,1038			
4	7,3863E-2	0,14056	0,13319	0,13173	0,12956		
5	0,1151	5,7594E-2	0,14317	8,208E-2	0,1374	9,122E-2	
6	7,3977E-2	7,757E-2	0,12145	8,3559E-2	0,10861	8,5593E-2	8,8127E-2

Within level 'JC' of factor 'Layout'

Groups	t	P(perm)	Unique perms	P(MC)
0, 1	2,6742	0,039	126	0,026
0, 2	1,3463	0,219	126	0,24
0, 3	0,42717	0,695	126	0,655
0, 4	0,6997	0,556	126	0,538
0, 5	0,97675	0,357	91	0,367
0, 6	6,218	0,007	126	0,001
1, 2	1,8219E-2	0,99	123	0,987
1, 3	2,1911	0,086	126	0,054
1, 4	2,728	0,026	126	0,028
1, 5	4,161	0,009	91	0,002
1, 6	8,6733	0,011	126	0,001
2, 3	1,4417	0,187	123	0,205
2, 4	1,6449	0,128	126	0,128
2, 5	1,7724	0,149	91	0,109
2, 6	3,6414	0,012	126	0,009
3, 4	0,14531	0,921	126	0,881
3, 5	4,179E-2	0,987	91	0,974
3, 6	2,698	0,011	126	0,026
4, 5	0,17391	0,912	91	0,86
4, 6	3,0962	0,033	126	0,016
5, 6	11,69	0,009	91	0,001

Denominators

Groups	Denominator	Den.df
0, 1	1*Res	8
0, 2	1*Res	8
0, 3	1*Res	8
0, 4	1*Res	8
0, 5	1*Res	8
0, 6	1*Res	8
1, 2	1*Res	8
1, 3	1*Res	8
1, 4	1*Res	8
1, 5	1*Res	8
1, 6	1*Res	8
2, 3	1*Res	8
2, 4	1*Res	8
2, 5	1*Res	8
2, 6	1*Res	8
3, 4	1*Res	8
3, 5	1*Res	8
2, 5	1*Res	8
2, 6	1*Res	8
3, 4	1*Res	8
3, 5	1*Res	8
3, 6	1*Res	8
4, 5	1*Res	8
4, 6	1*Res	8
5, 6	1*Res	8

Average Distance between/within groups

	0	1	2	3	4	5	6
0	0,26524						
1	1,0034	0,51013					
2	1,1694	0,37119	0,2795				
3	1,2492	0,40854	0,25124	0,3087			
4	1,6065	0,61314	0,45459	0,40684	0,3027		
5	1,9342	0,93085	0,76481	0,68499	0,3796	0,25499	
6	2,5961	1,5928	1,4267	1,3469	0,98968	0,66193	9,7784E-2

Within level 'ST7' of factor 'Layout'

Groups	t	P(perm)	Unique perms	P(MC)
0, 1	2,8708	0,034	126	0,027
0, 2	8,0366	0,012	91	0,001
0, 3	4,8008	0,007	126	0,003
0, 4	5,7901	0,008	126	0,001
0, 5	8,901	0,01	126	0,001
0, 6	14,141	0,005	126	0,001
1, 2	3,0486	0,041	91	0,016
1, 3	2,1809	0,069	126	0,069
1, 4	1,9223	0,138	126	0,086
1, 5	5,4686	0,008	126	0,001
1, 6	9,6472	0,007	126	0,001
2, 3	0,29877	0,781	91	0,748
2, 4	1,2785	0,275	91	0,261
2, 5	4,5001	0,004	91	0,003
2, 6	11,284	0,006	91	0,001
3, 4	0,87921	0,389	126	0,384
3, 5	2,5938	0,045	126	0,033
3, 6	5,8548	0,008	126	0,001
4, 5	4,6239	0,01	126	0,001
4, 6	9,966	0,011	126	0,001
5, 6	3,6193	0,016	126	0,014

Denominators

Groups	Denominator	Den.df
0, 1	1*Res	8
0, 2	1*Res	8
0, 3	1*Res	8
0, 4	1*Res	8
0, 5	1*Res	8
0, 6	1*Res	8
1, 2	1*Res	8
1, 3	1*Res	8
1, 4	1*Res	8
1, 5	1*Res	8
1, 6	1*Res	8
2, 3	1*Res	8
2, 4	1*Res	8
2, 5	1*Res	8
2, 6	1*Res	8
3, 4	1*Res	8
3, 5	1*Res	8
3, 6	1*Res	8
4, 5	1*Res	8
4, 6	1*Res	8
5, 6	1*Res	8

Average Distance between/within groups

	0	1	2	3	4	5	6
0	0,35116						
1	0,61548	0,423					
2	1,0853	0,5117	9,8191E-2				
3	1,1461	0,64065	0,37401	0,56123			
4	0,94936	0,44454	0,19722	0,41564	0,26857		
5	1,8034	1,2144	0,71809	0,68513	0,854	0,43115	
6	2,5173	1,9284	1,4321	1,3713	1,568	0,71575	0,30158

```
3, 6            1*Res                         8
4, 5            1*Res                         8
4, 6            1*Res                         8
5, 6            1*Res                         8

Average Distance between/within groups
          0                    1                    2                    3
          4                    5                    6
0     3,6013E-2

1     5,7694E-2            4,1791E-2

2     8,2263E-2            7,2375E-2             0,1019

3     5,1104E-2            8,0197E-2            9,1906E-2            6,6273E-2

4     4,2374E-2            7,5468E-2            9,3314E-2            5,5559E-2
      5,7512E-2
5     2,7275E-2            6,7713E-2            8,4158E-2             4,049E-2
       3,869E-2            1,2947E-2
6     8,3597E-2             0,13773              0,13699             7,1125E-2
      6,6845E-2            7,0013E-2            9,3587E-3

Within level 'JT7' of factor 'Layout'
                                                         Unique
Groups              t                P(perm)              perms          P(MC)
0, 1             0,70737              0,458                 91            0,524
0, 2             0,83961              0,405                125             0,4
0, 3              0,5805              0,605                126            0,575
0, 4            7,2818E-3               1                  126            0,992
0, 5              2,5513              0,022                126            0,037
0, 6              3,2379              0,021                126            0,006
1, 2             0,43327              0,786                 91            0,675
1, 3               2,421               0,06                 91            0,046
1, 4              1,1701              0,339                 91            0,284
1, 5              14,798              0,006                 91            0,001
1, 6              14,661              0,007                 91            0,001
2, 3              1,9664              0,093                126            0,077
2, 4              1,1449              0,321                126            0,292
2, 5              5,4201              0,007                126            0,001
2, 6              6,3495              0,008                126            0,003
3, 4              0,8006              0,428                126            0,469
3, 5               3,317              0,012                125            0,008
3, 6              4,4199              0,006                126            0,001
4, 5              4,1084              0,009                126            0,005
4, 6              5,1168              0,003                126            0,001
5, 6              2,4529              0,042                126            0,045
```

PERMANOVA post-hoc results of OCR of textile substrates in factor ‘Layout’

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem2
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                          Abbrev.          Type
                              Levels
Layout                        La               Fixed            6
Time Interval                 Ti               Fixed            7

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Layout'

Within level '0' of factor 'Time Interval'
                                                          Unique

Groups                t               P(perm)              perms
                    P(MC)
CC, CT7             0,54262            0,615                126
                     0,61
CC, JC              0,52983            0,629                126
                    0,614
CC, JT7              0,6074            0,663                126
                    0,539
CC, SC               1,8176            0,109                126
                    0,111
CC, ST7              4,4495            0,003                126
                    0,008
CT7, JC             0,12244            0,883                126
                    0,902
CT7, JT7            0,91055            0,417                126
                      0,4
CT7, SC              1,9007            0,112                126
                     0,09
CT7, ST7             3,5239            0,028                126
                     0,01
JC, JT7             0,91151            0,403                126
                    0,391
JC, SC               2,1806             0,07                126
                    0,052
JC, ST7              4,0088            0,009                126
                    0,005
JT7, SC              0,5623            0,559                125
                    0,575
JT7, ST7             3,9127             0,01                126
                    0,004
SC, ST7              5,3746            0,008                126
                    0,001
```

```
JC, JT7             1,9586            0,098             41          0,087
JC, SC              3,8179            0,018             55          0,004
JC, ST7             5,0705            0,007             41          0,001
JT7, SC            0,69977            0,552             91          0,486
JT7, ST7             1,569            0,152             66          0,159
SC, ST7              2,064            0,092             66          0,078

Denominators
Groups           Denominator            Den.df
CC, CT7          1*Res                    8
CC, JC           1*Res                    8
CC, JT7          1*Res                    8
CC, SC           1*Res                    8
CC, ST7          1*Res                    8
CT7, JC          1*Res                    8
CT7, JT7         1*Res                    8
CT7, SC          1*Res                    8
CT7, ST7         1*Res                    8
JC, JT7          1*Res                    8
JC, SC           1*Res                    8
JC, ST7          1*Res                    8
JT7, SC          1*Res                    8
JT7, ST7         1*Res                    8
SC, ST7          1*Res                    8

Average Distance between/within groups
             CC               CT7               JC               JT7               SC
ST7
CC       0,83413
CT7      0,59612          0,49559
JC       0,59055          0,40543          0,27567
JT7       0,6102          0,45478          0,43171          0,37145
SC       0,56291          0,42218           0,4858          0,29452          0,14067
ST7      0,60074          0,54684          0,60805          0,37032          0,15431
         9,9182E-2

Within level '4' of factor 'Time Interval'
                                                          Unique
Groups              t                P(perm)              perms          P(MC)
CC, CT7          3,1021E-2            0,979                126            0,977
CC, JC             2,0649             0,065                126            0,072
CC, JT7            2,0419             0,077                 66            0,084
CC, SC            0,32834             0,717                 91            0,746
CC, ST7            1,6264             0,152                 41            0,138
CT7, JC            2,0659             0,069                126            0,089
CT7, JT7           2,3731             0,068                 91            0,044
CT7, SC           0,43561             0,679                 91            0,684
CT7, ST7           2,2365              0,04                 66            0,064
JC, JT7            1,8058             0,149                 91            0,116
JC, SC             2,1101             0,031                 91            0,056
JC, ST7            2,2412              0,01                 66            0,056
JT7, SC            2,8388             0,041                 66            0,027
JT7, ST7           5,0855             0,008                 48            0,001
SC, ST7            1,7476             0,145                 35            0,116

Denominators
Groups           Denominator            Den.df
CC, CT7          1*Res                    8
CC, JC           1*Res                    8
CC, JT7          1*Res                    8
CC, SC           1*Res                    8
```

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, JC	1*Res	8
CC, JT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CT7, JC	1*Res	8
CT7, JT7	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
JC, JT7	1*Res	8
JC, SC	1*Res	8
JC, ST7	1*Res	8
JT7, SC	1*Res	8
JT7, ST7	1*Res	8
SC, ST7	1*Res	8

Average Distance between/within groups

	CC	CT7	JC	JT7	SC	ST7
CC	1,0786E-2					
CT7	1,295E-2	1,6989E-2				
JC	9,8601E-3	1,2532E-2	1,2201E-2			
JT7	1,5166E-2	1,8906E-2	1,6403E-2	2,316E-2		
SC	1,3977E-2	1,9824E-2	1,6677E-2	1,7685E-2	1,3456E-2	
ST7	4,2925E-2	3,8886E-2	3,9746E-2	4,8789E-2	5,4494E-2	2,4634E-2

Within level '1' of factor 'Time Interval'

Groups	t	P(perm)	Unique perms	P(MC)
CC, CT7	1,5342	0,122	66	0,163
CC, JC	1,3466	0,144	91	0,24
CC, JT7	0,50657	0,532	17	0,621
CC, SC	3,3209	0,017	91	0,01
CC, ST7	2,6846	0,025	91	0,034
CT7, JC	0,10472	0,886	126	0,918
CT7, JT7	1,4719	0,256	41	0,206
CT7, SC	0,99986	0,437	126	0,323
CT7, ST7	0,52404	0,748	91	0,61
JC, JT7	1,2857	0,212	56	0,237
JC, SC	0,82756	0,661	126	0,422
JC, ST7	0,37293	0,855	126	0,717
JT7, SC	3,1332	0,013	56	0,015
JT7, ST7	2,5402	0,013	56	0,035
SC, ST7	1,2045	0,305	126	0,273

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, JC	1*Res	8
CC, JT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CT7, JC	1*Res	8
CT7, JT7	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
JC, JT7	1*Res	8
JC, SC	1*Res	8
JC, ST7	1*Res	8
JT7, SC	1*Res	8
JT7, ST7	1*Res	8
SC, ST7	1*Res	8

Average Distance between/within groups

	CC	CT7	JC	JT7	SC	ST7
CC	4,1841E-2					
CT7	0,28538	0,44857				
JC	0,26665	0,36461	0,43415			
JT7	3,4231E-2	0,28013	0,25989	3,0578E-2		
SC	9,7137E-2	0,27255	0,24708	8,5861E-2	5,4525E-2	
ST7	0,17469	0,28745	0,27318	0,16341	0,11727	0,16929

Within level '2' of factor 'Time Interval'

Groups	t	P(perm)	Unique perms	P(MC)
CC, CT7	0,3177	0,736	56	0,767
CC, JC	2,5433	0,074	91	0,03
CC, JT7	1,1891	0,346	91	0,264
CC, SC	1,1804	0,342	126	0,261
CC, ST7	0,524	0,559	91	0,614

CC, ST7	1*Res	8
CT7, JC	1*Res	8
CT7, JT7	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
JC, JT7	1*Res	8
JC, SC	1*Res	8
JC, ST7	1*Res	8
JT7, SC	1*Res	8
JT7, ST7	1*Res	8
SC, ST7	1*Res	8

Average Distance between/within groups

	CC	CT7	JC	JT7	SC	ST7
CC	0,37766					
CT7	0,27928	0,26277				
JC	2,8931	2,8613	3,6198			
JT7	0,42575	0,39319	2,6787	0,28661		
SC	0,27286	0,24086	2,9169	0,44228	0,24979	
ST7	0,27726	0,26453	3,0609	0,58701	0,19859	8,0435E-2

Within level '5' of factor 'Time Interval'

Groups	t	P(perm)	Unique perms	P(MC)
CC, CT7	1,434	0,308	126	0,187
CC, JC	1,7391	0,007	126	0,125
CC, JT7	2,817	0,01	123	0,019
CC, SC	2,1216	0,074	91	0,089
CC, ST7	0,40217	0,772	126	0,692
CT7, JC	0,53314	0,563	126	0,633
CT7, JT7	1,1386	0,259	126	0,306
CT7, SC	2,9948E-3	1	125	0,996
CT7, ST7	1,1857	0,304	126	0,25
JC, JT7	0,46688	0,643	126	0,65
JC, SC	0,59244	0,623	126	0,569
JC, ST7	1,553	0,148	126	0,156
JT7, SC	1,3081	0,23	126	0,207
JT7, ST7	2,524	0,046	91	0,041
SC, ST7	1,6379	0,134	125	0,129

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, JC	1*Res	8
CC, JT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CT7, JC	1*Res	8
CT7, JT7	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
JC, JT7	1*Res	8
JC, SC	1*Res	8
JC, ST7	1*Res	8
JT7, SC	1*Res	8
JT7, ST7	1*Res	8
SC, ST7	1*Res	8

Average Distance between/within groups

	CC	CT7	JC	JT7	SC	ST7
CC	0,19434					
CT7	1,0501	1,6107				
JC	1,4152	1,6061	1,9892			
JT7	1,9072	1,7056	1,7118	1,8651		
SC	0,91861	1,1883	1,3786	1,4826	1,1351	
ST7	0,41348	1,1303	1,4845	1,8608	0,98601	0,61962

Within level '6' of factor 'Time Interval'

Groups	t	P(perm)	Unique perms	P(MC)
CC, CT7	1,2911	0,351	91	0,241
CC, JC	2,4438	0,032	91	0,051
CC, JT7	2,5537	0,025	66	0,038
CC, SC	2,8324	0,006	66	0,016
CC, ST7	2,5359	0,053	91	0,023
CT7, JC	1,0622	0,302	126	0,333
CT7, JT7	1,6845E-2	0,973	91	0,988
CT7, SC	0,25307	0,815	91	0,834
CT7, ST7	3,6415E-2	0,971	126	0,969
JC, JT7	1,2663	0,244	91	0,232
JC, SC	1,0453	0,38	91	0,338
JC, ST7	1,2446	0,27	125	0,24
JT7, SC	0,37171	0,688	66	0,7
JT7, ST7	3,1527E-2	0,954	90	0,98
SC, ST7	0,33703	0,76	91	0,756

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, JC	1*Res	8
CC, JT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CT7, JC	1*Res	8
CT7, JT7	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
JC, JT7	1*Res	8
JC, SC	1*Res	8
JC, ST7	1*Res	8
JT7, SC	1*Res	8
JT7, ST7	1*Res	8
SC, ST7	1*Res	8

Average Distance between/within groups

	CC	CT7	JC	JT7	SC	ST7
CC	0,33025					
CT7	1,1568	1,7424				
JC	1,9964	1,8345	2,1028			
JT7	0,86432	1,2152	1,5484	0,8391		
SC	1,0265	1,2595	1,4885	0,74965	0,9346	
ST7	0,93755	1,2446	1,4971	0,74793	0,7719	0,87735

```
CT7, JC            2,5361          0,057          91
                 0,031
CT7, JT7           1,0898          0,363          66
                 0,288
CT7, SC            1,0836          0,401          91
                 0,312
CT7, ST7           0,2779          0,732          66
                 0,789
JC, JT7            1,253           0,267          91
                 0,245
JC, SC             1,0128          0,338         126
                 0,336
JC, ST7            2,4174          0,047          91
                 0,042
JT7, SC            0,1375          0,883          91
                 0,903
JT7, ST7         0,95609           0,393          66
                 0,361
SC, ST7          0,97178           0,457          91
                 0,355

Denominators
Groups           Denominator            Den.df
CC, CT7          1*Res                    8
CC, JC           1*Res                    8
CC, JT7          1*Res                    8
CC, SC           1*Res                    8
CC, ST7          1*Res                    8
CT7, JC          1*Res                    8
CT7, JT7         1*Res                    8
CT7, SC          1*Res                    8
CT7, ST7         1*Res                    8
JC, JT7          1*Res                    8
JC, SC           1*Res                    8
JC, ST7          1*Res                    8
JT7, SC          1*Res                    8
JT7, ST7         1*Res                    8
SC, ST7          1*Res                    8

Average Distance between/within groups
            CC              CT7              JC
JT7         SC              ST7
CC       0,22272

CT7       0,1675          0,14539

JC       0,56145          0,53275          0,50149

JT7      0,33046          0,29355          0,47362
         0,42464
SC       0,34804          0,30486          0,50056
         0,38292          0,47589
ST7      0,17613          0,12214          0,51951
         0,28627          0,30415          0,14316
Within level '3' of factor 'Time Interval'
                                                            Unique

Groups                 t              P(perm)              perms
                 P(MC)
CC, CT7          9,5433E-3             0,994                 91
                 0,992
CC, JC             0,1764              0,898                 56
                 0,861
CC, JT7           0,90805              0,397                 91
                 0,376
CC, SC             1,3498              0,301                126
                 0,208
CC, ST7            1,7811              0,122                 91
                 0,106
CT7, JC           0,26977              0,83                  41
                 0,796
CT7, JT7           1,2434              0,278                 41
                 0,254
CT7, SC            2,0538              0,061                 91
                 0,092
CT7, ST7           2,7401              0,009                 66
                 0,026
```

PERMANOVA post-hoc results of OCR of textile substrates in factor ‘Time Interval’

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem2
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                      Abbrev.          Type         Levels
Layout                    La               Fixed           6
Time Interval             Ti               Fixed           7

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Time Interval'

Within level 'CC' of factor 'Layout'
                                              Unique
Groups            t            P(perm)         perms          P(MC)
0, 1           3,2984           0,008            91           0,012
0, 2           1,7429           0,047           126           0,113
0, 3           2,0021           0,025           126           0,091
```

```
Average Distance between/within groups
        0                1                2                3                4
      5                6
0    1,2201E-2

1      0,29809          0,43415

2      0,67112          0,53361          0,50149

3      0,66874          0,50211          0,35132          0,27567

4       3,0942           2,8931           2,6975           2,6633          3,6198

5       1,6956            1,494           1,2753           1,2112          2,6669
     1,9892
6        2,287           2,0598           1,8148           1,8053          2,6511
     1,8492           2,1028

Within level 'JT7' of factor 'Layout'
                                               Unique
Groups           t            P(perm)          perms          P(MC)
0, 1          4,5752           0,009             56           0,003
0, 2          2,4025           0,044             91           0,047
0, 3          2,0815            0,04             91           0,072
0, 4          5,6318           0,007             91           0,002
0, 5          3,2622           0,007            126           0,016
0, 6          3,9849           0,011             91           0,006
1, 2          1,9175           0,076             41           0,084
1, 3          1,5698           0,139             41           0,156
1, 4          4,9312           0,014             41           0,002
```

```
0, 4        1,9324      0,155      126     0,075
0, 5        4,0004      0,012      126     0,007
0, 6        3,1357      0,006       91     0,014
1, 2        1,0747      0,379       91     0,332
1, 3        1,8085      0,155       66     0,113
1, 4        1,4922       0,23       91     0,163
1, 5        3,0885      0,023       91     0,011
1, 6        2,6303      0,031       66     0,032
2, 3        1,4298      0,275      126     0,199
2, 4       0,65271      0,557      126     0,535
2, 5        1,1049       0,27      126      0,28
2, 6        1,4859      0,173       66     0,163
3, 4        1,0437      0,348      126     0,315
3, 5          1,05        0,4      126     0,341
3, 6       0,70298      0,567       91     0,513
4, 5       0,12907       0,85      126     0,898
4, 6       0,64714      0,494       91     0,513
5, 6       0,69935        0,5       66      0,52

Denominators
Groups     Denominator     Den.df
0, 1       1*Res            8
0, 2       1*Res            8
0, 3       1*Res            8
0, 4       1*Res            8
0, 5       1*Res            8
0, 6       1*Res            8
1, 2       1*Res            8
1, 3       1*Res            8
1, 4       1*Res            8
1, 5       1*Res            8
1, 6       1*Res            8
2, 3       1*Res            8
2, 4       1*Res            8
2, 5       1*Res            8
2, 6       1*Res            8
3, 4       1*Res            8
3, 5       1*Res            8
3, 6       1*Res            8
4, 5       1*Res            8
4, 6       1*Res            8
5, 6       1*Res            8

Average Distance between/within groups
        0              1              2              3
      4              5              6
0   1,0786E-2

1   5,8545E-2      4,1841E-2

2    0,16353        0,13609        0,22272

3    0,61497        0,58933        0,58368        0,83413

4    0,28054        0,26835        0,27524        0,58822
    0,37766
5    0,28364        0,23196        0,22618        0,54954
     0,2619        0,19434
6    0,38217        0,33049        0,30215          0,568
    0,31575        0,25564        0,33025

Within level 'CT7' of factor 'Layout'
                                          Unique
Groups          t          P(perm)         perms        P(MC)
0, 1         1,8543         0,009          126         0,101
0, 2         3,3235         0,008           91          0,01
0, 3         3,0911         0,014           91         0,008
0, 4         2,6565         0,048          126         0,034
0, 5         1,9045         0,028          126         0,104
0, 6         1,9036         0,067          126         0,101
1, 2        0,74148         0,601           91         0,498
1, 3         1,0891         0,254           91         0,319
1, 4        0,28358         0,819          126         0,792
1, 5         1,3215         0,315           91         0,237
1, 6         1,3537          0,28          125         0,206
2, 3         2,0599         0,051           66         0,072
2, 4        0,68658         0,551           91         0,509
2, 5         1,5902         0,219           91         0,144
2, 6         1,6067          0,22           91         0,164
3, 4         1,5537         0,146           91         0,168
3, 5        0,86043         0,418           91         0,402
3, 6        0,91585         0,425           91         0,365
4, 5         1,4484         0,313          126         0,196
4, 6          1,473         0,289          126          0,17
5, 6      7,4498E-2         0,891          125         0,938

Denominators
Groups     Denominator     Den.df
0, 1       1*Res            8
0, 2       1*Res            8
0, 3       1*Res            8
0, 4       1*Res            8
0, 5       1*Res            8
0, 6       1*Res            8
1, 2       1*Res            8
1, 3       1*Res            8
1, 4       1*Res            8
1, 5       1*Res            8
1, 6       1*Res            8
2, 3       1*Res            8
2, 4       1*Res            8
2, 5       1*Res            8
2, 6       1*Res            8
3, 4       1*Res            8
3, 5       1*Res            8
3, 6       1*Res            8
4, 5       1*Res            8
4, 6       1*Res            8
5, 6       1*Res            8

Average Distance between/within groups
        0              1              2              3
4       5              6
0   1,6989E-2

1    0,32154        0,44857

2    0,18657        0,28359        0,14539
```

```
1, 5        3,1494      0,011       56     0,011
1, 6          3,74      0,009       41     0,006
2, 3       0,31407      0,781       66     0,749
2, 4        1,3018      0,224       66     0,235
2, 5        2,6296      0,015       91     0,027
2, 6        2,4753      0,049       66      0,05
3, 4        1,7151      0,108       41     0,129
3, 5        2,7353      0,017       66     0,024
3, 6        2,6987      0,008       66     0,025
4, 5        2,2965      0,026       91     0,055
4, 6        1,8528      0,084       66     0,108
5, 6        1,2857      0,263       91     0,246

Denominators
Groups     Denominator     Den.df
0, 1       1*Res            8
0, 2       1*Res            8
0, 3       1*Res            8
0, 4       1*Res            8
0, 5       1*Res            8
0, 6       1*Res            8
1, 2       1*Res            8
1, 3       1*Res            8
1, 4       1*Res            8
1, 5       1*Res            8
1, 6       1*Res            8
2, 3       1*Res            8
2, 4       1*Res            8
2, 5       1*Res            8
2, 6       1*Res            8
3, 4       1*Res            8
3, 5       1*Res            8
3, 6       1*Res            8
4, 5       1*Res            8
4, 6       1*Res            8
5, 6       1*Res            8

Average Distance between/within groups
        0              1              2              3
4       5              6
0    2,316E-2

1   7,5686E-2      3,0578E-2

2    0,38723         0,3408        0,42464

3    0,41216        0,36675         0,3531        0,37145

4    0,62935        0,55367        0,38802        0,38676
    0,28661
5     2,1967          2,121         1,8442         1,8863
1,6191             1,8651
6     1,2427          1,167        0,90859        0,93227
    0,69422         1,3597         0,8391

Within level 'SC' of factor 'Layout'
                                          Unique
Groups          t          P(perm)         perms        P(MC)
0, 1         7,2605         0,009          126         0,001
0, 2         2,1855         0,005          126         0,051
0, 3         3,9959         0,007          126         0,003
0, 4         2,3422         0,009           91         0,045
0, 5         2,8775         0,009          126         0,018
0, 6         4,1605          0,01           91         0,005
1, 2         1,3274         0,149          126         0,204
1, 3        0,77669         0,524           66         0,468
1, 4        0,60272          0,52           91         0,513
1, 5         2,4751         0,011          126         0,044
1, 6          3,677          0,01           91          0,01
2, 3         1,0718         0,382          126          0,34
2, 4        0,92526         0,473           91         0,386
2, 5         1,6762          0,14          125         0,127
2, 6          2,561         0,043           91         0,024
3, 4        0,13964         0,895           91         0,888
3, 5         2,3538         0,024          126         0,043
3, 6         3,5181         0,011           91         0,004
4, 5         2,2757         0,033           91         0,051
4, 6         3,3871         0,007           66         0,007
5, 6        0,46536         0,656           91         0,644

Denominators
Groups     Denominator     Den.df
0, 1       1*Res            8
0, 2       1*Res            8
0, 3       1*Res            8
0, 4       1*Res            8
0, 5       1*Res            8
0, 6       1*Res            8
1, 2       1*Res            8
1, 3       1*Res            8
1, 4       1*Res            8
1, 5       1*Res            8
1, 6       1*Res            8
2, 3       1*Res            8
2, 4       1*Res            8
2, 5       1*Res            8
2, 6       1*Res            8
3, 4       1*Res            8
3, 5       1*Res            8
3, 6       1*Res            8
4, 5       1*Res            8
4, 6       1*Res            8
5, 6       1*Res            8

Average Distance between/within groups
        0              1              2              3
4       5              6
0   1,3456E-2

1    0,16265      5,4525E-2

2     0,4182        0,31001        0,47589

3    0,20594      9,8577E-2        0,30886        0,14067

4    0,22092        0,17304        0,33609        0,18695
    0,24979
5     1,1728         1,0102        0,91825           0,98
    0,98819         1,1351
```

```
3       0,60656              0,48166          0,44372          0,49559

4       0,28392              0,32833          0,20148          0,41294
      0,26277
5        1,1567               1,0918           1,0703           1,0796
1,0752                       1,6107
6        1,2823               1,2002           1,1909           1,1681
1,1787                       1,3668           1,7424

Within level 'JC' of factor 'Layout'
                                                    Unique
Groups           t              P(perm)              perms          P(MC)
0, 1          1,6631              0,026               126           0,126
0, 2          3,6794              0,006               126           0,007
0, 3          5,8575               0,01                56           0,002
0, 4          2,2661              0,006               126           0,059
0, 5          2,0916              0,002               126           0,072
0, 6          2,9655              0,006               126           0,014
1, 2          1,4693              0,176               126           0,164
1, 3          1,7592              0,171                56           0,127
1, 4          2,0317              0,074               126           0,076
1, 5          1,6857              0,059               126           0,125
1, 6          2,5148              0,026               126           0,034
2, 3        1,103E-2                  1                56           0,992
2, 4           1,759              0,128               126            0,11
2, 5           1,233              0,275               126           0,242
2, 6          2,0391              0,048               126           0,066
3, 4          1,7702              0,156                56           0,108
3, 5          1,2544              0,284                56           0,246
3, 6          2,0758               0,04                56            0,08
4, 5         0,88071              0,357               126           0,404
4, 6         0,51471              0,587               126           0,627
5, 6         0,52852              0,614                91            0,61

Denominators
Groups        Denominator               Den.df
0, 1          1*Res                       8
0, 2          1*Res                       8
0, 3          1*Res                       8
0, 4          1*Res                       8
0, 5          1*Res                       8
0, 6          1*Res                       8
1, 2          1*Res                       8
1, 3          1*Res                       8
1, 4          1*Res                       8
1, 5          1*Res                       8
1, 6          1*Res                       8
2, 3          1*Res                       8
2, 4          1*Res                       8
2, 5          1*Res                       8
2, 6          1*Res                       8
3, 4          1*Res                       8
3, 5          1*Res                       8
3, 6          1*Res                       8
4, 5          1*Res                       8
4, 6          1*Res                       8
5, 6          1*Res                       8
```

```
6       1,4202               1,2576           1,0705           1,2143
1,1993                      0,89698           0,9346

Within level 'ST7' of factor 'Layout'
                                                    Unique
Groups           t              P(perm)              perms          P(MC)
0, 1          3,0138              0,007               126           0,021
0, 2          2,9687              0,006                91           0,026
0, 3         0,55125               0,57                91           0,565
0, 4         0,20468              0,874                66           0,844
0, 5          1,4131              0,369               126           0,197
0, 6          3,7712              0,006               126           0,006
1, 2         0,19908              0,818                66           0,851
1, 3          2,3138               0,07                91           0,067
1, 4          2,8248               0,02                66           0,017
1, 5         0,62361              0,653               126           0,538
1, 6          3,1335               0,01               125           0,016
2, 3          2,2045               0,03                66           0,053
2, 4          2,7503              0,024                30           0,021
2, 5         0,69319              0,616                91           0,528
2, 6          3,1927              0,017                91           0,014
3, 4          0,5737              0,642                48           0,584
3, 5          1,3122              0,345                91           0,253
3, 6          3,6828              0,006                91           0,008
4, 5          1,4296              0,331                66           0,195
4, 6           3,776              0,006                66           0,008
5, 6          2,1577              0,065               126           0,054

Denominators
Groups        Denominator               Den.df
0, 1          1*Res                       8
0, 2          1*Res                       8
0, 3          1*Res                       8
0, 4          1*Res                       8
0, 5          1*Res                       8
0, 6          1*Res                       8
1, 2          1*Res                       8
1, 3          1*Res                       8
1, 4          1*Res                       8
1, 5          1*Res                       8
1, 6          1*Res                       8
2, 3          1*Res                       8
2, 4          1*Res                       8
2, 5          1*Res                       8
2, 6          1*Res                       8
3, 4          1*Res                       8
3, 5          1*Res                       8
3, 6          1*Res                       8
4, 5          1*Res                       8
4, 6          1*Res                       8
5, 6          1*Res                       8

Average Distance between/within groups
             0                    1                2                3
4       5                    6
0     2,4634E-2

1      0,18646              0,16929

2      0,16987              0,13137          0,14316

3     6,5832E-2             0,17559          0,15673        9,9182E-2

4       5,54E-2             0,19598          0,17631         8,102E-2
      8,0435E-2
5      0,37383              0,40187          0,39856          0,39057
0,3914                      0,61962
6        1,208               1,0335           1,0492            1,187
1,2144                        1,009          0,87735
```

PERMADISP results of OCR

PERMDISP
Distance-based test for homogeneity of multivariate dispersions

Resemblance worksheet
Name: Resem2
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Group factor: Time Interval
Number of permutations: 999

Number of groups: 7
Number of samples: 210

DEVIATIONS FROM CENTROID
F: 11,384 df1: 6 df2: 203
P(perm): 0,001

PAIRWISE COMPARISONS

```
Groups          t          P(perm)
(0,1)        4,1072          1E-3
(0,2)        6,6218          1E-3
```

```
(0,3)          6,7892          1E-3
(0,4)          3,3894          1E-3
(0,5)          6,9772          1E-3
(0,6)          7,1476          1E-3
(1,2)          2,1202         0,134
(1,3)          3,1015        3,4E-2
(1,4)          2,7992          3E-3
(1,5)           5,854          1E-3
(1,6)          5,8027          1E-3
(2,3)          1,2219          0,34
(2,4)          2,3688         0,151
(2,5)          5,1113          1E-3
(2,6)           4,937          1E-3
(3,4)          2,0633          0,27
(3,5)          4,5383          1E-3
(3,6)          4,2648          1E-3
(4,5)         0,59354         0,714
(4,6)         0,15625         0,923
(5,6)         0,66773         0,589

MEANS AND STANDARD ERRORS
Group     Size     Average           SE
0           30     1,5431E-2     2,9063E-3
1           30       0,15237     3,3214E-2
2           30       0,25672     3,6323E-2
3           30       0,32833     4,5997E-2
4           30       0,83786       0,24263
5           30        1,0047       0,14175
6           30       0,88023       0,12096
```

PERMADISP results of OCR in sisal layouts

```
PERMDISP
Distance-based test for homogeneity of multivariate dispersions

Resemblance worksheet
Name: Resem7
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Group factor: Time Interval
Number of permutations: 999

Number of groups: 3
Number of samples: 30

DEVIATIONS FROM CENTROID
F: 7,6866  df1: 2  df2: 27
P(perm): 0,005

PAIRWISE COMPARISONS
Groups              t          P(perm)
(4,5)          3,7312             1E-3
(4,6)          3,9611             1E-3
(5,6)         0,42698            0,704

MEANS AND STANDARD ERRORS
Group     Size     Average          SE
4           10     0,12501     3,5612E-2
5           10     0,65535        0,1376
6           10     0,58032       0,10929
```

PERMANOVA post-hoc results of OCR duplication of textile substrates in factor ‘Layout’

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem1
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 999

Factors
Name          Abbrev.          Type          Levels
```

```
Layout         La              Fixed           6

PAIR-WISE TESTS

Term 'La'

                                                Unique
Groups              t            P(perm)         perms        P(MC)
CC, CT7          1,3028           0,196            88         0,218
CC, JC           0,76562          0,471            91         0,478
CC, JT7          1,5909           0,135            63         0,144
CC, SC            2,368           0,097            66          0,04
CC, ST7          2,9858           0,008            91         0,022
CT7, JC          2,1312           0,046           126         0,065
CT7, JT7         0,11762          0,914            91         0,927
CT7, SC          1,1811            0,37            91         0,263
CT7, ST7         2,0808           0,045           126         0,057
JC, JT7          2,5094           0,038            91         0,039
JC, SC           3,2626           0,032            91         0,011
JC, ST7          3,8486            0,01           126         0,005
JT7, SC          2,1728            0,07            66         0,053
JT7, ST7          4,342           0,011            91         0,003
SC, ST7          3,6831           0,011            91         0,008

Denominators
Groups           Denominator          Den.df
CC, CT7          1*Res                  8
CC, JC           1*Res                  8
CC, JT7          1*Res                  8
CC, SC           1*Res                  8
CC, ST7          1*Res                  8
CT7, JC          1*Res                  8
CT7, JT7         1*Res                  8
CT7, SC          1*Res                  8
CT7, ST7         1*Res                  8
JC, JT7          1*Res                  8
JC, SC           1*Res                  8
JC, ST7          1*Res                  8
JT7, SC          1*Res                  8
JT7, ST7         1*Res                  8
SC, ST7          1*Res                  8

Average Distance between/within groups
           CC           CT7           JC            JT7           SC            ST7
CC       258,33
CT7      228,65       173,68
JC        236,1       300,82       275,88
JT7      217,43       124,07       300,86        78,806
SC       244,01       118,95       345,22        76,809        40,144
ST7      285,72       135,71       392,68        126,94        56,812        13,649
```

PERMANOVA results of HOBO loggers (left) and PERMADISP (right)

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem2
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                Abbrev.            Type            Levels
location            lo                 Fixed             2

PAIR-WISE TESTS

Term 'lo'


                                                 Unique
Groups                                             t            P(perm)
                                                 perms          P(MC)
south west, north east                           7,8272           0,001
                                                   996          0,001

Denominators
Groups                                           Denominator
                                                 Den.df
```

```
PERMDISP
Distance-based test for homogeneity of multivariate dispersions

Resemblance worksheet
Name: Resem2
Data type: Distance
Selection: All
Normalise
Resemblance: D1 Euclidean distance

Group factor: location
Number of permutations: 999

Number of groups: 2
Number of samples: 255

DEVIATIONS FROM CENTROID
F: 296,94  df1: 1  df2: 253
P(perm): 0,001

PAIRWISE COMPARISONS
Groups                                                  t            P(perm)
(south west,north east)                              17,232            1E-3

MEANS AND STANDARD ERRORS
Group                 Size        Average          SE
south west             165         1,0188        2,5213E-2
north east              90        0,34749        2,5377E-2
```

```
south west, north east                              1*Res
253

Average Distance between/within groups
                       south west               north east
south west               1,1704
north east               1,1816                   0,48012
```

PERMANOVA results leaf number

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: leaf number
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name              Abbrev.     Type      Levels
Layout            La          Fixed        6
Time Interval     Ti          Fixed        5

PERMANOVA table of results
                                                                      Unique
Source     df        SS          MS        Pseudo-F      P(perm)      perms      P(MC)
La          5      75,873      15,175      0,19753        0,957        999       0,968
Ti          4    1,4256E5       35639       463,92        0,001        999       0,001
LaxTi      20      2941,8      147,09       1,9147        0,015        999       0,012
Res       120      9218,5      76,821
Total     149    1,5479E5

Details of the expected mean squares (EMS) for the model
Source     EMS
La         1*V(Res) + 25*S(La)
Ti         1*V(Res) + 30*S(Ti)
LaxTi      1*V(Res) + 5*S(LaxTi)
Res        1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source     Numerator      Denominator      Num.df     Den.df
La         1*La           1*Res               5        120
Ti         1*Ti           1*Res               4        120
LaxTi      1*LaxTi        1*Res              20        120

Estimates of components of variation
Source         Estimate       Sq.root
S(La)           -2,4659       -1,5703
S(Ti)            1185,4         34,43
S(LaxTi)         14,054        3,7488
V(Res)           76,821        8,7648
```

PERMANOVA post-hoc results of leaf number in factor 'Layout'

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: leaf number
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                          Abbrev.          Type          Levels
Layout                        La               Fixed            6
Time Interval                 Ti               Fixed            5

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Layout'

Within level '0' of factor 'Time Interval'

                              Unique
Groups                                  t                          P(perm)
                               perms                               P(MC)
CC, CT7                       Denominator is 0
```

```
Denominators
Groups                    Denominator               Den.df
CC, CT7                   1*Res                        8
CC, SC                    1*Res                        8
CC, ST7                   1*Res                        8
CC, FT                    1*Res                        8
CC, Control               1*Res                        8
CT7, SC                   1*Res                        8
CT7, ST7                  1*Res                        8
CT7, FT                   1*Res                        8
CT7, Control              1*Res                        8
SC, ST7                   1*Res                        8
SC, FT                    1*Res                        8
SC, Control               1*Res                        8
ST7, FT                   1*Res                        8
ST7, Control              1*Res                        8
FT, Control               1*Res                        8

Average Distance between/within groups
                 CC            CT7            SC            ST7            FT
               Control
CC             12,039

CT7            8,9255         5,2536

SC             9,1908         7,6191         8,7989

ST7            10,847         8,3396         9,6701         12,574
```

CC, SC	Denominator is 0
CC, ST7	Denominator is 0
CC, FT	Denominator is 0
CC, Control	Denominator is 0
CT7, SC	Denominator is 0
CT7, ST7	Denominator is 0
CT7, FT	Denominator is 0
CT7, Control	Denominator is 0
SC, ST7	Denominator is 0
SC, FT	Denominator is 0
SC, Control	Denominator is 0
ST7, FT	Denominator is 0
ST7, Control	Denominator is 0
FT, Control	Denominator is 0

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	0
CC, SC	1*Res	0
CC, ST7	1*Res	0
CC, FT	1*Res	0
CC, Control	1*Res	0
CT7, SC	1*Res	0
CT7, ST7	1*Res	0
CT7, FT	1*Res	0
CT7, Control	1*Res	0
SC, ST7	1*Res	0
SC, FT	1*Res	0
SC, Control	1*Res	0
ST7, FT	1*Res	0
ST7, Control	1*Res	0
FT, Control	1*Res	0

Average Distance between/within groups

	CC	CT7	SC	ST7	FT	Control
CC	0					
CT7	0	0				
SC	0	0	0			
ST7	0	0	0	0		
FT	0	0	0	0	0	
Control	0	0	0	0	0	0

Within level '1' of factor 'Time Interval'

Groups	t	P(perm)	Unique perms	P(MC)
CC, CT7	1,8259	0,101	91	0,106
CC, SC	3,2294	0,034	91	0,01
CC, ST7	2,2454	0,054	91	0,06
CC, FT	2,9521	0,019	91	0,019
CC, Control	1,2204	0,263	66	0,282
CT7, SC	2,0443	0,104	91	0,084
CT7, ST7	1,1835	0,253	126	0,26
CT7, FT	1,925	0,072	126	0,096
CT7, Control	5,1327E-2	0,986	91	0,962
SC, ST7	0,18669	0,854	116	0,865
SC, FT	0,82307	0,466	126	0,436
SC, Control	1,1305	0,306	91	0,286
ST7, FT	0,43564	0,657	126	0,682
ST7, Control	0,96784	0,365	91	0,36
FT, Control	1,4858	0,185	66	0,193

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CC, FT	1*Res	8
CC, Control	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
CT7, FT	1*Res	8
CT7, Control	1*Res	8
SC, ST7	1*Res	8
SC, FT	1*Res	8
SC, Control	1*Res	8
ST7, FT	1*Res	8
ST7, Control	1*Res	8
FT, Control	1*Res	8

Average Distance between/within groups

	CC	CT7	SC	ST7	FT	Control
CC	11,762					
CT7	12,279	7,0031				
SC	17,116	7,8417	6,2593			
FT	10,26	9,6728	8,2524	10,976	10,354	
Control	13,523	14,811	11,106	14,447	10,386	10,347

Within level '3' of factor 'Time Interval'

Groups	t	P(perm)	Unique perms	P(MC)
CC, CT7	0,84707	0,409	126	0,42
CC, SC	1,8726	0,113	126	0,095
CC, ST7	1,3347	0,202	126	0,192
CC, FT	1,4101	0,217	126	0,205
CC, Control	0,58859	0,562	126	0,565
CT7, SC	0,85482	0,419	116	0,401
CT7, ST7	0,49004	0,703	126	0,623
CT7, FT	0,5929	0,564	126	0,57
CT7, Control	0,4058	0,667	126	0,685
SC, ST7	0,26206	0,804	81	0,794
SC, FT	0,10862	0,921	123	0,925
SC, Control	1,641	0,148	126	0,144
ST7, FT	0,11866	0,918	126	0,914
ST7, Control	0,97986	0,312	126	0,395
FT, Control	1,0745	0,315	126	0,3

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CC, FT	1*Res	8
CC, Control	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
CT7, FT	1*Res	8
CT7, Control	1*Res	8
SC, ST7	1*Res	8
SC, FT	1*Res	8
SC, Control	1*Res	8
ST7, FT	1*Res	8
ST7, Control	1*Res	8
FT, Control	1*Res	8

Average Distance between/within groups

	CC	CT7	SC	ST7	FT	Control
CC	12,721					
CT7	11,835	12,987				
SC	13,063	9,937	8,0741			
ST7	13,42	11,235	8,7302	12,284		
FT	13,855	11,649	9,6157	11,254	14,1	
Control	9,9687	9,5151	9,0712	10,879	10,897	8,8069

Within level '4' of factor 'Time Interval'

Groups	t	P(perm)	Unique perms	P(MC)
CC, CT7	0,5963	0,635	66	0,589
CC, SC	1,6	0,147	91	0,161
CC, ST7	1,1955	0,285	49	0,271
CC, FT	1,1861	0,324	66	0,26
CC, Control	0,36326	0,905	23	0,73
CT7, SC	0,99468	0,214	66	0,37
CT7, ST7	0,65617	0,584	91	0,527
CT7, FT	0,85357	0,559	91	0,423
CT7, Control	0,9535	0,451	41	0,352
SC, ST7	0,26142	0,762	91	0,808
SC, FT	0,23749	0,97	126	0,814
SC, Control	1,9579	0,082	91	0,084
ST7, FT	0,40542	0,709	126	0,682
ST7, Control	1,5068	0,193	56	0,165
FT, Control	1,3643	0,239	91	0,223

Denominators

Groups	Denominator	Den.df
CC, CT7	1*Res	8
CC, SC	1*Res	8
CC, ST7	1*Res	8
CC, FT	1*Res	8
CC, Control	1*Res	8
CT7, SC	1*Res	8
CT7, ST7	1*Res	8
CT7, FT	1*Res	8
CT7, Control	1*Res	8
SC, ST7	1*Res	8
SC, FT	1*Res	8
SC, Control	1*Res	8
ST7, FT	1*Res	8
ST7, Control	1*Res	8
FT, Control	1*Res	8

Average Distance between/within groups

	CC	CT7	SC	ST7	FT	Control
CC	7,5251					
CT7	7,3214	7,6242				
SC	10,415	8,9132	10,442			
ST7	10,116	9,2925	9,4704	12,054		
FT	14,103	12,768	14,052	14,431	19,965	
Control	5,7532	6,6259	10,677	10,278	13,824	6,1265

```
ST7              19,846          14,025          12,562          16,854

FT               22,311            13,5          10,366          14,523
                 15,462
Control          14,754          10,423          11,789          16,064
                 16,098           16,151

Within level '2' of factor 'Time Interval'
                                                                 Unique
Groups                          t               P(perm)          perms
                           P(MC)
CC, CT7                    0,59016              0,573              91
                           0,589
CC, SC                     0,55071              0,606             126
                           0,632
CC, ST7                    0,16006              0,838              66
                           0,867
CC, FT                     0,90469              0,358              66
                           0,385
CC, Control                 1,7879                0,1              91
                           0,102
CT7, SC                     1,5591              0,134              66
                           0,158
CT7, ST7                   0,36085              0,807              66
                           0,728
CT7, FT                     1,8934              0,097              66
                           0,093
CT7, Control                2,9822              0,043              91
                           0,016
SC, ST7                    0,71231              0,502              91
0,51
SC, FT                     0,46035               0,59              91
0,66
SC, Control                 1,5034              0,176             126
                           0,186
ST7, FT                     1,0459              0,291              66
                           0,304
ST7, Control                 1,898               0,09              91
                           0,087
FT, Control                0,98842              0,375              91
                           0,364
```

PERMANOVA post-hoc results of leaf number in factor ‘Time Interval’

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: leaf number
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                        Abbrev.          Type          Levels
Layout                      La               Fixed              6
Time Interval               Ti               Fixed              5

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Time Interval'

Within level 'CC' of factor 'Layout'
                                                  Unique
Groups           t            P(perm)             perms          P(MC)
0, 1          5,1835            0,011               12           0,002
0, 2           12,89            0,011               16           0,001
0, 3          16,307            0,011               16           0,001
0, 4          33,724            0,004               12           0,001
1, 2          5,2959            0,011               91           0,001
1, 3          8,1732            0,009               91           0,001
1, 4          13,308            0,012               66           0,001
2, 3          3,0818            0,026              116           0,014
2, 4          7,1322             0,01               81           0,001
3, 4          3,1712             0,01               71           0,015

Denominators
Groups        Denominator                 Den.df
0, 1          1*Res                          8
0, 2          1*Res                          8
0, 3          1*Res                          8
0, 4          1*Res                          8
1, 2          1*Res                          8
1, 3          1*Res                          8
1, 4          1*Res                          8
2, 3          1*Res                          8
2, 4          1*Res                          8
3, 4          1*Res                          8

Average Distance between/within groups
         0               1               2               3               4
0        0
1   23,476          11,762
2   56,997          33,522          12,039
3   76,924          53,448          20,956          12,721
4   94,314          70,839          37,317          17,391
    7,5251

Within level 'CT7' of factor 'Layout'
                                                  Unique
Groups           t            P(perm)             perms          P(MC)
```

```
Within level 'ST7' of factor 'Layout'
                                                  Unique
Groups           t            P(perm)             perms          P(MC)
0, 1           6,441            0,007               16           0,002
0, 2          12,394             0,01               12           0,001
0, 3          14,472            0,007               16           0,001
0, 4          19,597             0,01               16           0,001
1, 2          2,1511            0,067               91           0,063
1, 3          3,4121            0,007              126           0,012
1, 4          6,0269            0,007              126           0,001
2, 3          1,5082            0,202               91            0,16
2, 4          4,6188            0,011               91           0,002
3, 4          3,0697            0,017              116           0,017

Denominators
Groups        Denominator                 Den.df
0, 1          1*Res                          8
0, 2          1*Res                          8
0, 3          1*Res                          8
0, 4          1*Res                          8
1, 2          1*Res                          8
1, 3          1*Res                          8
1, 4          1*Res                          8
2, 3          1*Res                          8
2, 4          1*Res                          8
3, 4          1*Res                          8

Average Distance between/within groups
         0               1               2               3               4
0        0
1   41,024          16,854
2   58,028          18,752          12,574
3   68,035          27,011          13,019          12,284
4    87,99          46,966          29,962          21,181          12,054

Within level 'FT' of factor 'Layout'
                                                  Unique
Groups           t            P(perm)             perms          P(MC)
0, 1          7,9983            0,007               16           0,001
0, 2          13,665            0,008               12           0,001
0, 3          13,414            0,008               16           0,001
0, 4          10,548            0,011               16           0,001
1, 2           1,039            0,338               66           0,328
1, 3          2,9974            0,025              126           0,013
1, 4          4,0568            0,027              126           0,004
2, 3          2,4661             0,05               91           0,041
2, 4           3,681            0,017               91           0,004
3, 4          1,8084            0,119              123           0,107

Denominators
Groups        Denominator                 Den.df
0, 1          1*Res                          8
0, 2          1*Res                          8
0, 3          1*Res                          8
0, 4          1*Res                          8
1, 2          1*Res                          8
1, 3          1*Res                          8
1, 4          1*Res                          8
2, 3          1*Res                          8
2, 4          1*Res                          8
3, 4          1*Res                          8
```

```
0, 1          13,153      0,012        16      0,001
0, 2          29,395      0,011        12      0,001
0, 3           15,2       0,015        16      0,001
0, 4          26,936       0,01        12      0,001
1, 2          8,3499      0,007        79      0,001
1, 3          7,2164      0,009       107      0,001
1, 4          13,908      0,006        91      0,001
2, 3           2,233      0,062        51      0,047
2, 4          8,0208      0,009        66      0,001
3, 4          3,5199      0,023        91      0,009

Denominators
Groups        Denominator        Den.df
0, 1          1*Res                 8
0, 2          1*Res                 8
0, 3          1*Res                 8
0, 4          1*Res                 8
1, 2          1*Res                 8
1, 3          1*Res                 8
1, 4          1*Res                 8
2, 3          1*Res                 8
2, 4          1*Res                 8
3, 4          1*Res                 8

Average Distance between/within groups
        0           1           2           3           4
0       0
1    32,924      7,0031
2    59,871      26,946      5,2536
3    71,289      38,364      12,758      12,987
4    91,687      58,763      31,817      20,877
     7,6242

Within level 'SC' of factor 'Layout'
                                       Unique
Groups          t       P(perm)        perms       P(MC)
0, 1          17,909      0,005        16      0,001
0, 2          17,062      0,007        16      0,001
0, 3          23,277      0,007        16      0,001
0, 4          21,196      0,006        16      0,001
1, 2          3,6828      0,018        91      0,011
1, 3          7,4083      0,007       113      0,001
1, 4          10,047      0,008       126      0,001
2, 3           2,951      0,023       116      0,031
2, 4          6,2783      0,011       126      0,002
3, 4          3,9782      0,013       126      0,004

Denominators
Groups        Denominator        Den.df
0, 1          1*Res                 8
0, 2          1*Res                 8
0, 3          1*Res                 8
0, 4          1*Res                 8
1, 2          1*Res                 8
1, 3          1*Res                 8
1, 4          1*Res                 8
2, 3          1*Res                 8
2, 4          1*Res                 8
3, 4          1*Res                 8

Average Distance between/within groups
        0           1           2           3           4
0       0
1    39,765      6,2593
2    54,003      14,238      8,7989
3    66,593      26,828       13,02      8,0741
4    86,405       46,64      32,402      19,886
     10,442
```

```
Average Distance between/within groups
        0           1           2           3           4
0       0
1    44,716      15,462
2    51,731      12,788      10,354
3    67,219      23,495      16,775        14,1
4    84,275      40,116      33,101      22,228      19,965

Within level 'Control' of factor 'Layout'
                                       Unique
Groups          t       P(perm)        perms       P(MC)
0, 1          5,4854      0,009        12      0,001
0, 2          11,268      0,004        16      0,001
0, 3          23,314      0,009        16      0,001
0, 4          40,152      0,015        12      0,001
1, 2          1,8865       0,07        91      0,091
1, 3          6,0923      0,008        91      0,002
1, 4            9,85      0,013        66      0,002
2, 3          5,2884      0,009       116      0,002
2, 4          10,423      0,004        91      0,001
3, 4          5,5804      0,012        90      0,001

Denominators
Groups        Denominator        Den.df
0, 1          1*Res                 8
0, 2          1*Res                 8
0, 3          1*Res                 8
0, 4          1*Res                 8
1, 2          1*Res                 8
1, 3          1*Res                 8
1, 4          1*Res                 8
2, 3          1*Res                 8
2, 4          1*Res                 8
3, 4          1*Res                 8

Average Distance between/within groups
        0           1           2           3           4
0       0
1    32,593      16,151
2    46,214      16,058      10,347
3    73,583      40,989      27,369      8,8069
4    95,649      63,055      49,435      22,066      6,1265
```

PERMANOVA results of relative shoot survival rate

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: survivalrate
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name              Abbrev.    Type     Levels
Layout            La         Fixed       6
Time Interval     Ti         Fixed       5

PERMANOVA table of results
                                                               Unique
Source    df      SS         MS      Pseudo-F    P(perm)      perms     P(MC)
La         5     3160        632      3,3147      0,012        997      0,008
Ti         4    94427      23607      123,81      0,001        998      0,001
LaxTi     20    5733,3    286,67      1,5035      0,095        998      0,085
Res      120    22880     190,67
Total    149  1,262E5
```

```
Details of the expected mean squares (EMS) for the model
Source      EMS
La          1*V(Res) + 25*S(La)
Ti          1*V(Res) + 30*S(Ti)
LaxTi       1*V(Res) + 5*S(LaxTi)
Res         1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source      Numerator      Denominator        Num.df     Den.df
La          1*La           1*Res                 5         120
Ti          1*Ti           1*Res                 4         120
LaxTi       1*LaxTi        1*Res                20         120

Estimates of components of variation
Source          Estimate      Sq.root
S(La)             17,653       4,2016
S(Ti)             780,53       27,938
S(LaxTi)            19,2       4,3818
V(Res)            190,67       13,808
```

PERMANOVA post-hoc results of relative survival rate in factor ‘Layout’

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: survivalrate
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                 Abbrev.        Type        Levels
Layout               La             Fixed          6
Time Interval        Ti             Fixed          5

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Layout'

Within level '0' of factor 'Time Interval'

                     Unique
Groups                     t                          P(perm)
                      perms                           P(MC)
CC, CT7              Denominator is 0

CC, SC               Denominator is 0

CC, ST7              Denominator is 0

CC, FT               Denominator is 0

CC, Control          Denominator is 0

CT7, SC              Denominator is 0

CT7, ST7             Denominator is 0

CT7, FT              Denominator is 0

CT7, Control         Denominator is 0

SC, ST7              Denominator is 0

SC, FT               Denominator is 0

SC, Control          Denominator is 0

ST7, FT              Denominator is 0

ST7, Control         Denominator is 0

FT, Control          Denominator is 0


Denominators
Groups               Denominator          Den.df
CC, CT7              1*Res                   0
CC, SC               1*Res                   0
CC, ST7              1*Res                   0
CC, FT               1*Res                   0
CC, Control          1*Res                   0
CT7, SC              1*Res                   0
CT7, ST7             1*Res                   0
CT7, FT              1*Res                   0
CT7, Control         1*Res                   0
SC, ST7              1*Res                   0
SC, FT               1*Res                   0
SC, Control          1*Res                   0
ST7, FT              1*Res                   0
ST7, Control         1*Res                   0
FT, Control          1*Res                   0

Average Distance between/within groups
                CC      CT7      SC      ST7      FT      Control
CC              0
CT7             0       0
SC              0       0        0
```

```
Within level '2' of factor 'Time Interval'
                                                                      Unique

Groups                      t                          P(perm)         perms
                     P(MC)
CC, CT7                   1,2649                        0,526             3
                      0,24
CC, SC                       1                            1               1
                      0,35
CC, ST7                 6,2336E-9                         1               2
                        1
CC, FT                       1                            1               1
                     0,334
CC, Control                  1                            1               1
                     0,381
CT7, SC                   2,4495                        0,159             2
                     0,037
CT7, ST7                  1,2649                        0,506             3
                      0,24
CT7, FT                   2,4495                          0,2             2
                     0,044
CT7, Control              2,4495                        0,159             2
                     0,036
SC, ST7                      1                            1               1
                     0,334
SC, FT               Denominator is 0

SC, Control          Denominator is 0

ST7, FT                      1                            1               1
                     0,333
ST7, Control                 1                            1               1
                     0,321
FT, Control          Denominator is 0

Denominators
Groups               Denominator            Den.df
CC, CT7              1*Res                     8
CC, SC               1*Res                     8
CC, ST7              1*Res                     8
CC, FT               1*Res                     8
CC, Control          1*Res                     8
CT7, SC              1*Res                     8
CT7, ST7             1*Res                     8
CT7, FT              1*Res                     8
CT7, Control         1*Res                     8
SC, ST7              1*Res                     8
SC, FT               1*Res                     0
SC, Control          1*Res                     0
ST7, FT              1*Res                     8
ST7, Control         1*Res                     8
FT, Control          1*Res                     0

Average Distance between/within groups
                CC       CT7       SC      ST7      FT      Control
CC               8
CT7           11,2        12
SC               4        12        0
ST7            6,4      11,2        4        8
FT               4        12        0        4       0
Control          4        12        0        4       0          0

Within level '3' of factor 'Time Interval'
                                                       Unique
Groups                 t            P(perm)             perms          P(MC)
CC, CT7             0,35355            1                  4            0,773
CC, SC               4,4272          0,024                4            0,003
CC, ST7               2,132          0,153                4            0,062
CC, FT               1,1767          0,441                4            0,285
CC, Control         0,63246          0,741                5            0,523
CT7, SC              2,1909          0,132                5            0,062
CT7, ST7             1,2344          0,378                5            0,249
CT7, FT             0,58977          0,777                5            0,575
CT7, Control         0,2582            1                  5            0,815
SC, ST7             0,89443           0,73                3            0,398
SC, FT                1,633          0,282                4            0,132
SC, Control          1,6222          0,272                4            0,135
ST7, FT             0,66667           0,78                5            0,537
ST7, Control        0,84853          0,598                5            0,414
FT, Control         0,27217            1                  5             0,79
```

```
ST7             0       0       0       0
FT              0       0       0       0       0
Control         0       0       0       0       0       0

Within level '1' of factor 'Time Interval'

                          Unique
Groups                            t                        P(perm)
                           perms                           P(MC)
CC, CT7                   Denominator is 0

CC, SC                    Denominator is 0

CC, ST7                           1                              1
                              1                            0,328
CC, FT                    Denominator is 0

CC, Control               Denominator is 0

CT7, SC                   Denominator is 0

CT7, ST7                          1                              1
                              1                            0,342
CT7, FT                   Denominator is 0

CT7, Control              Denominator is 0

SC, ST7                           1                              1
                              1                            0,355
SC, FT                    Denominator is 0

SC, Control               Denominator is 0

ST7, FT                           1                              1
                              1                             0,35
ST7, Control                      1                              1
                              1                            0,315
FT, Control               Denominator is 0


Denominators
Groups                    Denominator              Den.df
CC, CT7                   1*Res                         0
CC, SC                    1*Res                         0
CC, ST7                   1*Res                         8
CC, FT                    1*Res                         0
CC, Control               1*Res                         0
CT7, SC                   1*Res                         0
CT7, ST7                  1*Res                         8
CT7, FT                   1*Res                         0
CT7, Control              1*Res                         0
SC, ST7                   1*Res                         8
SC, FT                    1*Res                         0
SC, Control               1*Res                         0
ST7, FT                   1*Res                         8
ST7, Control              1*Res                         8
FT, Control               1*Res                         0

Average Distance between/within groups
                CC      CT7     SC      ST7     FT      Control
CC              0
CT7             0       0
SC              0       0       0
ST7             4       4       4       8
FT              0       0       0       4       0
Control         0       0       0       4       0       0
```

```
Denominators
Groups                    Denominator              Den.df
CC, CT7                   1*Res                         8
CC, SC                    1*Res                         8
CC, ST7                   1*Res                         8
CC, FT                    1*Res                         8
CC, Control               1*Res                         8
CT7, SC                   1*Res                         8
CT7, ST7                  1*Res                         8
CT7, FT                   1*Res                         8
CT7, Control              1*Res                         8
SC, ST7                   1*Res                         8
SC, FT                    1*Res                         8
SC, Control               1*Res                         8
ST7, FT                   1*Res                         8
ST7, Control              1*Res                         8
FT, Control               1*Res                         8

Average Distance between/within groups
                CC        CT7       SC        ST7       FT        Control
CC              12
CT7             18,4      28
SC              28        25,6      8
ST7             23,2      24        12,8      20
FT              18,4      22,4      19,2      19,2      24
Control         22,4      24,8      23,2      23,2      23,2      32

Within level '4' of factor 'Time Interval'
                                                                 Unique
Groups                      t                 P(perm)            perms        P(MC)
CC, CT7                   1,4434              0,294                4          0,184
CC, SC                    3,2863              0,041                5          0,013
CC, ST7                   1,8383               0,16                6          0,109
CC, FT                     1,633              0,246                5          0,145
CC, Control               Negative
CT7, SC                   1,1314              0,418                5          0,299
CT7, ST7                 0,45291              0,843                6          0,651
CT7, FT                   0,2325                1                  5          0,845
CT7, Control              1,4434              0,314                4          0,183
SC, ST7                   0,5164              0,846                5           0,62
SC, FT                   0,80178              0,581                5          0,449
SC, Control               3,2863              0,024                5          0,011
ST7, FT                  0,21822                1                  6          0,821
ST7, Control              1,8383              0,178                6          0,112
FT, Control                1,633              0,209                5          0,141

Denominators
Groups                    Denominator              Den.df
CC, CT7                   1*Res                         8
CC, SC                    1*Res                         8
CC, ST7                   1*Res                         8
CC, FT                    1*Res                         8
CC, Control               1*Res                         8
CT7, SC                   1*Res                         8
CT7, ST7                  1*Res                         8
CT7, FT                   1*Res                         8
CT7, Control              1*Res                         8
SC, ST7                   1*Res                         8
SC, FT                    1*Res                         8
SC, Control               1*Res                         8
ST7, FT                   1*Res                         8
ST7, Control              1*Res                         8
FT, Control               1*Res                         8

Average Distance between/within groups
                CC        CT7       SC      ST7       FT        Control
CC              20
CT7             24,8      28
SC              36        27,2      20
ST7             34,4      30,4      24      36
FT              28,8      24,8      28      31,2      32
Control         16        24,8      36      34,4      28,8      20
```

PERMANOVA post-hoc results of relative survival rate in factor ‘Time Interval’

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: survivalrate
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                          Abbrev.          Type        Levels
Layout                        La               Fixed          6
Time Interval                 Ti               Fixed          5

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Time Interval'

Within level 'CC' of factor 'Layout'
                                                                Unique

Groups                  t                          P(perm)             perms
               P(MC)
0, 1           Denominator is 0
```

```
Within level 'ST7' of factor 'Layout'
                                                          Unique
Groups            t               P(perm)                 perms          P(MC)
0, 1              1                  1                      1            0,325
0, 2              1                  1                      1            0,341
0, 3             1,5               0,434                    2            0,167
0, 4           4,2212              0,007                    8            0,004
1, 2          6,2336E-9              1                      2              1
1, 3           0,89443             0,742                    3            0,428
1, 4           3,7528              0,015                    7            0,006
2, 3           0,89443             0,731                    3            0,394
2, 4           3,7528              0,016                    7            0,005
3, 4           2,8402              0,037                    7            0,034

Denominators
Groups          Denominator                Den.df
0, 1            1*Res                         8
0, 2            1*Res                         8
0, 3            1*Res                         8
0, 4            1*Res                         8
1, 2            1*Res                         8
1, 3            1*Res                         8
1, 4            1*Res                         8
2, 3            1*Res                         8
2, 4            1*Res                         8
3, 4            1*Res                         8

Average Distance between/within groups
      0        1           2           3          4
0     0
1     4        8
```

```
0, 2                  1                          1              1
               0,344
0, 3                6,532                       0,01            5
               0,001
0, 4               11,225                       0,016           8
               0,001
1, 2                  1                          1              1
               0,356
1, 3                6,532                       0,006           5
               0,001
1, 4               11,225                       0,008           8
               0,001
2, 3               4,4272                       0,026           4
               0,009
2, 4               9,4281                       0,007          10
               0,001
3, 4               5,8138                       0,01            7
               0,002

Denominators
Groups         Denominator            Den.df
0, 1           1*Res                    0
0, 2           1*Res                    8
0, 3           1*Res                    8
0, 4           1*Res                    8
1, 2           1*Res                    8
1, 3           1*Res                    8
1, 4           1*Res                    8
2, 3           1*Res                    8
2, 4           1*Res                    8
3, 4           1*Res                    8

Average Distance between/within groups
      0      1      2      3      4
0     0
1     0      0
2     4      4      8
3    32     32     28     12
4    84     84     80     52     20

Within level 'CT7' of factor 'Layout'
                                                               Unique

Groups                t                       P(perm)          perms
               P(MC)
0, 1           Denominator is 0

0, 2               2,4495                       0,183           2
                0,04
0, 3               2,7456                       0,044           4
               0,021
0, 4                5,488                       0,006           7
               0,001
1, 2               2,4495                       0,169           2
               0,051
1, 3               2,7456                       0,06            4
               0,031
1, 4                5,488                       0,006           7
               0,002
2, 3               1,4142                       0,326           4
               0,185
2, 4                4,111                       0,032           7
               0,004
3, 4               2,3238                       0,103           7
               0,038

Denominators
Groups         Denominator            Den.df
0, 1           1*Res                    0
0, 2           1*Res                    8
0, 3           1*Res                    8
0, 4           1*Res                    8
1, 2           1*Res                    8
1, 3           1*Res                    8
1, 4           1*Res                    8
2, 3           1*Res                    8
2, 4           1*Res                    8
3, 4           1*Res                    8

Average Distance between/within groups
      0      1       2          3         4
0     0
1     0      0
2    12     12      12
3    28     28     20,8        28
4    64     64      52        40,8       28

Within level 'SC' of factor 'Layout'
                                                               Unique

Groups                t                       P(perm)          perms
               P(MC)
0, 1           Denominator is 0

0, 2           Denominator is 0

0, 3                  1                          1              1
               0,367
0, 4                  6                         0,01            7
               0,003
1, 2           Denominator is 0

1, 3                  1                          1              1
                0,35
1, 4                  6                         0,011           7
               0,002
2, 3                  1                          1              1
               0,341
2, 4                  6                         0,008           7
               0,001
3, 4               4,9193                       0,022           6
               0,002

Denominators
Groups         Denominator            Den.df
0, 1           1*Res                    0
0, 2           1*Res                    0
0, 3           1*Res                    8
0, 4           1*Res                    8
1, 2           1*Res                    0
```

```
2      4      6,4        8
3     12     12,8       12,8        20
4     56      52         52        45,6        36

Within level 'FT' of factor 'Layout'
                                                                 Unique
Groups                t                          P(perm)          perms
               P(MC)
0, 1           Denominator is 0
0, 2           Denominator is 0
0, 3                2,2361                        0,182            3
               0,063
0, 4                4,7434                        0,011            8
               0,002
1, 2           Denominator is 0
1, 3                2,2361                        0,192            3
               0,053
1, 4                4,7434                        0,007            8
               0,003
2, 3                2,2361                        0,164            3
0,05
2, 4                4,7434                        0,008            8
               0,002
3, 4                 2,582                        0,086            7
               0,035

Denominators
Groups         Denominator            Den.df
0, 1           1*Res                    0
0, 2           1*Res                    0
0, 3           1*Res                    8
0, 4           1*Res                    8
1, 2           1*Res                    0
1, 3           1*Res                    8
1, 4           1*Res                    8
2, 3           1*Res                    8
2, 4           1*Res                    8
3, 4           1*Res                    8

Average Distance between/within groups
      0      1      2       3        4
0     0
1     0      0
2     0      0      0
3    20     20     20      24
4    60     60     60     43,2      32

Within level 'Control' of factor 'Layout'
                                                                 Unique
Groups                t                          P(perm)          perms
               P(MC)
0, 1           Denominator is 0
0, 2           Denominator is 0
0, 3                 2,058                        0,178            4
               0,084
0, 4                11,225                        0,009            8
               0,001
1, 2           Denominator is 0
1, 3                 2,058                        0,178            4
               0,078
1, 4                11,225                        0,011            8
               0,001
2, 3                 2,058                        0,163            4
0,07
2, 4                11,225                        0,007            8
               0,001
3, 4                4,3301                        0,015            8
               0,004

Denominators
Groups         Denominator            Den.df
0, 1           1*Res                    0
0, 2           1*Res                    0
0, 3           1*Res                    8
0, 4           1*Res                    8
1, 2           1*Res                    0
1, 3           1*Res                    8
1, 4           1*Res                    8
2, 3           1*Res                    8
2, 4           1*Res                    8
3, 4           1*Res                    8

Average Distance between/within groups
      0      1      2      3      4
0     0
1     0      0
2     0      0      0
3    24     24     24     32
4    84     84     84     60     20
```

```
1, 3            1*Res                    8
1, 4            1*Res                    8
2, 3            1*Res                    8
2, 4            1*Res                    8
3, 4            1*Res                    8

Average Distance between/within groups
      0     1     2     3     4
0     0
1     0     0
2     0     0     0
3     4     4     4     8
4    48    48    48    44    20
```

PERMANOVA results (left) and post-hoc results of root segment elongation in factor 'Layout' (right)

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem1
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 999

Factors
Name            Abbrev.          Type         Levels
Layout          La               Fixed            6

PERMANOVA table of results

                Unique
Source          df        SS              MS              Pseudo-F
                P(perm)  perms          P(MC)
La               5       2700,5          540,1            0,79881
0,614              999   0,545
Res             24        16227         676,13

Total           29        18928


Details of the expected mean squares (EMS) for the model
Source          EMS
La              1*V(Res) + 5*S(La)
Res             1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source          Numerator                 Denominator                    Num.df
                Den.df
La              1*La                      1*Res                              5
                   24

Estimates of components of variation
Source          Estimate               Sq.root
S(La)            -27,206                -5,216
V(Res)            676,13                26,003
```

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem1
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 999

Factors
Name            Abbrev.          Type         Levels
Layout          La               Fixed            6

PAIR-WISE TESTS

Term 'La'

                                                            Unique
Groups                   t                 P(perm)          perms           P(MC)
CC, Control           0,17695               0,875            126             0,87
CC, CT7               0,24273               0,812            126            0,807
CC, SC                 1,1878               0,267            126            0,296
CC, ST7               0,17651               0,864            126            0,883
CC, FT               5,4375E-2              0,932            126            0,957
Control, CT7          0,48651               0,631            126             0,65
Control, SC            1,3996               0,201            125            0,225
Control, ST7         2,5458E-2              0,961            126            0,983
Control, FT           0,14425               0,895            126            0,889
CT7, SC                1,1054               0,359            126            0,303
CT7, ST7               0,4277               0,675            126            0,679
CT7, FT               0,35174               0,759            126             0,72
SC, ST7                 1,296               0,221            126            0,213
SC, FT                 1,3226               0,196            126            0,224
ST7, FT               0,14568               0,916            126            0,894

Denominators
Groups                Denominator               Den.df
CC, Control           1*Res                       8
CC, CT7               1*Res                       8
CC, SC                1*Res                       8
CC, ST7               1*Res                       8
CC, FT                1*Res                       8
Control, CT7          1*Res                       8
Control, SC           1*Res                       8
Control, ST7          1*Res                       8
Control, FT           1*Res                       8
CT7, SC               1*Res                       8
CT7, ST7              1*Res                       8
CT7, FT               1*Res                       8
SC, ST7               1*Res                       8
SC, FT                1*Res                       8
ST7, FT               1*Res                       8

Average Distance between/within groups
                     CC           Control            CT7             SC             ST7
                     FT
CC                 32,529

Control            24,286          25,177
```

```
CT7          24,162       21,331       22,633

SC           35,994       35,224       30,942       42,931

ST7          27,879       25,471       26,624       39,632       34,997

FT           23,725       20,129       20,222       33,424       25,376
             24,053
```

PERMANOVA results (left) and post-hoc results of wet weight loss in factor ‘Layout’ (right)

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem1
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 999

Factors
Name           Abbrev.          Type          Levels
Layout         La               Fixed            6

PERMANOVA table of results

               Unique
Source         df        SS           MS             Pseudo-F
               P(perm)  perms         P(MC)
La              5        1300         260,01          2,4286
0,058             999    0,07
Res            24       2569,5        107,06

Total          29       3869,6


Details of the expected mean squares (EMS) for the model
Source         EMS
La             1*V(Res) + 5*S(La)
Res            1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source         Numerator                 Denominator               Num.df
               Den.df
La             1*La                      1*Res                       5
                 24

Estimates of components of variation
Source         Estimate           Sq.root
S(La)            30,589             5,5308
V(Res)           107,06             10,347
```

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem1
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name           Abbrev.          Type          Levels
Layout         La               Fixed            6

PAIR-WISE TESTS

Term 'La'

                                                       Unique
Groups                    t            P(perm)         perms        P(MC)
CC, Control           9,3628E-3         0,986           126         0,989
CC, CT7                 1,2119          0,246           126         0,274
CC, SC                  2,5559          0,045           126         0,028
CC, ST7                0,48595          0,688           126         0,648
CC, FT                  1,4765          0,156           126         0,202
Control, CT7            1,5179           0,2            126         0,194
Control, SC             3,2593          0,014           126         0,017
Control, ST7           0,53622           0,6            126         0,584
Control, FT             1,6186          0,165           126         0,135
CT7, SC                 1,8109          0,101           126         0,107
CT7, ST7                1,6378          0,129           125         0,134
CT7, FT                 0,7387          0,478           126         0,447
SC, ST7                 2,8249          0,051           126         0,018
SC, FT                 0,21115          0,814           126         0,823
ST7, FT                 1,7977          0,136           126         0,105

Denominators
Groups                Denominator           Den.df
CC, Control           1*Res                   8
CC, CT7               1*Res                   8
CC, SC                1*Res                   8
CC, ST7               1*Res                   8
CC, FT                1*Res                   8
Control, CT7          1*Res                   8
Control, SC           1*Res                   8
Control, ST7          1*Res                   8
Control, FT           1*Res                   8
CT7, SC               1*Res                   8
CT7, ST7              1*Res                   8
CT7, FT               1*Res                   8
SC, ST7               1*Res                   8
SC, FT                1*Res                   8
ST7, FT               1*Res                   8

Average Distance between/within groups
                 CC           Control          CT7            SC            ST7
                 FT
CC             13,026

Control        9,3752        9,4352
```

```
CT7        10,884      9,4579      7,6197
SC         15,129      14,417      8,9281      6,7977
ST7        12,572      11,876      14,214      18,369      14,572
FT         16,456      15,356      12,616      13,184      19,937
           18,574
```

PERMANOVA results (left) and post-hoc results of new developed leaf number in factor 'Layout' (right)

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem2
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name            Abbrev.           Type          Levels
Layout          La                Fixed            6

PERMANOVA table of results

                Unique
Source          df        SS              MS               Pseudo-F
                P(perm)  perms            P(MC)
La               5        32,667          6,5333             1,3154
0,294              163    0,293
Res             24         119,2          4,9667

Total           29        151,87


Details of the expected mean squares (EMS) for the model
Source          EMS
La              1*V(Res) + 5*S(La)
Res             1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source          Numerator         Denominator                Num.df
                Den.df
La              1*La              1*Res                         5
                   24

Estimates of components of variation
Source          Estimate          Sq.root
S(La)            0,31333          0,55976
V(Res)            4,9667           2,2286
```

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem2
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name            Abbrev.           Type          Levels
Layout          La                Fixed            6

PAIR-WISE TESTS

Term 'La'

                                                       Unique
Groups               t            P(perm)              perms        P(MC)
CC, CT7           0,42426          0,755                 8          0,703
CC, SC             2,5298          0,073                11          0,036
CC, ST7            1,0265          0,397                 9          0,339
CC, FT            0,49424          0,709                10          0,627
CC, C              1,7408          0,142                 9          0,111
CT7, SC            1,8962          0,138                11          0,111
CT7, ST7          0,54687          0,684                10          0,594
CT7, FT           0,11744            1                  10          0,909
CT7, C             1,1068          0,374                 9           0,3
SC, ST7            1,3646           0,27                 9          0,208
SC, FT             1,5179           0,19                12          0,161
SC, C              1,0954          0,441                 8          0,337
ST7, FT           0,36116           0,81                10          0,715
ST7, C            0,49656          0,755                 8          0,656
FT, C             0,80539          0,508                10          0,446

Denominators
Groups            Denominator              Den.df
CC, CT7           1*Res                      8
CC, SC            1*Res                      8
CC, ST7           1*Res                      8
CC, FT            1*Res                      8
CC, C             1*Res                      8
CT7, SC           1*Res                      8
CT7, ST7          1*Res                      8
CT7, FT           1*Res                      8
CT7, C            1*Res                      8
SC, ST7           1*Res                      8
SC, FT            1*Res                      8
SC, C             1*Res                      8
ST7, FT           1*Res                      8
ST7, C            1*Res                      8
FT, C             1*Res                      8

Average Distance between/within groups
          CC        CT7        SC        ST7        FT        C
CC        2,4
CT7       2,2       2,8
SC        3,52      3,24       2,4
ST7       2,52      2,48       2,6       2,8
FT        2,64      2,68       3,36      2,76       3,6
C         2,56      2,52       2         2,04       2,72      1,8
```

PERMANOVA results effective quantum yield

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem1
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                Abbrev.      Type      Levels
Layout              La           Fixed        6
Time Interval       Ti           Fixed        4

PERMANOVA table of results
                                                                            Unique
Source       df      SS          MS            Pseudo-F       P(perm)       perms        P(MC)
La            5    0,53278     0,10656          1,7639         0,119          999         0,136
Ti            3    15,436      5,1455           85,179         0,001          996         0,001
LaxTi        15    1,7029      0,11353          1,8794         0,031          999         0,024
Res         336    20,297     6,0408E-2
Total       359    38,025

Details of the expected mean squares (EMS) for the model
Source       EMS
La           1*V(Res) + 59,82*S(La)
Ti           1*V(Res) + 89,556*S(Ti)
LaxTi        1*V(Res) + 14,975*S(LaxTi)
Res          1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source       Numerator       Denominator        Num.df      Den.df
La           1*La            1*Res                5           336
Ti           1*Ti            1*Res                3           336
LaxTi        1*LaxTi         1*Res               15           336

Estimates of components of variation
Source          Estimate          Sq.root
S(La)          7,7145E-4         2,7775E-2
S(Ti)          5,6781E-2          0,23829
S(LaxTi)       3,5472E-3         5,9559E-2
V(Res)         6,0408E-2          0,24578
```

PERMANOVA post-hoc results of effective quantum yield in factor ‘Layout’

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem1
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                          Abbrev.          Type          Levels
Layout                        La               Fixed            6
Time Interval                 Ti               Fixed            4

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Layout'

Within level '1' of factor 'Time Interval'

                                      Unique
Groups                                  t              P(perm)
perms                                 P(MC)
CC, Control                           0,67386           0,459
447                                   0,526
CC, CT7                                0,6557           0,567
646                                   0,505
CC, SC                                0,43443           0,682
469                                   0,654
CC, ST7                                1,6581           0,121
709                                   0,128
CC, Treatment                          3,4574           0,002
517                                   0,003
Control, CT7                          0,23117           0,826
656                                   0,835
Control, SC                           0,26406           0,784
441                                   0,793
```

```
Within level '3' of factor 'Time Interval'
                                                                        Unique

Groups                                 t             P(perm)            perms
                                     P(MC)
CC, Control                           0,19489          0,842              718
                                     0,857
CC, CT7                                0,8134          0,438              744
                                     0,429
CC, SC                                0,74421          0,444              749
                                     0,469
CC, ST7                                1,7011          0,104              743
                                     0,099
CC, Treatment                          1,7613          0,093              721
                                     0,099
Control, CT7                          0,98033           0,31              724
                                     0,335
Control, SC                           0,91285          0,362              738
                                      0,37
Control, ST7                           1,8608          0,069              733
                                     0,062
Control, Treatment                     1,9261          0,053              725
                                     0,065
CT7, SC                              6,7538E-2         0,917              745
                                     0,942
CT7, ST7                              0,78158          0,414              717
                                     0,447
CT7, Treatment                        0,79209           0,44              739
                                     0,423
SC, ST7                               0,85521          0,382              759
                                     0,397
SC, Treatment                           0,869          0,352              725
                                     0,408
ST7, Treatment                       2,3114E-2         0,978              718
                                     0,982

Denominators
Groups                               Denominator          Den.df
CC, Control                          1*Res                  28
CC, CT7                              1*Res                  28
CC, SC                               1*Res                  28
CC, ST7                              1*Res                  28
```

```
Control, ST7                                1,1458          0,347
725                                        0,278
Control, Treatment                          2,2099          0,035
327                                        0,039
CT7, SC                                      0,405          0,726
471                                        0,707
CT7, ST7                                   0,96737          0,353
629                                         0,35
CT7, Treatment                              1,0195          0,324
480                                        0,341
SC, ST7                                     1,3827           0,23
541                                        0,175
SC, Treatment                               2,7798          0,017
337                                         0,01
ST7, Treatment                             0,43078          0,628
576                                         0,68
```

Denominators

```
Groups                                     Denominator                Den.df
CC, Control                                1*Res                         28
CC, CT7                                    1*Res                         31
CC, SC                                     1*Res                         31
CC, ST7                                    1*Res                         31
CC, Treatment                              1*Res                         31
Control, CT7                               1*Res                         25
Control, SC                                1*Res                         25
Control, ST7                               1*Res                         25
Control, Treatment                         1*Res                         25
CT7, SC                                    1*Res                         28
CT7, ST7                                   1*Res                         28
CT7, Treatment                             1*Res                         28
SC, ST7                                    1*Res                         28
SC, Treatment                              1*Res                         28
ST7, Treatment                             1*Res                         28
```

Average Distance between/within groups

```
                            CC                  Control                  CT7
                            SC                    ST7                 Treatment
CC                     5,2229E-2

Control                5,8583E-2               6,953E-2

CT7                    8,6411E-2              9,6839E-2               0,11909

SC                     5,1219E-2              5,9872E-2             8,7644E-2
                       5,4895E-2
ST7                      0,12777                0,13453               0,15487
                         0,12772              0,19402
Treatment                7,91E-2              7,6828E-2               0,11914
                       7,6769E-2              0,14495               6,8933E-2
```

Within level '2' of factor 'Time Interval'

```
                                           Unique
Groups                                        t                 P(perm)
perms                                      P(MC)
CC, Control                                 1,7933          0,055
724                                        0,092
CC, CT7                                    0,59499          0,573
794                                        0,563
CC, SC                                     0,26812          0,825
647                                        0,791
CC, ST7                                     0,1621          0,897
797                                        0,885
CC, Treatment                               1,5864          0,149
760                                        0,135
Control, CT7                                1,2376          0,211
661                                        0,209
Control, SC                                 1,8082          0,045
699                                        0,078
Control, ST7                                1,8761          0,042
724                                         0,07
Control, Treatment                          0,8115          0,425
477                                        0,428
CT7, SC                                    0,36135          0,674
628                                        0,711
CT7, ST7                                   0,46101           0,63
662                                        0,648
CT7, Treatment                             0,95314          0,462
533                                        0,359
SC, ST7                                    0,11056          0,911
641                                        0,907
SC, Treatment                               1,5087          0,116
538                                        0,144
ST7, Treatment                               1,598            0,1
556                                        0,129
```

Denominators

```
Groups                                     Denominator                Den.df
CC, Control                                1*Res                         28
CC, CT7                                    1*Res                         30
CC, SC                                     1*Res                         30
CC, ST7                                    1*Res                         30
CC, Treatment                              1*Res                         30
Control, CT7                               1*Res                         26
Control, SC                                1*Res                         26
Control, ST7                               1*Res                         26
Control, Treatment                         1*Res                         26
CT7, SC                                    1*Res                         28
CT7, ST7                                   1*Res                         28
CT7, Treatment                             1*Res                         28
SC, ST7                                    1*Res                         28
SC, Treatment                              1*Res                         28
ST7, Treatment                             1*Res                         28
```

Average Distance between/within groups

```
                            CC               Control                   CT7
SC                          ST7             Treatment
CC                     0,20322

Control                0,13519              3,9256E-2

CT7                     0,1754                0,10144               0,16103

SC                     0,17456                0,11396               0,15732
                       0,16223
ST7                    0,18082                0,12106               0,16303
                       0,16008              0,17699
Treatment              0,14581              6,0426E-2               0,11712
                       0,12491              0,13383               7,7829E-2
```

```
CC, Treatment                              1*Res                         28
Control, CT7                               1*Res                         28
Control, SC                                1*Res                         28
Control, ST7                               1*Res                         28
Control, Treatment                         1*Res                         28
CT7, SC                                    1*Res                         28
CT7, ST7                                   1*Res                         28
CT7, Treatment                             1*Res                         28
SC, ST7                                    1*Res                         28
SC, Treatment                              1*Res                         28
ST7, Treatment                             1*Res                         28
```

Average Distance between/within groups

```
                            CC              Control              CT7                SC
ST7                    Treatment
CC                      0,3383

Control                0,32409              0,34297

CT7                    0,35417              0,35898            0,37482

SC                     0,35263              0,35755             0,3557           0,37971

ST7                    0,36777              0,38096            0,34504           0,35242
                       0,33322
Treatment              0,35374              0,36645            0,34008            0,3428
                       0,30929               0,31949
```

Within level '4' of factor 'Time Interval'

```
                                                                                 Unique
Groups                                        t                 P(perm)           perms
                                           P(MC)
CC, Control                                  2,206          0,114                 16
                                           0,036
CC, CT7                                    0,35408          0,888                202
                                           0,737
CC, SC                                     0,15176          0,874                217
                                           0,872
CC, ST7                                     1,6949          0,074                664
0,1
CC, Treatment                              0,40635           0,66                416
                                           0,686
Control, CT7                                1,9183          0,057                 32
                                           0,054
Control, SC                                 2,1793          0,069                 32
                                           0,036
Control, ST7                                4,4589          0,001                577
                                           0,001
Control, Treatment                           2,676          0,017                152
                                           0,014
CT7, SC                                    0,21048          0,936                337
                                           0,823
CT7, ST7                                    2,1221          0,033                663
                                           0,042
CT7, Treatment                             0,77155          0,533                465
                                           0,428
SC, ST7                                     1,9111          0,062                745
                                           0,061
SC, Treatment                              0,57085          0,562                609
0,56
ST7, Treatment                              1,2618          0,157                661
                                           0,208
```

Denominators

```
Groups                                     Denominator                Den.df
CC, Control                                1*Res                         28
CC, CT7                                    1*Res                         28
CC, SC                                     1*Res                         28
CC, ST7                                    1*Res                         28
CC, Treatment                              1*Res                         28
Control, CT7                               1*Res                         28
Control, SC                                1*Res                         28
Control, ST7                               1*Res                         28
Control, Treatment                         1*Res                         28
CT7, SC                                    1*Res                         28
CT7, ST7                                   1*Res                         28
CT7, Treatment                             1*Res                         28
SC, ST7                                    1*Res                         28
SC, Treatment                              1*Res                         28
ST7, Treatment                             1*Res                         28
```

Average Distance between/within groups

```
                            CC               Control               CT7                SC
                            ST7             Treatment
CC                     0,32693

Control                0,20833              8,2667E-3

CT7                    0,28433                0,16435            0,27531

SC                     0,29579                0,18926            0,27221           0,30347

ST7                    0,41137                0,42871            0,41219           0,40955
                       0,40328
Treatment              0,33037                0,26088             0,3142           0,32251
                       0,40189                0,37042
```

PERMANOVA post-hoc results of effective quantum yield in factor ‘Time Interval

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem1
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                 Abbrev.      Type      Levels
Layout               La           Fixed          6
Time Interval        Ti           Fixed          4

PAIR-WISE TESTS

Term 'LaxTi' for pairs of levels of factor 'Time Interval'

Within level 'CC' of factor 'Layout'
                                              Unique
Groups         t          P(perm)              perms          P(MC)
1, 2           1,8882       0,041                762          0,064
1, 3           5,5862       0,001                835          0,001
1, 4           6,4717       0,001                633          0,001
2, 3           3,1153       0,007                838          0,006
2, 4           4,2604       0,001                828          0,001
3, 4           1,3295       0,185                743          0,211

Denominators
Groups         Denominator              Den.df
1, 2           1*Res                        33
1, 3           1*Res                        31
1, 4           1*Res                        31
2, 3           1*Res                        30
2, 4           1*Res                        30
3, 4           1*Res                        28

Average Distance between/within groups
        1                   2                 3                  4
1   5,2229E-2
2    0,13653             0,20322
3    0,39832             0,37497            0,3383
4    0,56354             0,51338           0,37742            0,32693

Within level 'Control' of factor 'Layout'
                                              Unique
Groups         t          P(perm)              perms          P(MC)
1, 2           1,2587       0,212                412          0,225
1, 3           4,4661       0,002                844          0,001
1, 4           46,525       0,001                747          0,001
2, 3           4,9833       0,001                837          0,001
2, 4           75,298       0,001                676          0,001
3, 4            4,349       0,001                689          0,001

Denominators
Groups         Denominator              Den.df
1, 2           1*Res                        23
1, 3           1*Res                        25
1, 4           1*Res                        25
2, 3           1*Res                        26
2, 4           1*Res                        26
3, 4           1*Res                        28

Average Distance between/within groups
        1                   2                     3                   4
1    6,953E-2
2   5,5814E-2           3,9256E-2
3    0,41331              0,4275               0,34297
4    0,73428             0,75841               0,33922            8,2667E-3

Within level 'CT7' of factor 'Layout'
                                              Unique
Groups         t          P(perm)              perms          P(MC)
1, 2           0,5555       0,605                624          0,596
1, 3           2,8326       0,011                716          0,008
1, 4           6,2743       0,001                731          0,001
2, 3           2,3103       0,035                712          0,029
2, 4           5,4707       0,001                713          0,001
3, 4           2,4437       0,027                727          0,016

Denominators
Groups         Denominator              Den.df
1, 2           1*Res                        28
1, 3           1*Res                        28
1, 4           1*Res                        28
2, 3           1*Res                        28
2, 4           1*Res                        28
3, 4           1*Res                        28

Average Distance between/within groups
        1                 2                 3                 4
1   0,11909
2   0,13547           0,16103
3   0,32916           0,33125           0,37482
4   0,59068           0,56869           0,42619           0,27531

Within level 'SC' of factor 'Layout'
                                              Unique
Groups         t          P(perm)              perms          P(MC)
1, 2           1,5299       0,118                535          0,153
1, 3           3,3214       0,009                693          0,003
1, 4           6,5403       0,001                735          0,001
2, 3           2,1941       0,044                717          0,042
2, 4           4,9795       0,001                745          0,001
3, 4           2,1596       0,055                765          0,037

Denominators
Groups         Denominator              Den.df
1, 2           1*Res                        28
1, 3           1*Res                        28
1, 4           1*Res                        28
2, 3           1*Res                        28
2, 4           1*Res                        28
3, 4           1*Res                        28

Average Distance between/within groups
        1                   2                 3                  4
1   5,4895E-2
2    0,11214             0,16223
3    0,33336             0,33395           0,37971
4    0,57174             0,52839           0,41821            0,30347

Within level 'ST7' of factor 'Layout'
                                                        Unique
Groups             t               P(perm)               perms          P(MC)
1, 2           2,9105E-2             0,984                 662          0,977
1, 3             1,1228              0,273                 716          0,263
1, 4             2,0866              0,057                 735          0,033
2, 3             1,1477              0,249                 696          0,274
2, 4              2,136              0,038                 743          0,039
3, 4            0,96545              0,296                 748          0,338

Denominators
Groups         Denominator              Den.df
1, 2           1*Res                        28
1, 3           1*Res                        28
1, 4           1*Res                        28
2, 3           1*Res                        28
2, 4           1*Res                        28
3, 4           1*Res                        28

Average Distance between/within groups
        1                 2                 3                 4
1   0,19402
2   0,17686           0,17699
3   0,26488           0,26026           0,33322
4   0,35161           0,34966           0,36504           0,40328

Within level 'Treatment' of factor 'Layout'
                                              Unique
Groups         t          P(perm)              perms          P(MC)
1, 2           2,4233       0,019                356          0,023
1, 3           1,8489       0,065                664          0,078
1, 4           4,4256       0,001                700          0,001
2, 3           2,5801       0,019                683          0,014
2, 4           4,9858       0,001                694          0,001
3, 4           2,3937        0,03                768          0,027

Denominators
Groups         Denominator              Den.df
1, 2           1*Res                        28
1, 3           1*Res                        28
1, 4           1*Res                        28
2, 3           1*Res                        28
2, 4           1*Res                        28
3, 4           1*Res                        28

Average Distance between/within groups
        1                   2                     3                  4
1   6,8933E-2
2   8,7667E-2           7,7829E-2
3    0,23511             0,24428               0,31949
4    0,48224             0,51185               0,44181            0,37042
```

PERMADISP results of effective quantum yield

```
PERMDISP
Distance-based test for homogeneity of multivariate dispersions

Resemblance worksheet
Name: Resem1
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Group factor: Time Interval
Number of permutations: 999

Number of groups: 4
Number of samples: 360

DEVIATIONS FROM CENTROID
F: 87,814  df1: 3  df2: 356
P(perm): 0,001

PAIRWISE COMPARISONS
Groups           t          P(perm)
(1,2)         2,0473         0,174
(1,3)         16,834          1E-3
(1,4)         11,402          1E-3
(2,3)         11,436          1E-3
(2,4)         8,5052          1E-3
(3,4)         0,3999         0,775

MEANS AND STANDARD ERRORS
Group       Size       Average            SE
1             90      6,8527E-2          9,9232E-3
2             90       0,10406           1,4236E-2
3             90        0,2998           9,5011E-3
4             90       0,29204           1,6907E-2
```

PERMANOVA results (left) and post-hoc results of effective quantum yield in factor 'Layout' (right)

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Resem2
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name          Abbrev.          Type          Levels
Layout        La               Fixed            6

PAIR-WISE TESTS

Term 'La'

                                                              Unique
Groups                        t              P(perm)           perms          P(MC)
CC, Control                3,8633             0,035              16           0,003
CC, CT7                   0,54979             0,734             126           0,595
CC, SC                  8,1037E-2               1                56           0,932
CC, ST7                    1,4258             0,181             126           0,202
CC, FT                    0,34651              0,62             126           0,726
Control, CT7               2,6444             0,027              31           0,026
Control, SC                1,2376             0,264               8           0,252
Control, ST7               2,2021             0,003              31           0,054
Control, FT                1,6276             0,099              31           0,139
CT7, SC                   0,18626             0,968              91            0,83
CT7, ST7                   1,5758             0,108             126           0,146
CT7, FT                   0,59683             0,576             126            0,58
SC, ST7                    1,3057             0,191              91           0,239
SC, FT                    0,32275             0,862              91           0,749
ST7, FT                    1,0627             0,337             126           0,332

Denominators
Groups                   Denominator          Den.df
CC, Control              1*Res                   8
CC, CT7                  1*Res                   8
CC, SC                   1*Res                   8
CC, ST7                  1*Res                   8
CC, FT                   1*Res                   8
Control, CT7             1*Res                   8
Control, SC              1*Res                   8
```

```
Control, ST7              1*Res                  8
Control, FT               1*Res                  8
CT7, SC                   1*Res                  8
CT7, ST7                  1*Res                  8
CT7, FT                   1*Res                  8
SC, ST7                   1*Res                  8
SC, FT                    1*Res                  8
ST7, FT                   1*Res                  8

Average Distance between/within groups
                 CC       Control        CT7          SC          ST7          FT
CC            15,951
Control       27,625        1,146
CT7           16,192       21,564      21,047
SC            35,338       26,232      33,166      47,421
ST7           61,776        80,43      65,583      74,864      95,539
FT            40,205        35,67      38,708      43,364      73,118       54,97
```

PERMADISP results of effective quantum yield

```
PERMDISP
Distance-based test for homogeneity of multivariate dispersions

Resemblance worksheet
Name: Resem2
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Group factor: Layout
Number of permutations: 999

Number of groups: 6
Number of samples: 30

DEVIATIONS FROM CENTROID
F: 4,9933  df1: 5  df2: 24
P(perm): 0,046

PAIRWISE COMPARISONS
Groups                      t          P(perm)
(CC,Control)             2,3697          6E-3
(CC,CT7)                0,96767         0,718
(CC,SC)                  1,5566          0,17
(CC,ST7)                  2,556        1,5E-2
(CC,FT)                   3,953          9E-3
(Control,CT7)            7,6773        1,1E-2
(Control,SC)             2,4369        1,4E-2
(Control,ST7)            3,1485          7E-3
(Control,FT)             6,4012          1E-2
(CT7,SC)                 1,2738         0,385
(CT7,ST7)                2,3715        1,2E-2
(CT7,FT)                 3,8928          9E-3
(SC,ST7)                 1,2697         0,442
(SC,FT)                 0,63369         0,598
(ST7,FT)                 1,0033         0,549

MEANS AND STANDARD ERRORS
Group        Size    Average        SE
CC              5     11,187     4,3205
Control         5    0,91682    0,34381
CT7             5     15,755      1,902
SC              5     32,365     12,901
ST7             5     61,916     19,371
FT              5      41,47      6,326
```

PERMANOVA results of comparison between tank locations in parameters survival rate, leaf number, new leaf number and rel. effective quantum yield

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: survival
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name              Abbrev.          Type         Levels
Location          Lo               Fixed           4

PERMANOVA table of results

                  Unique
Source          df        SS            MS            Pseudo-F
                P(perm)  perms          P(MC)
Lo              3       1836,7         612,22           0,95411              0,42
                  155    0,442
Res             26        16683         641,67

Total           29        18520


Details of the expected mean squares (EMS) for the model
Source          EMS
Lo              1*V(Res) + 7,4667*S(Lo)
Res             1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source          Numerator            Denominator              Num.df
                Den.df
Lo              1*Lo                 1*Res                       3
                  26

Estimates of components of variation
Source          Estimate        Sq.root
S(Lo)            -3,9435         -1,9858
V(Res)            641,67          25,331

PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: leaf number
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 999

Factors
Name              Abbrev.          Type         Levels
Location          Lo               Fixed           4

PERMANOVA table of results

                Unique
Source          df        SS            MS            Pseudo-F
                P(perm)  perms          P(MC)
Lo              3       548,66         182,89           1,9257
0,137             923    0,168
Res             26       2469,2          94,97

Total           29       3017,9


Details of the expected mean squares (EMS) for the model
Source          EMS
Lo              1*V(Res) + 7,4667*S(Lo)
Res             1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source          Numerator            Denominator              Num.df
                Den.df
Lo              1*Lo                 1*Res                       3
                  26

Estimates of components of variation
Source          Estimate        Sq.root
S(Lo)             11,775          3,4314
V(Res)             94,97          9,7452
```

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: new leaf number
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 999

Factors
Name              Abbrev.          Type         Levels
Location          Lo               Fixed           4

PERMANOVA table of results

                Unique
Source          df        SS            MS            Pseudo-F            P(perm)
                 perms  P(MC)
Lo              3       9,1583         3,0528          0,55618              0,634
                  387   0,623
Res             26      142,71         5,4888

Total           29      151,87


Details of the expected mean squares (EMS) for the model
Source          EMS
Lo              1*V(Res) + 7,4667*S(Lo)
Res             1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source          Numerator            Denominator              Num.df          Den.df
Lo              1*Lo                 1*Res                       3              26

Estimates of components of variation
Source          Estimate        Sq.root
S(Lo)           -0,32625        -0,57118
V(Res)            5,4888          2,3428

PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: PAM
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 999

Factors
Name              Abbrev.          Type         Levels
Location          Lo               Fixed           4

PERMANOVA table of results

                Unique
Source          df        SS            MS            Pseudo-F            P(perm)
                 perms  P(MC)
Lo              3        7811          2603,7          1,1911               0,312
                  996   0,335
Res             26      56836          2186

Total           29      64647


Details of the expected mean squares (EMS) for the model
Source          EMS
Lo              1*V(Res) + 7,4667*S(Lo)
Res             1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares
Source          Numerator            Denominator              Num.df          Den.df
Lo              1*Lo                 1*Res                       3              26

Estimates of components of variation
Source          Estimate        Sq.root
S(Lo)             55,938          7,4792
V(Res)             2186           46,755
```

PERMANOVA post-hoc results of comparison between tank locations in parameters survival rate, leaf number, new leaf number and rel. effective quantum yield

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: survival
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Permutation of residuals under a reduced model
Number of permutations: 999

Factors
Name                 Abbrev.            Type          Levels
Location             Lo                 Fixed              4

PAIR-WISE TESTS

Term 'Lo'


                                                                              Uniqu
e
Groups                                                                            t
                                                                              P(per
m)
perms                                                                         P(MC)
south west, north east
0,1584                                                                            1
                                                                                 10
                                                                              0,874
south west, south west inner
1,1296
0,31                                                                             15
                                                                              0,295
south west, north east inner
1,4506
0,269                                                                             7
                                                                              0,186
north east, south west inner
                                                                              0,925
82
0,443                                                                            14
                                                                              0,354
north east, north east inner
1,2104
0,313                                                                             8
                                                                              0,252
south west inner, north east inner
                                                                              0,204
48                                                                                1
                                                                                  8
                                                                              0,849

Denominators
Groups
                                                                               Deno
minator
                                                                              Den.d
f
south west, north east                                                        1*Res
                                                                                 14
south west, south west inner                                                  1*Res
                                                                                 12
south west, north east inner                                                  1*Res
                                                                                 14
north east, south west inner                                                  1*Res
                                                                                 12
north east, north east inner                                                  1*Res
                                                                                 14
south west inner, north east inner                                            1*Res
                                                                                 12

Average Distance between/within groups
                                    south west                 north east
                                    south west inner           north east inner
south west                            36,429

north east                             33,75                     38,571

south west inner                        30                       29,167
                                          18,667
north east inner                      29,375                     29,375
                                            15                         15,714

PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: leaf number
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 999

Factors
Name                 Abbrev.            Type          Levels
Location             Lo                 Fixed              4

PAIR-WISE TESTS

Term 'Lo'
```

```
PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: new leaf number
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 999

Factors
Name                 Abbrev.            Type          Levels
Location             Lo                 Fixed              4

PAIR-WISE TESTS

Term 'Lo'


                                                                        Unique

Groups                                                                      t
                                                                        P(perm)
                                                                         perms
                                                                        P(MC)
south west, north east                                                  9,5533E-2
                                                                            1
                                                                           16
                                                                         0,93
south west, south west inner                                              0,92172
                                                                          0,389
                                                                           26
                                                                        0,344
south west, north east inner                                              0,77235
                                                                            0,5
                                                                           14
                                                                         0,44
north east, south west inner                                               1,0162
                                                                          0,312
                                                                           27
                                                                        0,331
north east, north east inner                                              0,88192
                                                                          0,444
                                                                           16
                                                                        0,405
south west inner, north east inner                                        0,31243
                                                                          0,785
                                                                           21
                                                                        0,785

Denominators
Groups                                                                  Denominator
                                                                        Den.df
south west, north east                                                  1*Res
                                                                           14
south west, south west inner                                            1*Res
                                                                           12
south west, north east inner                                            1*Res
                                                                           14
north east, south west inner                                            1*Res
                                                                           12
north east, north east inner                                            1*Res
                                                                           14
south west inner, north east inner                                      1*Res
                                                                           12

Average Distance between/within groups
                                    south west                 north east                 south
west inner                          north east inner
south west                            3,1071

north east                            2,8125                     3,1429

south west inner                      2,7083                     2,7917
2,6
north east inner                      2,5625                     2,625
2,125                                        2,2143



PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: PAM
Data type: Distance
Selection: All
Resemblance: D1 Euclidean distance

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 999

Factors
Name                 Abbrev.            Type          Levels
Location             Lo                 Fixed              4

PAIR-WISE TESTS

Term 'Lo'
```

Groups	t	P(perm)	Unique perms	P(MC)
south west, north east	0,27052	0,789	53	0,803
south west, south west inner	1,7813	0,116	42	0,093
south west, north east inner	1,7647	0,095	44	0,097
north east, south west inner	1,6124	0,119	53	0,14
north east, north east inner	1,6581	0,112	56	0,095
south west inner, north east inner	0,59593	0,57	31	0,564

Denominators

Groups	Denominator	Den.df
south west, north east	1*Res	14
south west, south west inner	1*Res	12
south west, north east inner	1*Res	14
north east, south west inner	1*Res	12
north east, north east inner	1*Res	14
south west inner, north east inner	1*Res	12

Average Distance between/within groups

	south west	north east	south west inner	north east inner
south west	12,429			
north east	13,438	16,857		
south west inner	10,5	12,708	3,1333	
north east inner	10,375	12,406	3,25	4,1071

Groups	t	P(perm)	Unique perms	P(MC)
south west, north east	0,85511	0,458	139	0,383
south west, south west inner	0,67219	0,512	124	0,519
south west, north east inner	0,69232	0,505	147	0,493
north east, south west inner	1,2928	0,266	138	0,218
north east, north east inner	1,4455	0,182	209	0,19
south west inner, north east inner	0,14673	0,89	82	0,889

Denominators

Groups	Denominator	Den.df
south west, north east	1*Res	14
south west, south west inner	1*Res	12
south west, north east inner	1*Res	14
north east, south west inner	1*Res	12
north east, north east inner	1*Res	14
south west inner, north east inner	1*Res	12

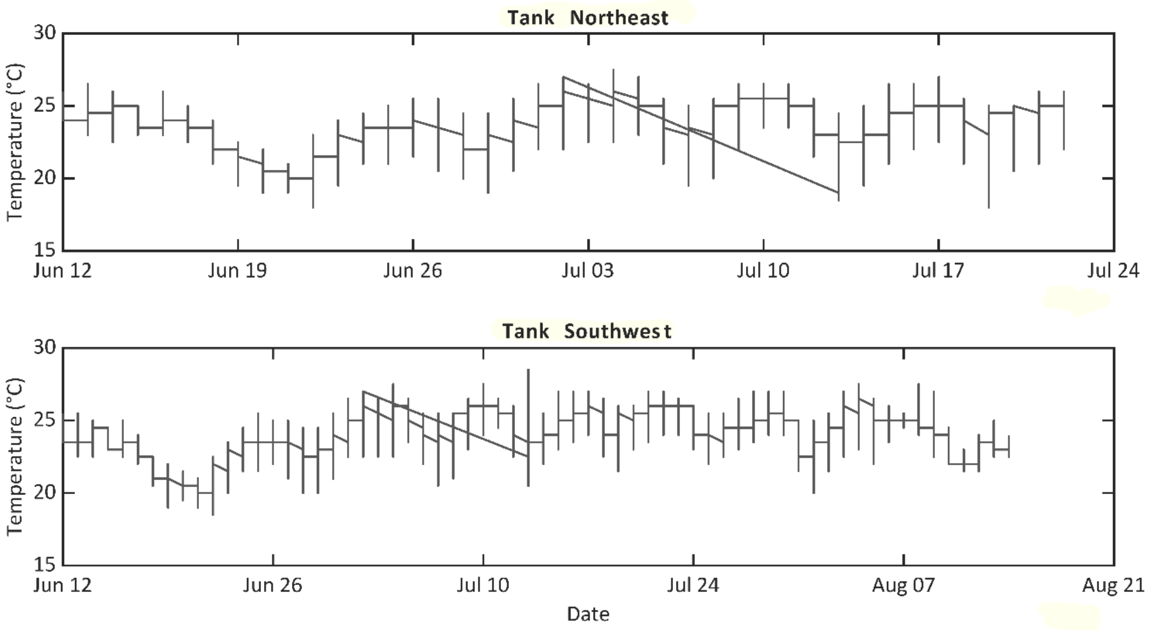
Average Distance between/within groups

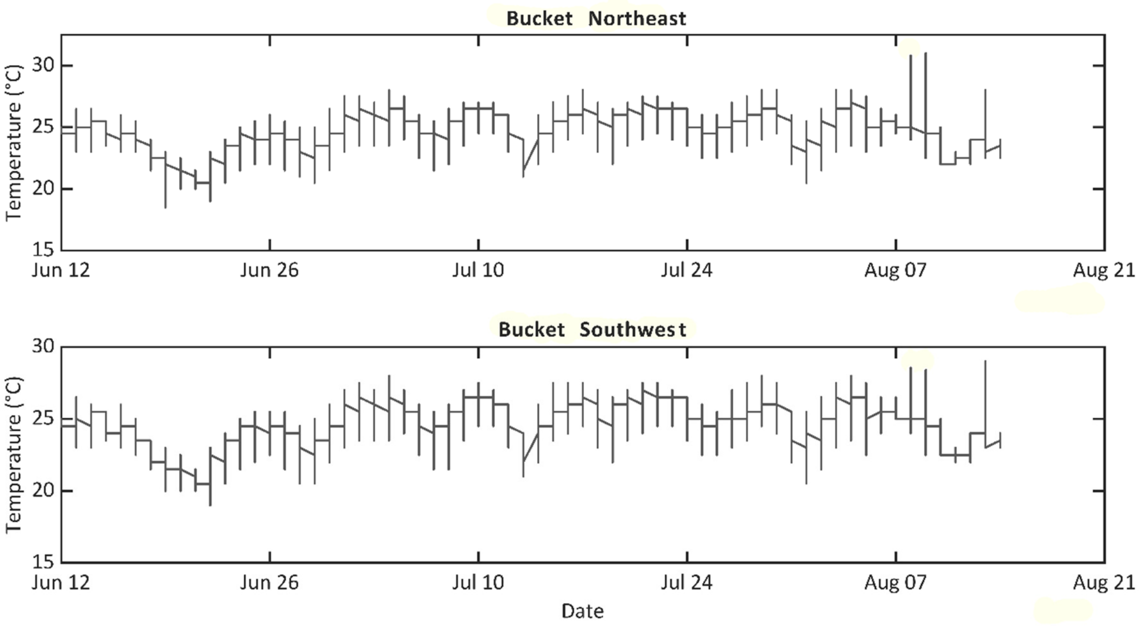
	south west	north east	south west inner	north east inner
south west	48,321			
north east	60,563	79,821		
south west inner	34,917	53,5	21,733	
north east inner	34,969	53,594	18,958	21,25

Appendix 9

Temperature profiles of loggers in buckets and tanks.

No recordings of logger of left tank after July 24th.



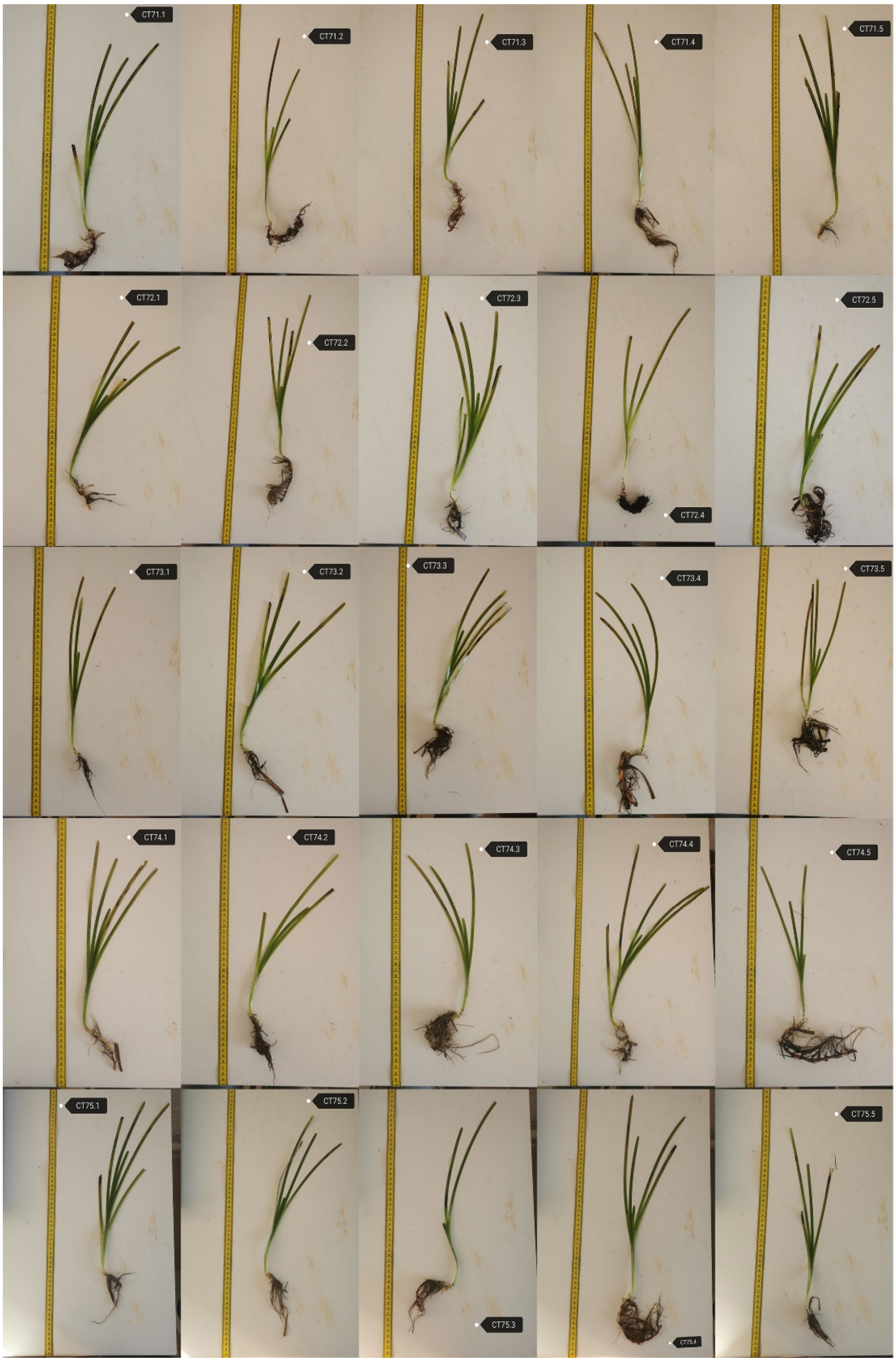


Appendix 10

Zostera marina shoots before (left) and after (right) the experiment

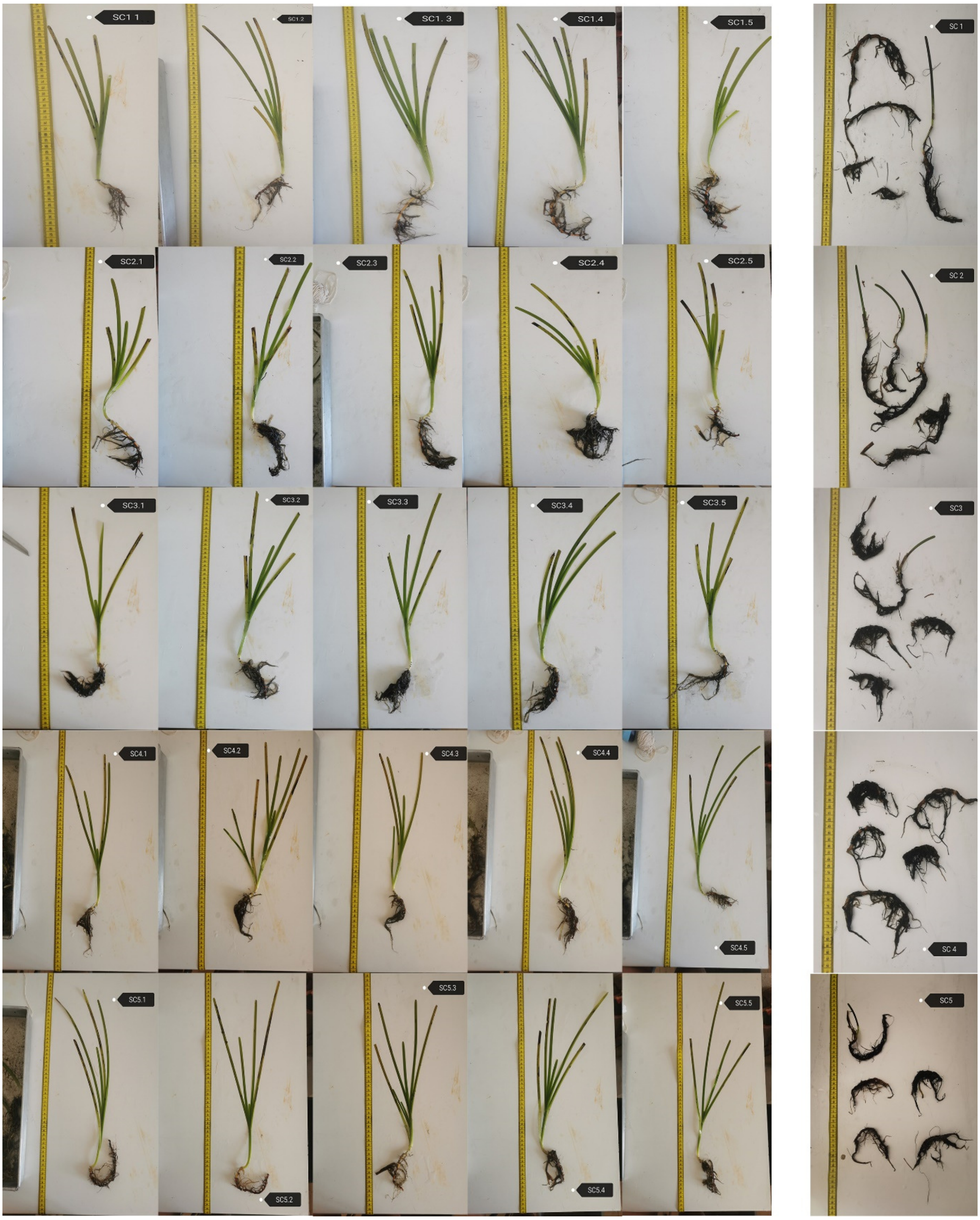
CC

CT7

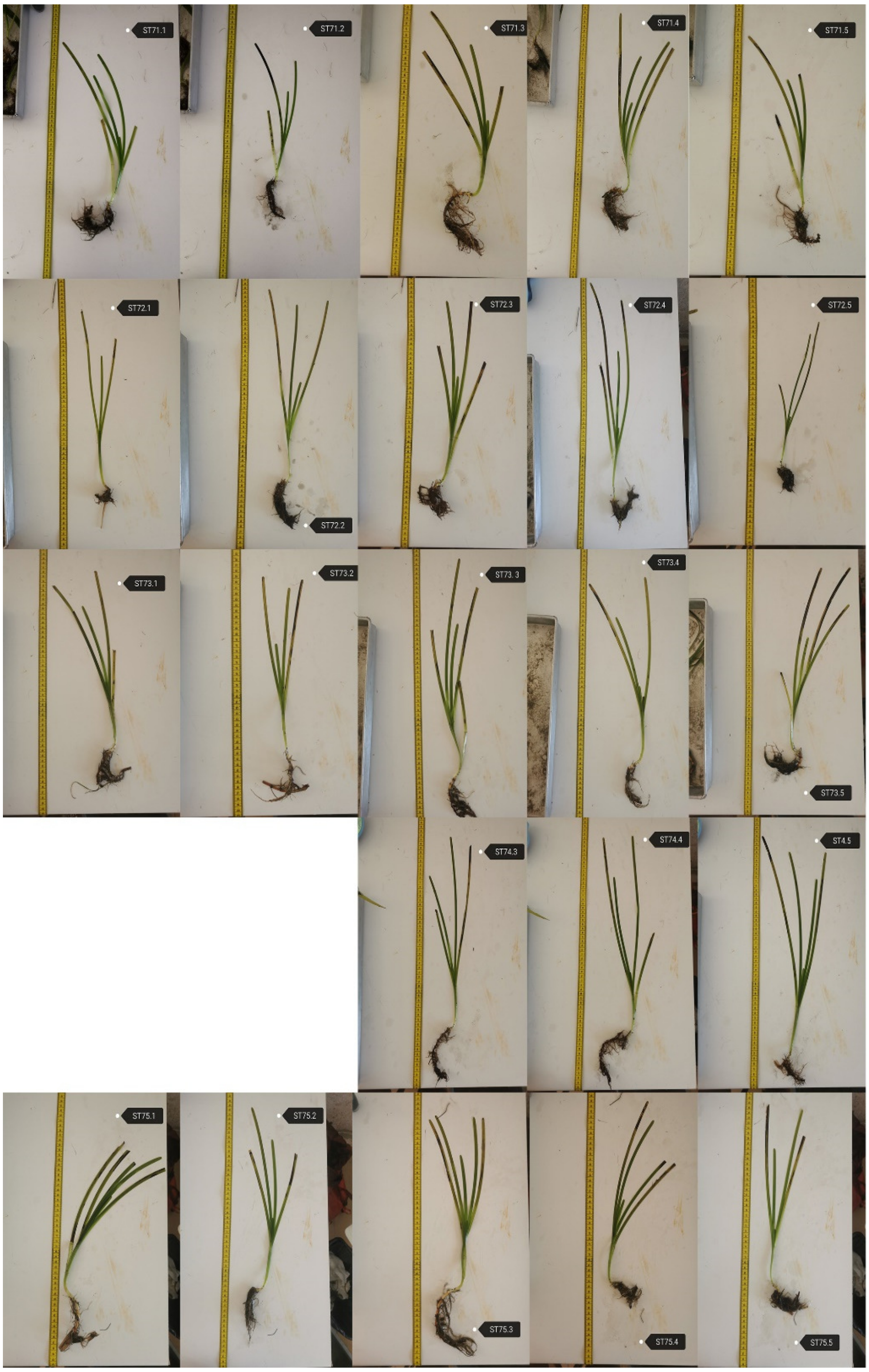

CT71.1
CT71.2
CT71.3
CT71.4
CT71.5
CT72.1
CT72.2
CT72.3
CT72.4
CT72.5
CT73.1
CT73.2
CT73.3
CT73.4
CT73.5
CT74.1
CT74.2
CT74.3
CT74.4
CT74.5
CT75.1
CT75.2
CT75.3
CT75.4
CT75.5


CT7 1
CT72
CT7 3
CT7 4
CT75

SC


SC1 1
SC1.2
SC1. 3
SC1.4
SC1.5
SC 1
SC2.1
SC2.2
SC2.3
SC2.4
SC2.5
SC 2
SC3.1
SC3.2
SC3.3
SC3.4
SC3.5
SC3
SC4.1
SC4.2
SC4.3
SC4.4
SC4.5
SC 4
SC5.1
SC5.2
SC5.3
SC5.4
SC5.5
SC5

ST7


ST71.1
ST71.2
ST71.3
ST71.4
ST71.5
ST72.1
ST72.2
ST72.3
ST72.4
ST72.5
ST73.1
ST73.2
ST73. 3
ST73.4
ST73.5
ST74.3
ST74.4
ST4.5
ST75.1
ST75.2
ST75.3
ST75.4
ST75.5


ST7 1
ST7 2
St73
St7 4
ST75

Control

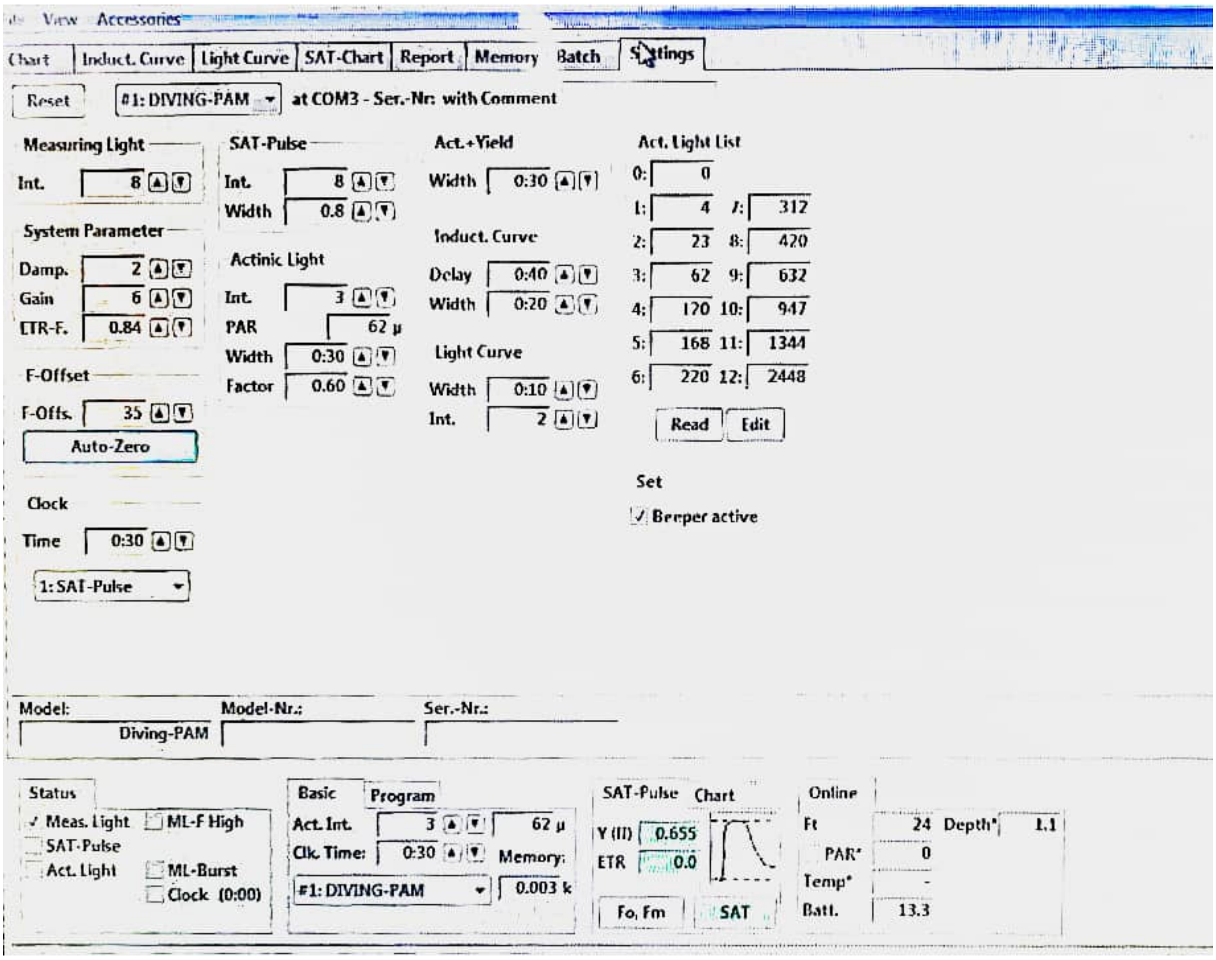

Control 1.1
Control 1.2
Control 1.3
Control 1.4
Control 1.5
Control 2.1
Control 2.2
Control 2.3
Control 2.4
Control 2.5
Control 3.1
Control 3.2
Control 3.3
Control 3.4
Control 3.5
Control 4.1
Control 4.2
Control 4.3
Control 4.4
Control 4.5
Control 5.1
Control 5.2
Control 5.3
Control 5.4
Control 5.5


Control 1
Control 2
Control 3
Control 4
Control 5

Fertilized Shoots

Appendix 11

WinControl-3 settings for *Heinz Walz GmbH Diving-PAM*



#1: DIVING-PAM at COM3 - Ser.-Nr: with Comment

Measuring Light
Int. 8

System Parameter
Damp. 2
Gain 6
ETR-F. 0.84

F-Offset
F-Offs. 35

Clock
Time 0:30
1: SAT-Pulse

SAT-Pulse
Int. 8
Width 0.8

Actinic Light
Int. 3
PAR 62 µ
Width 0:30
Factor 0.60

Act.+Yield
Width 0:30

Induct. Curve
Delay 0:40
Width 0:20

Light Curve
Width 0:10
Int. 2

Act. Light List
0: 0
1: 4
2: 23
3: 62
4: 120
5: 168
6: 220
7: 312
8: 420
9: 632
10: 947
11: 1344
12: 2448

Set
☑ Beeper active

Model: Diving-PAM
Model-Nr.:
Ser.-Nr.:

Status
☑ Meas. Light
☐ ML-F High
☐ SAT-Pulse
☐ Act. Light
☐ ML-Burst
☐ Clock (0:00)

Basic
Act. Int. 3 62 µ
Clk. Time: 0:30
#1: DIVING-PAM
Memory: 0.003 k

SAT-Pulse
Y (II) 0.655
ETR 0.0

Online
Ft 24
Depth* 1.1
PAR* 0
Temp* -
Batt. 13.3