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Turf Grass Sod Production Utilizing Hydroponic Systems

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TURF GRASS SOD PRODUCTION UTILIZING HYDROPONIC SYSTEMS

Raed Sameeh Raja Hussain

This thesis is submitted in partial fulfilment of the requirements for the degree of Master of Science in Horticulture

Under the Supervision of Dr. Moustafa Amin Fadel

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Declaration of Original Work

I, Raed Sameeh Raja Hussain, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*Turf Grass Sod Production Utilizing Hydroponic Systems*", hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Dr. Moustafa Amin Fadel, in the College of Food and Agriculture at UAEU. This work has not previously been presented or published, or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

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Abstract

Turf as a cover is a very essential component in enhancing the aesthetics and in climate modification of the landscapes in the arid region. The grasses employed for turf production are cultivable grass species of the poaceae family in the class monocots. It can considerably withstand the stress of traffic and mowing provided right grass species are selected and sod production undertaken. The UAE is characterized by a bi-seasonal Mediterranean climate with high temperatures and low rainfall. Like in any desert ecosystems, soils are poor in organic matter, with relatively low biological activities in UAE. In the present research, two warm season grasses namely Bermuda grass and Paspalum grass were selected for sod production using Rockwool alone, fabric jute alone and Rockwool with Jute fabric combination in automated hydroponic system with separate tanks for different substances i.e. water (Tank 1), pH adjustment (Tank 2), Iron Chelate and Calcium (Tank 3) and Nutrient solution (Tank 4).

The overall results indicate that the Bermuda grass was found better in terms of germination percentage, fresh and dry weight of biomass. In the case of the substrates used, the Jute Fabric in combination with Rockwool promoted the germination and furhter growth. The Rockwool alone promoted the fresh and dry weight of the plant biomass studied. In terms of length of plant, both grasses showed only a slight variation between the two substrates studied. While jute alone has failed to encourage germination of both species because the jute does not retain water and it dries easily.

The soilless production system is very suitable for UAE socio-economic and agro-ecological status. However, growers' acceptance of this new system

represents one of the key issues that must be addressed to ensure the successful dissemination of the technology and sustainability of the achievements. The turf grass cultivation using the hydroponic system can prove a very viable technology instrumental in enhancing the greenery in the country as well as the landscapes. This research is being conducted with the goal to provide a sustainable and effective alternative method of turf grass production. The hydroponic system can provide a breakthrough in the landscaping industry in UAE, once the method of turf grass production system is standardized.

Keywords: Bermuda grass, paspalum grass, hydroponic system, landscape.

Title and Abstract (in Arabic)

إنتاج شتلات النجيل باستخدام أنظمة الزراعة المائية

الملخص

يعتبر النجيل كغطاء عنصرا أساسيا جدا في تعزيز الجماليات وفي تعديل المناخ للمناظر الطبيعية في المنطقة القاحلة. المسطحات الخضراء المستخدمة لإنتاج النجيل هي أنواع النجيل القابلة للزراعة من العائلة أو الفصيلة النجيلية من طائفة أحادية الفلقة. ويمكن أن تصمد وتقاوم إلى حد كبير الإجهاد والضغط المطبق عليها من حركة المشي والقص المقدمة، يتم اختيار أنواع النجيل المناسبة وإنتاجها. تتميز دولة الإمارات العربية المتحدة بمناخ البحر الأبيض المتوسط الموسمية مع درجات حرارة عالية وانخفاض في معدل هطول الأمطار. ومثلما هو الحال في أي الأنظمة البيئية الصحراوية، فإن التربة فقيرة في المواد العضوية ذات الأنشطة البيولوجية المنخفضة نسبيا في الإمارات العربية المتحدة. في هذا البحث، تم اختيار نوعين من النجيل ذات الموسم الدافئ وهما نجيل البرمودا ونجيل الباسبالوم لإنتاج النجيل باستخدام الصوف الصخري لوحده ، الجوت لوحده ومزيج الصوف الصخري والجوت في نظام الزراعة المائي الآلي مع خزانات منفصلة لمواد مختلفة أي المياه (خزان 1)، وتعديل درجة الحموضة(خزان 2)، شيلات الحديد والكالسيوم (خزان 3) ومحلول مغذي (خزان 4).

وتشير النتائج الكلية إلى أن نجيل برمودا وجد أفضل من حيث نسبة الإنبات والوزن الطازج والجاف للكتلة الحيوية. وفي حالة الركائز المستخدمة، يشجع نسيج الجوت بالاشتراك مع الصوف الصخري على الإنبات والنمو الفائق. وشجع الصوف الصخري لوحده الوزن الطازج والجاف للكتلة الحيوية النباتية المدروسة. من حيث طول النبات، أظهر كلا النوعين من النجيل فقط تباين طفيف بين الركيزتين الاثنين اللاتي تم دراستهم ، بينما فشل الجوت لوحده في تشجيع الإنبات لكلا النوعين من النجيل وذلك بسبب أن الجوت لايحتفظ بالماء كما أنه يجف بسهولة.

إن نظام الإنتاج بدون تربة مناسب جدا للوضع الاجتماعي والاقتصادي والإيكولوجي في دولة الإمارات العربية المتحدة. ومع ذلك، فإن قبول المزارعين لهذا النظام الجديد يمثل إحدى القضايا الرئيسية التي يجب معالجتها لضمان النشر الناجح للتكنولوجيا واستدامة

الإنجازات. زراعة النجيل باستخدام نظام الزراعة المائية يمكن أن تثبت تكنولوجيا قابلة للحياة جدا مفيدة في تعزيز المساحات الخضراء في البلاد وكذلك المناظر الطبيعية. ويجري هذا البحث بهدف توفير طريقة بديلة مستدامة وفعالة لإنتاج النجيل (المسطحات الخضراء). ويمكن أن يوفر نظام الزراعة المائية طفرة في صناعة المناظر الطبيعية في دولة الإمارات العربية المتحدة، وبمجرد أن يتم توحيد طريقة ونظام إنتاج النجيل .

مفاهيم البحث الرئيسية: نجيل البرمودا، نجيل الباسبالم، نظام الزراعة المائية، المناظر الطبيعية.

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I wish to express my deep sense of gratitude and sincere thanks to my research supervisor Dr. Moustafa Amin Fadel, Associate Professor, Department of Aridland Agriculture, College of Food and Agriculture, UAE University. I thank him for his periodical guidance in planning and execution of the work and the useful time spent in intellectual discussions are unforgettable experience, which ever remain fresh in my memory. I would also like to thank my committee members, Dr. Shyam S. Kurup, Associate Professor and Dr. Elke Neumann, Assistant Professor, Department of Aridland Agriculture for their critical suggestions and kind help.

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Dedication

To my dear father

To my dear mother

God bless them

To the one who encouraged me to continue my scientific career, mate Derby, dear wife

To my heart, my children, Laith, Amos, and Jad

And to everyone who encouraged me and helped me complete this work

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List of Abbreviations

µm	Micrometre
B	Boron
Cl	Chlorine
Cu	Copper
$CuSO_4$	Copper(II) sulfate
DTPA	Diethylene triamine penta acetic acid
H_3BO_3	Boric acid
Hcl	Hydrochloric acid
K	Potassium
Kcl	Potassium chloride
KH_2PO_4	Monopotassium phosphate
KNO_3	Potassium nitrate
Mg	Magnesium
$MgSO_4$	Magnesium sulfate
mM	Millimetre
Mn	Manganese
$MnCl_2$	Manganese (II) chloride
Mo	Molybdenum
N	Nitrogen
Na_2MoO_3	Sodium molybdate
Na_2SiO_3	Sodium silicate
NH_4NO_3	Ammonium nitrate
Ni	Nickel
$NiSO_4$	Nickel (II) sulfate
P	Phosphorus
pH	potential of hydrogen
ppm	Parts per million
S	Sulphur
Si	Silicon
Zn	Zinc
$ZnSO_4$	Zinc sulfate

Chapter 1: Introduction

1.1 Overview

Like forests or prairie grasslands, lawns are part of dynamic ecosystems: communities of plants, soil, and microbes; insects and earthworms and the birds that feed on them; and humans who mow, water, fertilize, and utilize the lawn. The interactions of all these community members shape the dynamic equilibrium of a lawn (McDonald, 1999). The common choice of people throughout the world is to sight, sit on, play and walk in attractive grassy areas (Behe *et al.*, 2005). Turf grass is used for lawns, golf courses, and sports stadiums around the world which are referred to as utility turfs. In residential projects, this grass is used due to its qualities of quick and easy growth as well as its resistance to soil erosion and ultimately to enhance property value. The turf sod is the grass itself and the layer of soil beneath it that holds the roots intact. This small patch of turf grass is used particularly to repair a small area of lawn, golf course, or athletic field that has withered.

Turf sod is also very helpful in keeping the surroundings aesthetically superior, climate modification and in making the quality of air better. Though the turf industry has a promising future, it is facing different challenges which include heavy use of commercial fertilizers, water issues, rise in temperature and environmental constraints (Morris, 2006). High turf grass quality also requires other maintenance practices such as irrigation, fertilization, proper mowing practices, aeration and sand dressing, all with associated environmental impacts (Tidåker *et al.*, 2017). This research is a pioneering attempt, to undertake turf grass production in a hydroponic system as a medium of production in the UAE.

1.2 Background of the Study

The United Arab Emirates (UAE) lies between 22°30 and 26°10 north latitude and between 51° and 56°25 east longitude is situated at southeast of Arabian Peninsula with an area of 83,600 km (Abdelfattah and Shahid, 2007). The UAE is characterized by a bi-seasonal Mediterranean climate with high temperatures and low rainfall. Like in any desert dominated regions, soils are poor in organic matter, with relatively low biological activities (El-Keblawy and Ksiksi, 2005). Most of the country is comprised of desert with sand dunes, gullies, and oases. South and west of the country have deserts that are part of a vast sandy desert called *Rub' al Khali* or Empty Quarter. In the north, Al Hajar mountains elevate at some places to more than 2,000 m. The line of the Tropic of Cancer passes across the UAE, making the weather in the UAE hot and sunny (Shahid *et al.*, 2013). By moving away from pure aesthetics, landscapes, especially those in hot, arid, subtropical environments, can function to improve the microclimate of our developed world (Hopkins and Al-Yahyai, 2015).

AlShrouf (2017) stated that the use of hydroponics method economized the use of irrigation water, fertilizer saving and also the productivity in UAE farming systems. The use of more than one properly selected variety or species will broaden the genetic base of a turf stand, and improve its ability to withstand differing environmental conditions (Morris, 1992). The hydroponics system is being used in the UAE, very effectively to grow high quality fruits and vegetables, particularly fresh lettuces, that may not grow otherwise in the open soil cultivation of the country (Bardsley, 2014).

1.3 Purpose of the Study

In UAE, surface water resources are almost not in existence and groundwater resources are often non-renewable. The scarcity of fresh water in UAE is becoming more challenging issue due to the increase in the population over the last few decades. Efficient water use is the most economically and environmentally preferable solution especially in drought conditions and increasing competition over limited water supplies. Therefore, exploiting the soilless growing media is a logical alternative to the present conventional soil based production systems in this region (Mazahreh *et al.,* 2015). Nevertheless, substantial reductions in energy consumption and greenhouse gas emissions can be achieved by improving efficiency, reducing transmission losses, reducing peak demand, developing renewable resources and applying modern cogeneration technology (Premanandh, 2011). The turfgrass cultivation using the hydroponic system can prove instrumental in improving the greenery of the country and in landscaping. This research is being conducted with the purpose to provide a sustainable and effective alternative method of turf grass production. This system of turfgrass production in hydroponics can provide a breakthrough for landscaping industry in the UAE, once the method system is standardized.

1.4 Research Objectives

The research objectives can be summarized as follows:

1. Designing and developing a suitable hydroponic system for the growth of turf grasses such as Paspalum and Bermuda grass.

2. Standardization of suitable substrate by germination studies to determine the best substrate to grow turfgrass in hydroponics system.

3. Evaluation of various growth parameters using seeds and stolons in different substrates in hydroponics

4. Evaluation of hydroponically produced sods through the assessment of survival rate, color, firmness and manageability.

Chapter 2: Review of Literature

Traditional agriculture is having trouble, water supplies are running out and food demand is only increasing and there is also a growing demand for plants grown without the use of chemical pesticides and fertilizers. Hydroponics is the science of growing plants in a soil less medium. The roots feed on a nutrient rich solution that contains all the essential elements necessary for the normal plant growth and development. Plants grown hydroponically are not physiologically different than plants grown in soil. Both inorganic and organic components need to be decomposed into inorganic elements in order to become available for plant uptake (Carpenter, 1994). However, the plant processes involved in obtaining minerals from a soil solution compared to a hydroponic solution are different. Mineral nutrients become available for plant uptake when soil colloids release minerals into the soil solution through solubilization of soil minerals and organic matter (Resh, 1995). In hydroponic culture, dissolved nutrients are delivered to the plant in a solution rather than a soil solution. Therefore, hydroponics allows to maintain the plant in an ideal nutrient condition. However, the margin of error is great due to the lack of buffering capacity, which can result in plant starvation or nutritional stress. Hydroponic culture allows for increases in density spacing and yields due to minimal competition among roots. Herbs have the potential to grow up to 25 percent faster in a hydroponic solution compared to soil. Plants grown hydroponically have a threefold increase in vitamins and minerals compared to plants grown in soil (Skagg, 1996).

2.1 Turf Grass

The turf grasses are cultivable grass species of the monocot angiosperm plant family Poaceae and the major plant species that covers the exposed lands and has very specific benefits in the landscape. It is also the most practical surface for many types of outdoor recreation. It is the only landscape plant material that can overcome the stresses of traffic and mowing. The turf grasses grow back even after trampling, tearing and mowing. And mowed lawns are a standard component of many urban fire control strategies. The turf grass reduces the amount of surface runoff water.

The turf grasses not only form play grounds but also provides enrichment of local biodiversity through extensively managed roughs in areas with intensively managed agriculture (Tanner and Gange, 2005) and promotes soil carbon (C) sequestration (Qian and Follett, 2002; Tidåker *et al.*, 2017). The turf grass is also used in green facades or breathing facades (known to improve the quality of air and reduce environmental pollution in buildings) which is the need of the day (Farid *et al.*, 2016).

Based on their characteristics, there are typically two types of turf grasses, cool-season grasses and warm-season grasses (Huang, 2008). The cool season turf grasses include Festuca rubraL., Poa pratensisL., Agrostis tennuifolius L., and Lolium perenne L., while Cynodon dactylon L.C. Rich, Buchloe dactyloides Engelmann, Zoysia tenuifolia Willd., Paspalum vaginatum L., Eremochloa ophiuroides (Munro) Hack. and Stenotaphrum secundatum (Walter) Kuntze are categorized as warm season turfgrass (Alshammary et al., 2004). While the cool-season grasses grown in cold areas like the Northern countries, the warm-season grasses are more commonly found in tropical and sub-tropical environments. Since these grasses have different characteristics, they also have different water and irrigation requirements (Carrow et al., 2010).

The warm season grasses can easily grow in areas even with little water supply, however, the cool-season grasses require proper irrigation and have higher water requirements to sustain and grow. It may also be noted, that the same kind of turf grass may have different water requirements in different environments based on their cultivator adaptations and the climate of the area.

Additionally, warm season turfgrass requires more sunlight in order to perform photosynthesis (Baldwin et al., 2009). Thus less than normal sunshine can cause the warm-season turfgrass to die. Although sod is grown on specialist farms in most countries, it is always feasible to use the turf grass grown in the same region as it has already adapted to the local climate and is easy to grow as well as transport, without causing much damage to it (Carrow et al., 2001).

A summary of most commonly used cool-season and warm-season turf grasses is given in Table 1, below (Watschke and Schmidt, 1992)

Table 1: Cool and warm season turf grasses

Type of Season	TURFGRASSES	
	Common Name	**Botanical Name**
Cool Season	Zoysia grass	*Zoysia matrella, Zoysia tenuifolia, Zoysia japonica*
	Centipede grass	*Eremochloa ophiuroides*
	St. Augustine grass	*Stenotaphrum secundatum*
	Seashore paspalum	*Paspalum vaginatum*
Warm Season	Tall Fescue	*Festuca arundinacea*
	Bermuda grass	*Cyanodon dactylon, Cyanodon transvaalensis*
	Perennial Rye Grass	*Lolium perenne*
	Creeping Bent grass	*Agrostis stolonifera*
	Kentucky Blue grass	*Poa pratensis*
	Fine Fescue	*Festuca tenuifolia* (often includes *Festuca ovina* – sheep's fescue and *Festuca rubra* – red fescue)

The most important factors that affect turfgrass growth and development include temperature, moisture, light, weather conditions, as well as geography (Alshammary *et al*., 2004; Carrow *et al*., 2010). Since the climate can change over the years, there are different recommendations for different turfgrass growth, mowing, and sowing. Climate can also affect the growth time for sod, which typically takes around 10 to 18 months to grow properly (Carrow *et al*., 2001; 2010).

Bermuda grass is common in the warmer parts of both hemispheres and in the United States extends into the arid regions of the West. In the latter parts, it is of little importance from a commercial standpoint, since the climate is too dry for its development without irrigation. Under irrigation, other forage crops give better results. Although Bermudagrass is found under a variety of conditions, it is not a shade-loving plant and thrives best in open ground. This is a low perennial, producing extensively creeping stolons and rhizomes and erect flower-culms, a few inches to a foot or more in height, ending in 3 to 6 slender digitate spikes (Hitchcock, 1914)

Bermuda grass (*Cynodon dactylon* L.), a common warm season turf species, grows worldwide as a turfgrass species in a wide range of climates, soils, and environmental conditions. The grass can be manipulated to produce dwarf varieties which require less mowing as well as more stress (i.e., salinity and drought) tolerant cultivars which require less maintenance (i.e., fertigation, fertilization and irrigation), and grow in poor soil conditions. These characteristics can be very beneficial for turfgrass growth in arid and semi-arid regions where the soils are usually saline/sodic and water is limited for irrigation and other agricultural uses (Pessarakli *et al.,* 2005). As the fresh water resources are reducing, the recycled water takes its place. Salinity in the recycled water is higher as well as the presence of detrimental salts is much higher in the re-used water (Dai *et al*., 2009). The effects of salt on the green turf grass may include, but are not limited to, physiological drought, ion toxicity, and ion imbalances (Alshammary *et al*., 2004). Most coolseason turf grass is particularly susceptible to salinity stress during seed germination with the possible exception of perennial ryegrass (*Lolium perenne* L.) (Dai *et al*., 2009; Alshammary *et al*., 2004). Thus, soils and irrigation water with increased salt content can pose as the biggest hurdle for turf grass development than to the maintenance of mature turfgrass (Camberato and Martin, 2004).

Compared to Bermuda grass, seashore Paspalum can form a higher quality turf in reduced light conditions, in soils ranging in pH from 3.6 to 10.2, in waterlogged soils, and with fewer applications of nitrogen fertilizer (Brosnan and Deputy, 2008).

Turfgrass, like other agronomic and horticulture vegetation, needs ample quantities of water to grow. Lower quantity of water or a drought can cause the turf grass to lose its green color and turn brown

(Handreck and Black, 2002). This leads to patches of brown colour or withered grass which does not appeal to aesthetic sense. Thus (Huang, 2008) suggested that proper irrigation systems are extremely important to turfgrass growth and development. The quantity of water required depends upon two factors, namely:

- Total water needed for growth
- Water needed for transpiration (loss of water from the shoot)

- Water loss from the soil (due to evaporation)

One more issue in growing quality turfgrass is the increase in salt levels, both in the soil as well as in water.

Turfgrass cultivation includes many mechanical processes used to modify the characteristics of the turf and the root zone. Those practices are intended to alleviate the problems of compaction, poor aeration, and thatch build-up, whereas other practices, such as grooming, are more often used to improve surface uniformity by reducing the grain. The principal cultivation practices used are coring, spiking, slicing, drilling, vertical mowing, and, to a limited extent, air or water injection (Gaussoin *et al.*, 2013). Costea *et al.* (2012) revealed that the beginning of spring is setting the weeds of both monocotyledonous and dicotyledonous and presence of the weeds in turf is a consequence of the inadequate execution of the maintenance works. In this connection hydroponics can also be chosen as one of the methods of sod production.

2.2 Natural and Taxonomic Distribution

The turfgrass species are in the family Poaceae which was formerly known as Gramineae under the class Monocotyledoneae. More than 800 genera comprising over ten thousand species belong to the Poaceae (Piperno and Sues, 2005). Each species may contain a number of cultivars or varieties. Most cultivars are produced by hybridization followed by natural selection and also artificial selection. In consideration of life cycle, annual and perennial turfgrasses are available throughout the ecosystems (Prasad *et al.*, 2005). Differences in ecological adaptation of turf determine their obvious geographical distribution over the climatic regions of the world. Bermudagrass, Cowgrass, Serangoongrass, Zoysiagrass St. Augustinegrass, Bahiagrass, Seashore Papalum, and Centipedegrass are highly appreciated as tropical warm season turfgrasses. On the other hand, Kentucky bluegrass, Rough Bluegrass, Canada Bluegrass, Annual Bluegrass, and Annual Ryegrass have established their position in the list of cool season turfs (Chapman and Peat, 1992).

2.3 Description of Bermuda Grass

Taxonomic Position

Class :	Monocotyledons
Order :	Poales
Family:	Poaceae
Genus:	*Cynodon*
Species:	*dactylon* (L.) Pers.

Plant Description

A gray-green perennial; culms extensively creeping, either below the surface of the soil forming rhizomes, or above ground forming stolons, the fertile shoots ascending, smooth, a few inches to as much as 2 feet in height; sheaths smooth, flattened and keeled, villous on each side at the throat; ligule a very short ciliate-fringed membrane; blades flat, 2 to 4 mm. wide, 1/2 to 2 inches long or on sterile shoots sometimes much longer, more or less scabrous, at least on the margin, sharp-pointed; inflorescence consisting of 3 to 6 slender ascending spikes 1 to 2 inches long, digitate at the summit of the culms, pubescent at the base, the rachis 1/3 to 1/2 mm. wide; spike -lets much compressed, often purplish, ovate, about 2 1/2 mm. long; glumes narrow, pointed, scabrous on the keel, shorter than the spike-let, the lemma pubescent on the margin and often also on the keel (Hitchcock, 1914).

Description of Paspalumgrass

Taxonomic Position

Class : Monocotyledons

Order : Poales

Family: Poaceae

Genus: *Paspalum*

Species: *vaginatum* SW

2.4 Plant Description

Perennial. Culms creeping with stolons, branching and rooting at nodes, erect or ascending to 15–30 cm high; nodes swollen, glabrous; internodes glabrous, 1.4–5.0 cm by 1.2–1.8 mm. Sheath chartaceous, glabrous, 6–11 cm long, margins membranous. Blades chartaceous, linear, 12–27 by 0.3–0.8 cm, glabrous, apex acuminate. Inflorescence sub-opposite or opposite racemose, with 2 racemes; rachis triangular. Spikelets solitary, 2-seriate, obovate to lanceolate, 2 mm long, apex acute. Lower glumes absent. Upper glumes membranous, ovate-lanceolate, 1.5–1.6 mm long, 5– nerved, glabrous, apex acute. Lower floret sterile; lemma membranous, elliptic, 1.5– 1.6 by 1.3–1.4 mm, glabrous, 3-nerved, transversely wrinkled; palea hyaline, elliptic, apex acute. Upper floret hermaphrodite; lemma crustaceous, lanceolate, 1.5–1.6 by 1.2–1.3 mm, apex acute; palea crustaceous, lanceolate, 1.4–1.5 by 0.9–1.0 mm, minutely hairy at tip. Stamens 3; anthers black, 0.7–0.8 mm long. Stigmas divided blackish (Norsaengsri and Chantaranothai, 2008).

2.5 Morphology

Most grasses are established by seeding, but, in some cases, they can also be established vegetatively using sod, sprigs, stolons, or plugs. Turfgrasses have an extensive fibrous root system. It is common for grasses to have several tons of roots per acre. The bulk of the root system is in the top 10 to 15 cm of soil. They may have some roots that grow down several feet into the soil. The three major types of stems associated with turfgrass are the crown, the flowering culm, and lateral or creeping stems. The crown, the principal meristematic region, is an un-elongated stem. At reproductive stage, it produces an elongated stem, which is called the flowering culm. Some turfgrass species have lateral or creeping stems called stolons and rhizomes. These stems elongate horizontally from the crown of the parent plant. Stolons grow along the surface of the ground, while rhizomes grow beneath the surface. Shoots and roots form at nodes on the horizontal stems (Chapman and Peat, 1992). A leaf of turfgrass is divided into two major parts: the sheath and the blade. The blade is the upper, relatively flat part of the leaf. The sheath is the cylindrical portion of the leaf that surrounds the culm or young leaves. The sheath margin (the area where the two edges come together around the culm) can be used for identification. These two edges or margins can be open (not touching), closed (seamless), or overlapping. The sheaths are rolled around each other and support the leaf blades, holding them above the ground so that they can intercept sun light. A collar is the growing area or band that divides the sheath and leaf blade. Auricles are outgrowths that arise on each side of the collar. They can be short and blunt, long and clasping, or absent. Another feature, the ligule, is an outgrowth that arises at the inside junction of the sheath and leaf blade. The inflorescence, produced at the top of the culm, is the flowering part of a grass plant and is where seeds are formed (Turgeon, 2005).

Erusha *et al.,* (2001) studied the root and top growth responses of kentucky bluegrass cultivars when grown in hydroponics. They were reported the study with the objectives of (i) evaluate Kentucky bluegrass (*Poa pratensis* L.) cultivars and experimental lines for root production, depth, and distribution in hydroponics (ii) to determine ability to redistribute roots as solution levels decline and (iii) to assess production of clipping yield, verdure, and top growth. Fifteen Kentucky bluegrass cultivars and one experimental line were studied in hydroponics experiments. ‘Georgetown’ produced the most root mass at 1460 mg, while ‘Kenblue’ and NE 80-88 had the least production at 1122 and 1099 mg, respectively. Total root production varied by 25% among entries. Root production was greatest for all cultivars in the range of 0 to 300 mm, declining with depth, but all entries produced roots at depths >600 mm. NE 80-88 had 90% of its root growth in this range, while ‘Touchdown’ had 71%. Root production declined considerably at depths >450 mm. ‘Birka’, ‘Dormie’, ‘Eclipse’, and Touchdown had the greatest roots, while ‘Aspen’, Georgetown, NE 80-88, and ‘Park’ had the least. Touchdown had the most roots (i.e., 27% of root mass) remaining in the hydroponic solution at the end of each experiment, while NE 80-88 had the least at 8.7%. Total top growth varied among the Kentucky bluegrass cultivars by 42%. ‘America’ produced the most total top growth at 9.2 g, while Kenblue had the least at 5.4 g. Aspen produced the most clippings with a yield of 3.7 g, while ‘Challenger’ and Eclipse had the lowest production at 2.1 g. Results of the experiments indicated that the hydroponic systems can be used to effectively separate Kentucky bluegrass genotypes for rooting and top growth responses.

Mascarini *et al*. (2001) determined the water consumption of two Gerbera cultivars (Testarossa and Nevada) in hydroponics by adjusting current use models during spring, summer and autumn seasons. Water consumption by the plants was evaluated as the difference between the water added to each growth bag and the water drained on trays, so as to determine the crop's evapotranspiration (Etc). With the data registered in the greenhouse regarding temperature, relative humidity, cloudiness, and radiation, potential or reference evapotranspiration (Eto) was determined applying current use formulae like Blanney-Criddle and Penman-Monteith modified by Food and Agriculture Organization.

Shimozono *et al.* (2002) reported the nutrient dynamics through leachate by intermittent irrigation and turf grass growth was monitored in sands amended with food waste compost and chemical fertilizer in pots. The plants were grown 170 days in pots and nutrient dynamics/losses were evaluated in four different stages. The maximal nitrogen loss occurred as nitrate nitrogen, which was higher in food waste compost than chemical fertilizer treatment. Initially, the loss of nitrogen as ammonium (NH_4)-nitrogen was prominent. Fast nitrogen loss was observed in chemical fertilizer, which was totally exhausted by 134 days after sowing of turf grass seeds. Because of slow-release characteristics, the nutrient losses were delayed in food waste compost, and it took comparatively longer periods (about 170 days) for near-exhaustion of nitrogen. The food waste compost amendment enhanced K retention and decreased its leaching loss compared to P in the present observation. Elevated concentrations of salts leached out, and the electrical conductivity in the leachate was proportionately maintained with the amount of food waste compost application. The amount of salt dissociation and electrical conductivity of leachate were inversely correlated with nitrogen uptake and shoot dry-matter production. The total nitrogen uptake by shoot was higher in food waste compost amended treatments until later stages of turf grass growth but was much lower in chemical fertilizer treated plants. Comparatively, the food waste compost pellets treatment showed superior performance over sole food waste compost in sustaining nutrients in growing media. Finally, longer retention of nutrients with better performance in plant growth was observed in food waste compost amended treatments in spite of higher leaching loss of nutrients.

The correct supply of water and nutrients is important in hydroponic growing systems in order to use water efficiently, avoid stress situations and control production. Lizarraga *et al.* (2003) evaluated two irrigation scheduling techniques for hydroponic tomato production in Navarra, northern Spain, related to the crop water requirements. The results showed that although daily over-irrigation was applied (45.7% of drainage), 18% of the total yield (35 kgm^{-2}) was affected by blossom end rot problems, due to water stress suffered by the crop. Irrigation scheduling by time clock was not flexible enough to satisfy the varying crop water requirements through the day and during the season. With constant irrigation intervals and volumes, water and fertilizers were wasted during the morning whereas during the afternoon, the plants suffered water stress. The authors recommended that the irrigation scheduling by radiation method at a level of 0.81 MJm^{-2}, with some supplementary time clock irrigation applications during the hours of darkness appeared to be a good solution for hydroponic tomato production.

The responses of three switchgrass (*Panicum virgatum* L.) cultivars to seed priming and differential aging conditions was reported by Hacisalihoglu (2008). The author determined the effectiveness of priming on three non-aged and aged switchgrass cultivars of ‘Cave in rock’ ‘Dacotah’, and ‘Kanlow’. Seeds were primed with a synthetic calcium silicate and water at 30°C for five days. Seed, carrier and water proportions were 1 g, 0.5 g, and 1.5 mL, respectively. There was a 5% point (pp, Cave in rock), 8 pp (Dacotah), and 19 pp (Kanlow) increase in primed seeds compared with non-treated control seeds. Furthermore, priming decreased mean germination time by 26–36% in all seeds compared with the non-treated control.

Accelerated aging was induced by storing seeds for 0, 10, and 21 days at 42°C and 95% relative humidity (RH). Germination percentage decreased and mean germination time increased with the aging. These results suggested that priming is an effective technique to improve the performance of switchgrass cultivars.

The effects that core cultivation and topdressing compost onto established Kentucky bluegrass (*Poa pratensis* L.) on soil water content and turf canopy temperatures and quality responses during periods of drought was reported by Johnson *et al.* (2009) Compared to the control, compost treatments at 66 and 99 m^3 ha^{-1} reduced turf canopy temperature by 1.2-3.3°C during 4-10 days of dry down, indicating less drought stress. While 'Nuglade' and 'Livingston' turf quality of control (no compost treatment) declined to an unacceptable level on day 8 of dry down, plots with 66 and 99 m^3ha^{-1} compost treatments maintained acceptable turf quality during the entire dry down periods. In Experiment II, turf quality of 'Kenblue' declined to below 6 on day 3 for the non-cultivated and no-compost-topdressed treatment, on day 5 for the core-cultivated but no compost top-dressed control and on day 9 for 66 and 99 m^3ha^{-1} compost treatments. Our results suggested that compost topdressing after core cultivation is a management practice that could reduce turfgrass irrigation requirements.

Li *et al.* (2012) studied the most effective method of fertilizing turfgrass during the early growth stage following seedling emergence. The field experiment was performed on turfgrass (tall fescue, *Festuca arundinacea* Schreb.) comparing a check (no fertilizer applied), two conventional fertilization techniques (equal additions and linearly increasing application rates over time) to the exponential additions fertilization method to test the relative effectiveness of this latter technique relative to conventional methods. Results showed that the exponential growth period for fescue is the first 5 weeks following planting. Biomass accumulation, total nitrogen (N) concentration, and N content per seedling in turfgrass seedlings fertilized using the exponential addition fertilization technique were 32, 35, and 70% greater than those treated with traditional methods, respectively.

Matthieu *et al.* (2011) characterized the ability of turfgrass roots to penetrate a compacted subsurface layer. Seven turfgrasses were grown in soil columns and each column was divided into three sections with the top and bottom packed to a bulk density of 1.6 gcm^{-3}, and the middle (treatment) layer packed to 1.6, 1.7, 1.8, 1.9, or 2.0 gcm^{-3}. Subsurface compaction reduced root mass for two of the species, and inhibited deep root growth in all seven species, with the greatest reduction occurring between 1.7 and 1.8 gcm^{-3}. There appears to be little difference between species in ability to penetrate compacted soils, suggesting that soil preparation and routine management practices, rather than grass selection, is the more viable way to handle soil compaction problems in turf.

Kauer *et al.* (2013) studied the impact of N rate and weather during the growing season on the effect of returned clippings and on efficiency of returned clippings. Over a five-year period, a field experiment was conducted on a sward of *Festuca rubra rubra* and *Poa pratensis*. Measured experimental factors included two clipping treatments, with clippings removed or clippings returned, as well as seven fertilizer rates. The swards' dry matter yield was significantly influenced by clippings treatment, applied N rate, year, and these interactions. Returning turfgrass clippings provide significant positive effects on the dry matter yield only when plants are fertilized with N. Without N fertilization, the effect was negative or absent. Returned clippings impact (RCLI) increased with N rate up to 213 $kgNha^{-1}$ and then started to decrease. The annual effect of returned clippings at N level 240

$kgha^{-1}$ depended mainly on the amount of returned clippings in May and June, as well as on precipitation during May. The annual efficiency of returned clippings at the same N level was mostly associated with precipitation in May and June and the average temperatures in July. We conclude that the annual effect of returning grass clippings on mown turf is beneficial only with mineral fertilizers. Also, if the moisture condition is a limiting factor to the decomposition of clippings then the moisture conditions must be improved with the irrigation.

Dede and Ozdemir (2015) reported the Composts produced from composting municipal sewage sludge with bulking agent, namely hazelnut husk (HH), pine litter (PL), corn straw (CS) and sawdust (SW), were seeded with turfgrass mix and cultivated in a container to compare the suitability of composted substrates to produce turfgrass in greenhouse conditions. The performance of substrate was determined by both substrate properties compared to standard peat and by measuring plant growth parameters on each substrate during turfgrass sod establishment. The physio-chemical properties of all substrates were satisfactory for container substrates, but HH and PL substrates performed better in plant growth parameters than in SW and CS composts. The comprehensive growth index values obtained for plants growing in peat, HH and PL were 0.94, 0.87 and 0.84, respectively, which were higher than those in the CS and SW. Plant growth showed linear above-ground dry matter accumulation in all substrates, but was slower in SW and CS. HH and PL substrates appeared to be suitable for containerized sod production for natural soil and peat substitution. Bio solid proved to be an efficient component as a nutrient source ingredient of composted substrates for turfgrass.

Tolerance of four cool season turfgrass species viz. sheep fescue, perennial ryegrass, colonial bentgrass and rough bluegrass to sulfur dioxide was studied by investigating their injury and physiological responses under sulfur dioxide stress for 14 days. Results showed that sheep fescue and perennial ryegrass had better sulfur dioxide tolerance than rough bluegrass and colonial bentgrass. Chlorophyll *a* and carotenoid contents were significantly higher in the sulfur dioxide tolerant turfgrass species (sheep fescue and perennial ryegrass) than in the sulfur dioxide sensitive turfgrass species (rough bluegrass and colonial bentgrass). Relatively lower levels of reactive oxygen species, malondialdehyde, and electrolyte leakage were observed in sulfur dioxide tolerant turfgrass species. Gradually increased antioxidant enzyme activities and proline content in sulfur dioxide tolerant turfgrass species could counteract such damages and harmful effects caused by reactive oxygen species and electrolyte leakage, respectively. Sulfite reductase played an important role in sulfur metabolism and subsequently reduced oxidative pressure on sulfur dioxide tolerant turfgrass species (Li *et al.*, 2015).

The effects of municipal wastewater on soil chemical properties in cultivating turfgrass using subsurface drip irrigation was studied by Tabatabaei *et al.* (2017). The authors studied the effects of water quality, depths and distances of lateral installation on soil chemical properties during turfgrass cultivation. A field experiment was conducted using a Split Plot design based on the Randomized Complete Block with two treatments (well's and wastewater), and eight sub-treatments (45 and 60 cm distance of the laterals and 15, 20, 25, and 30 cm depths of laterals) in three replicates on a sandy-loam soil. Soil samples were collected from 0–30 and 30–60 cm depth for measuring nitrate (NO_3^-), electrical conductivity (EC), and pH at the end of the experiment. Results indicated that by increasing lateral distance, NO_3^- level increased in both layers. With installing laterals in deeper levels, NO_3^- concentration decreased at the beginning, then increased in the first layer, whereas in the second layer NO_3^- concentration decreased. In addition, installing laterals in deeper depth, caused an increase in soil EC in the top layer, but a decrease in the lower layer. However, the results showed that there was no significant effect of experimental factors on soil pH. The results also showed that with increasing laterals depth, Fc level decreased at the soil surface.

Chapter 3: Materials and Methods

3.1 Research Hypotheses

The research will test the following two hypotheses

1. There is no significant difference of growing turfgrass in different substrates
2. Turf sod produced in hydroponics is significantly better than typically produced one according to the specialized evaluation criteria.

3.2 Experimental Site

The experiments were conducted in the Greenhouse of Al Foah, College of Food and Agriculture United Arab Emirates University. It lies in the co-ordinate latitude and longitude of 24.2191° N and 55.7146° E.

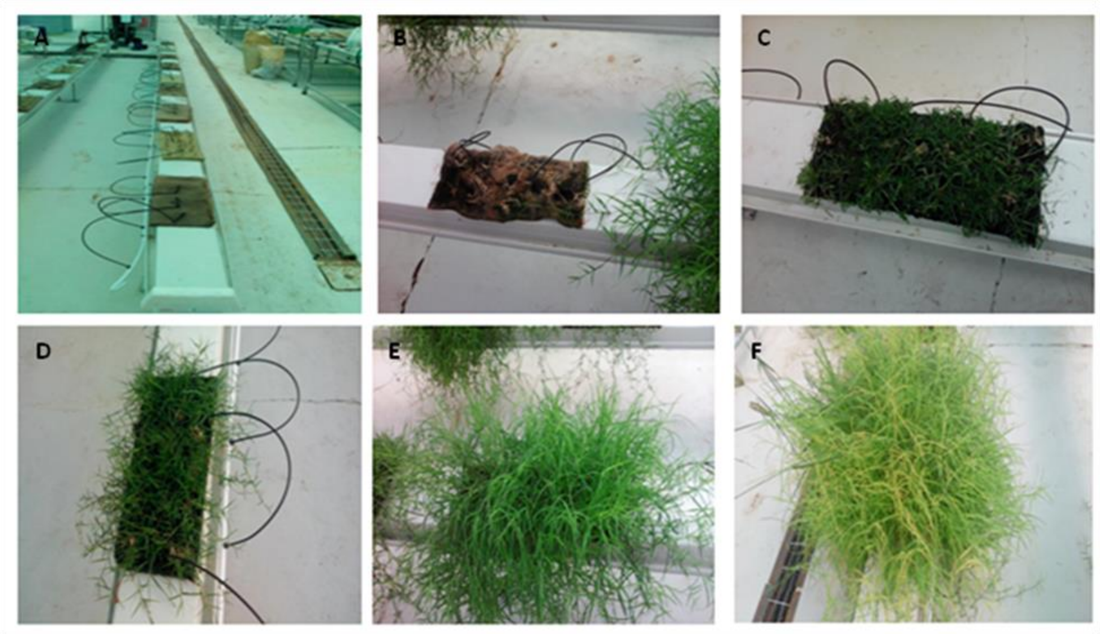

Figure 1: Production of turfgrass sod production in hydroponic system under green house conditions. 'A' and 'B'- Jute/Rockwool Substrate; 'C' to 'F' – Various stages of turfgrass growth

3.3 Selection of Turf Grasses and Substrates

There are two different types of turf grasses used in the present experiments. They are Bermuda grass and Paspalum grass. The Bermuda grass is a typical warm season turfgrass and the Paspalum grass survives saline stress and also drought conditions. On the basis of these nature, the grasses which best suit the climatic conditions of UAE are selected for the present hydroponics experiments and turf grass sod production studies. Three substrates were used in this study, Jute Fabric, Rockwool and a combination of Jute Fabric and Rock wool . Poor results of Jute Fabric led to excluding it from results. The other two substrates were used until the end of the experiment . Dimension of each sod was 20×50×5 cm.

3.4 Procuring of Seeding Materials

The seeds and stolons of Bermuda grass and Paspalum grass were procured and seeds and stolons were healthy and disease free.

3.5 Germination Studies of Turf Seeds

The germination studies were conducted with a slight modification of method given by Salehi *et al.* (2008). Hundred seeds for each of the two substrate beds, rock wool alone and rock wool and jute fabric combination were wet daily. In both substrates, three replications of 100 seeds of both grasses were used. Seeds were considered germinated, when the radicles were about 3mm long and discarded after counting. Germination tests were continued up to 20 days.

The germination percentage was calculated using the formula:

$$\text{Germination Percentage} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds sown}} \times 100$$

3.6 Re-generation Studies of Turf Stolons

The re-generation studies were conducted using stolons of both Bermuda and Paspalum grasses. Hundred stolons for each of the two substrate beds, rock wool and rock wool and jute fabric combination were placed in trays and daily sprinkled with water. Three replicates were maintained for each grass and substrates. The tests were continued up to 20 days.

The re-generation percentage was calculated using the formula

$$\text{Re-generation Percentage} = \frac{\text{Number of stolons re-generated}}{\text{Number of stolons tested}} \times 100$$

3.7 Hydroponic System Setup and Nutrient Solution Preparation

The hydroponic system was comprised of a total of four tanks. The first tank contained fresh water and three other tanks that stored various chemicals and fertilizers necessary for grass growth and nutrition.

The second tank contained dilute acid solution of HCl that is required to adjust to reduce the alkaline nature of water and balances the pH levels of the water for reuse. The more the alkalinity of water, the more the pH will tend to rise in the nutrient solution. Depending on the alkalinity of water, the acid solution is added to neutralize the alkalinity and counter the pH rise.

Tank 3 contained iron chelate and calcium. The iron chelate was added in the form DTPA (Diethylene triamine penta acetic acid), analytical grade chemical. The concentration of the iron chelate was maintained at 60 ppm .Calcium Nitrate is used as the source of Nitrogen and Calcium . Although the Calcium chloride is also readily soluble in water, it is not used. Even a small amount of chloride content in the fertilizer, combined with chloride that may be present in the source water, could overload the chloride content in the fertilizer program. The concentration of calcium carbonate is 150 ppm in the tank. The reason for maintenance of a separate tank for calcium is that, the calcium can combine with phosphates and sulfates to form insoluble precipitates.

This tank contained the nutrient solution prepared according to Shavrukov *et al.* (2012) which is optimized for monocot plants like wheat and barley. Since the present study also deals with the monocot plants, the same composition of nutrient solution is prepared with slight modifications. The Si and Ni elements were not considered significant in case of turf grass and Cl was already mixed in the tank in the form of Calcium Chloride, modifications of the nutrients are made for this study. The chemicals used in this study are analytical Grade and procured from Sigma-Aldrich, USA. The details of the composition of nutrients are given below.

Table 2: Nutrient composition for hydroponic culture of turf grasses

Elements		Salts Used	**Concentration (mM) according to the method of Shavrukov *et al.*(2012)**	**Actual Nutrient Concentration (used)(mM)**
Macro	N	NH_4NO_3	0.2	0.2
	K, N	KNO_3	5.0	5.0
	Mg, S	$MgSO_4$	2.0	2.0
	P,K	KH_2PO_4	0.1	0.1
	Si	Na_2SiO_3	0.5	0.0
Micro			(µM)	(µM)
	B	H_3BO_3	12.5	12.5
	Mn	$MnCl_2$	2.0	2.0
	Zn	$ZnSO_4$	3.0	3.0
	Cu	$CuSO_4$	0.5	0.5
	Mo	Na_2MoO_3	0.1	0.1
	Ni	$NiSO_4$	0.1	0.0
	Cl	KCl	25.0	0.0

The water in the system is pumped through a pump which is also attached at single point to the three tanks. The minerals are mixed in water which is then passed on to the growing area. The water passes through the plants and is absorbed. Any extra water is then pumped out. The irrigation water then passes through a special water filter which results in purification of the irrigation water which is ready to be used again. This is a “closed” hydroponic system which allows water and nutrient reuse. In order to maintain an adequate supply of nutrients to the crop, a frequent testing of the nutrient solution composition is made.

The water is then re-pumped in the irrigation system. Thus the water is taken from the fresh water tank, which passes to the reused water tank. Later it passes from the three tanks of acid, iron and calcium, and fertilizer nutrients respectively. After that the water is passed to the growing area.

3.8 pH and Electrical Conductivity Values

The pH of the fresh water was maintained between 5 and 6. This was adjusted automatically. The electrical conductivity of the water was also measured using a conductivity meter. The conductivity was maintained between 1.2 and 1.4 m S/cm.

3.9 Planting on Substrates

The sod seeds were planted in four (4) rows, each row comprising of nine (9) sample plants. Thus, in total, thirty-six (36) sample plants were sowed. It must be noted that the hydroponic system was already in place at the green house, prior to the plantation. On the first day the water was given to the plants four times, at an interval of six hours. The duration of watering the plants was ten minutes each time. It must be noted that the intervals and numbers of time the hydroponic system was used to deliver water to the plants changed. For example, the next day, the plants were irrigated three times, at 8-hour intervals and the duration of irrigation was increased to 15 minutes as compared to only 10 minutes the previous day.

Similarly, on the 31st of March, the samples were given water 9 times, each time the water was given for seven (7) minutes. The irrigation time was increased from thereon; however, the duration for which irrigation was performed was reduced each day.

3.10 Studies of Growth Parameters

The growth parameters such as length of leaf, fresh and dry weight of germinated sods were recorded. The leaf length was measured on 10, 20 and 30th day after planting. For fresh and dry weight, the green matters were calculated after the

35th day of growth. Once the fresh weight is noted, the green matter was dried under sunlight (Joubert and Myburgh., 2014) and the dry weight was recorded.

3.11 Transferring Sods to Open Field

After nearly two months of growth, the grass was taken outside the greenhouse and planted in the premises of the lawn in Islamic Institute. It must be noted that the hydroponic system was also shifted to the area and thus the only change in the grass environment was that of the direct sunlight as compared to the greenhouse. Here the length and flexibility measurements for all samples were taken and recorded.

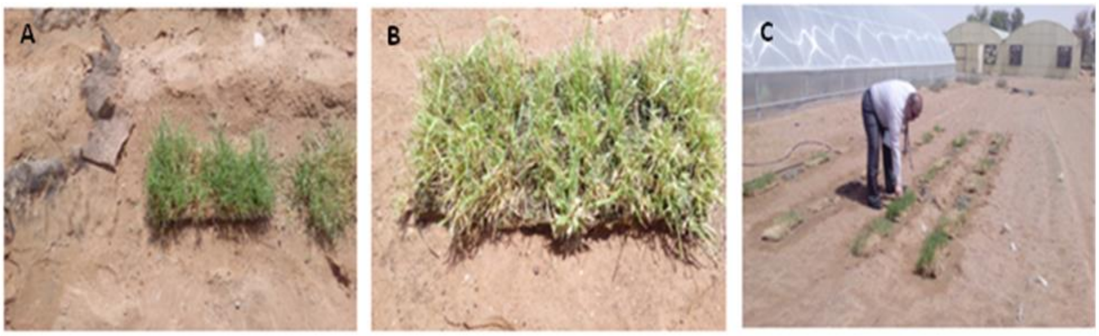

Figure 2: 'A' and 'B' – Open field trial under natural conditions; 'C' – Measurement of soil penetration

3.12 Statistical Analysis

All the data in this study are collected from triplicates. The results are expressed as a mean value of three replicates and their standard error was calculated. The significance of mean deviation was calculated using one-way ANOVA (Andrews *et al.,* 1973) at p value 0.05 using SPSS (Statistical Package for Social Sciences) version 11.5.

Chapter 4: Results

The two grass species namely Paspalum and Bermuda grasses were grown using hydroponic system amended with nutrient solution. Different parameters of the growth of grass like germination percentage of seeds, emerging percentage of stolon, fresh weight, plant length and dry weight were recorded at specific time periods and the results are discussed in this chapter.

4.1 Germination and Generation Percentages

The germination of seeds of both Paspalum and Bermuda grasses as well as the percentage of the stolons of the grasses were studied on two different substrates namely Jute fabric combined with Rock wool and Rock wool alone (Table. 3). After one week of irrigation of the seeds and stolon, the germination starts. It must be noted that the first irrigation was performed on 28th March 2016 while on 5thApril 2016 the germination started in both Rockwool as well as the combination of Jute Fabric and Rockwool.

Table 3: Germination and emerging percentage of Paspalum and Bermuda grass on different substrates

Substrate	**Germination Percentage***		**Emerging Percentage***	
	Paspalum Seeds	**Bermuda Seeds**	**Paspalum Stolon**	**Bermuda Stolon**
Jute Fabric and Rockwool	64.67(±0.88) **	95.67(±0.67) **	85.00(±1.15) **	97.33(±1.20) **
Rockwool	70.33(±1.45) **	94.00(±2.08) **	70.33(±1.20) **	86.33(±1.86) **
Soil	73.10[a]	98.00[b]	81.33[c]	96.27[c]

***Results are mean of three replicates and their standard errors are given in brackets
**Significant at P value 0.05
[a]Patton *et al.,* 2009; [b]Golestani *et al.,* 2014; 'c' Hacisalihoglu, 2007.

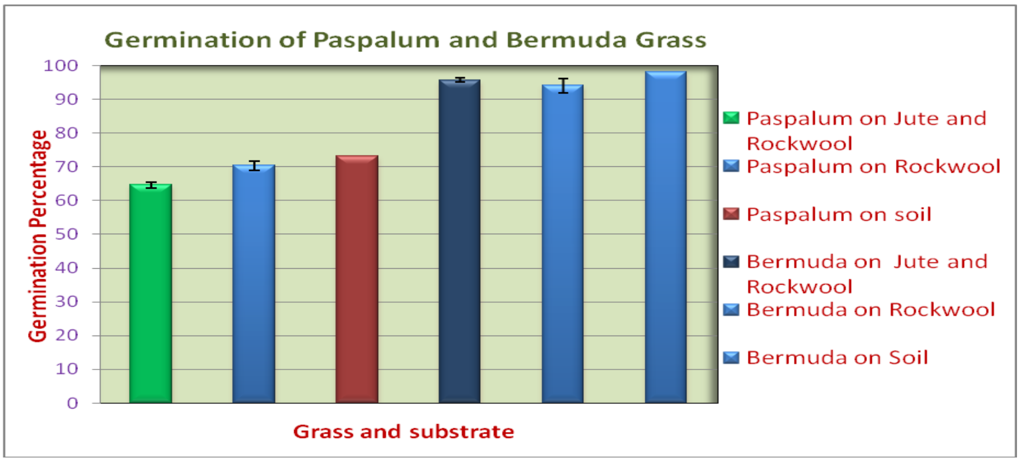

Figure 3: Germination percentage of Paspalum and Bermuda grasses (seeds)

Between the two substrates the Jute Fabric combined with Rock wool showed better results in terms of germination percentage and generation/emerging percentage except the seeds of Paspalumgrass. The highest germination percentage of 95.67 ±0.67 % was recorded with the seeds of Bermuda grass in Jute fabric combined with Rockwool as a substrate. However, the germination percentage of Paspalum on the same substrate was recorded as only 64.67±0.88%. The data was compared with the published data on the germination percentage of Paspalumgrass and Bermuda grass of the previous studies geminated in the soil.

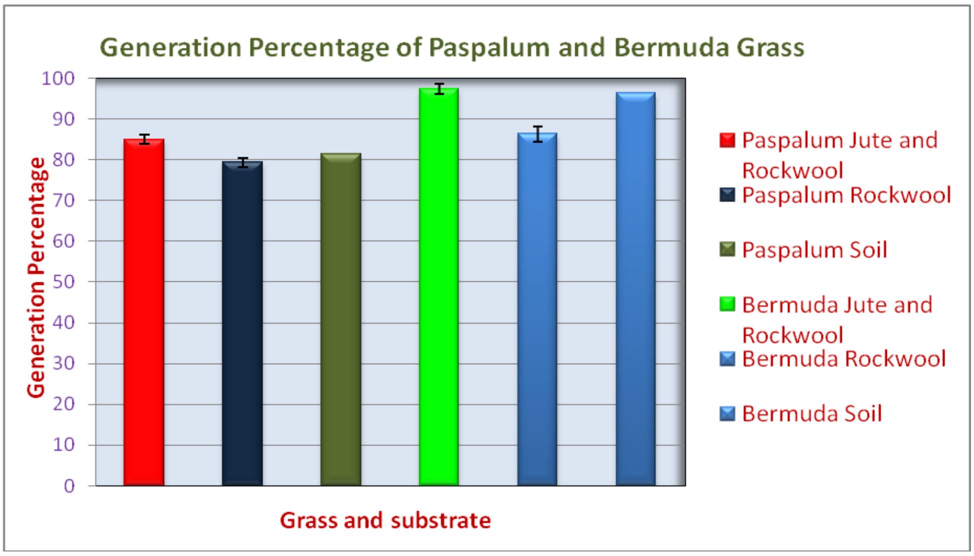

Figure 4: Regeneration percentage of Paspalum and Bermuda grasses (stolons)

The highest regeneration percentage was noticed in the stolons of Bermuda grass 97.33±1.20% in Jute Fabric combined with Rock wool substrate. The regeneration percentage was found more than germination percentage except for the stolon of Bermudagrass (86.33%) in Rockwool. The generation percentage was published by Hacisalihoglu, 2007 is compared with the present study.The results are significant at p value 0.05 when analyzed using One Way ANOVA (Analysis of Variance).

4.2 Fresh Weight of the Grasses after 35 Days of Planting

The fresh weight of the grasses was measured after 35 days of planting on the two substrates in hydroponic culture. The results showed that the fresh weight of the biomass produced from the seeds of Paspalum on Jute Fabric and Rockwool was significantly lowest i.e. 0.66 ±0.17 gm.

Table 4: Fresh weight of Paspalum and Bermuda grass on two different substrates after 35 days after planting

Substrate	**Fresh Weight*(gm)**			
	Paspalum		**Bermuda**	
	Seeds	**Stolon**	**Seeds**	**Stolon**
Jute Fabric and Rock wool	0.66(±0.17)**	88.03(±2.25)**	277.23(±7.90)**	199.63(±5.95)
Rock wool	25.23(±0.58)**	54.90(±6.82)**	444.03(±20.93)**	190.77(±34.88)
Soil	23.77[a]	68.54[a]	420.70 [a]	190.00 [a]

*Results are mean of three replicates and their standard errors are given in brackets

**Significant at P value 0.05; [a]- Pessarakli and Hayat. (2006)

The Bermudagrass grown on Rock wool from seeds showed the highest biomass in terms of fresh weight (444.03±0.17gm) followed by the same grass produced from the seeds on Jute fabric and Rock wool combination (277.23±7.90gm).

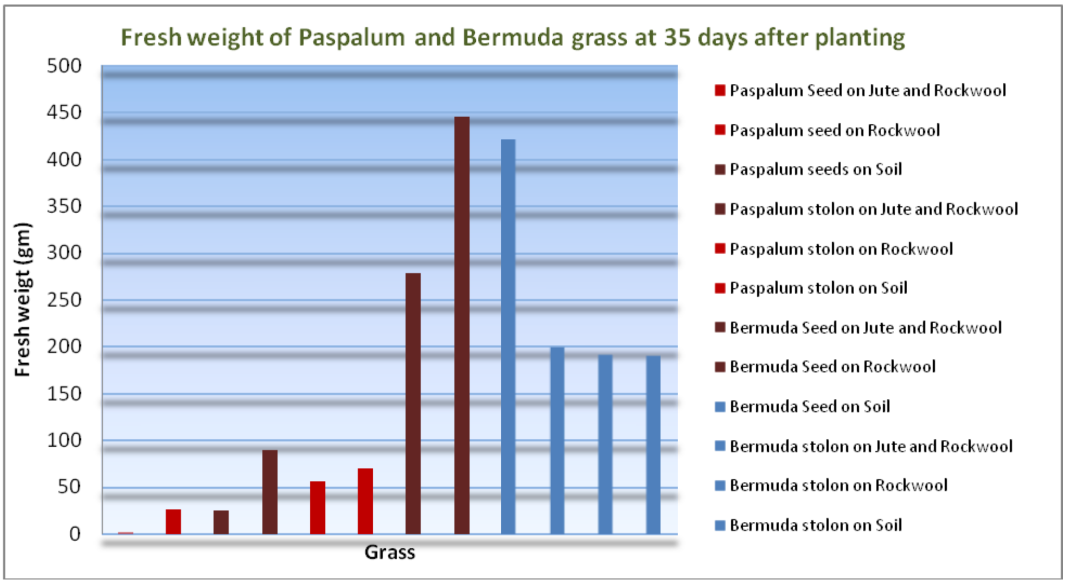

Figure 5: Fresh weight of Paspalum and Bermuda grasses

The Paspalum grass grown from the seeds produced the least biomass both on Rock wool (25.23±0.58 gm) and Jute fabric + Rock wool (0.66±0.17 gm). All the results were found significant at p value 0.05 except the biomass of Bermudagrass produced by stolon in both the substrates.

4.3 Plant Length (cm) of Paspalum and Bermuda Grasses produced by Hydroponics

The length of grass is one of the most important parameters in turfgrass management. So the length of the plant was measured at three different intervals i.e. 10, 20 and 30 days after planting. There is a significant difference among the length of grasses during these three different periods of samplings. After the 10^{th} day of planting the plant length ranged from 1.17 ±0.09 cm (Paspalum seeds on Jute fabric + Rockwool) to 5.30±0.06 cm (Paspalum grass produced from stolons on Rockwool). After the 20^{th} day it was from 25.33 cm for Paspalum as well as Bermuda grass from seeds on Jute Fabric + Rockwool to 33.83±2.85 cm (Paspalum grass produced from stolons on Rock wool).

Table 5: Plant length (cm) of Paspalum and Bermuda grass on two different substrates

Substrate	**Days after Planting**	**Plant Length* (cm)**			
		Paspalum		**Bermuda**	
		Seeds	**Stolon**	**Seeds**	**Stolon**
Jute Fabric and Rockwool	10 Days	1.17(±0.09)**	5.00(±0.28) **	2.13(±0.58)**	4.83(±0.20)**
	20 Days	25.33(±2.90)**	33.60(±2.84)**	25.33(±1.74)**	27.56(±1.85)**
	30 Days	36.83(±2.46)**	47.00(±1.45)**	37.50(±1.44)**	42.67(±4.00)**
Rockwool	10 Days	1.2(±0.07)**	5.30(±0.058)**	2.10(±0.58)**	5.00(±0.00)**
	20 Days	26.67(±2.60)**	33.83(±2.85)**	26.17(±1.74)**	28.50(±1.32)**
	30 Days	36.83(±1.92)**	47.67(±1.45)**	37.17(±1.59)**	42.67(±4.06)**

*****Results are mean of three replicates and their standard errors are given in brackets

**Significant at P value 0.05

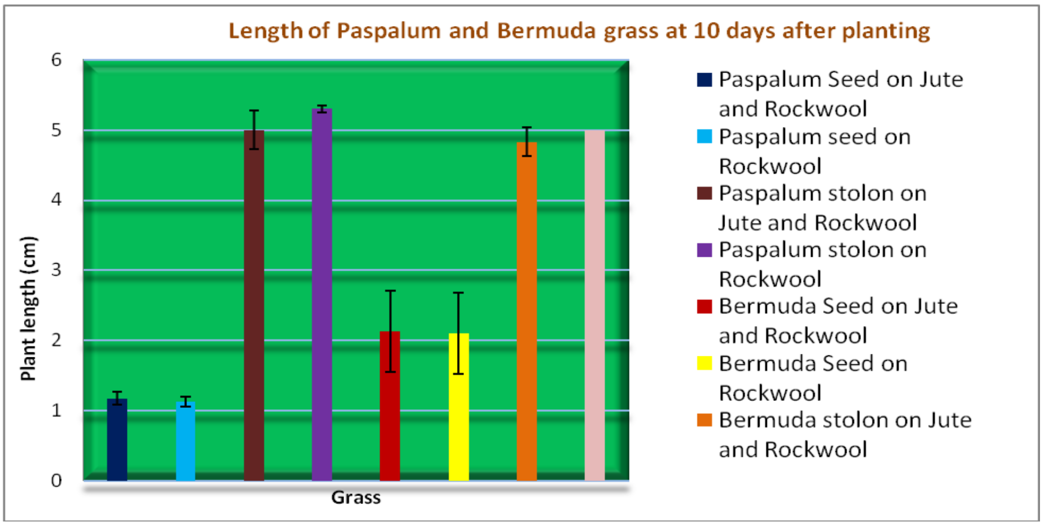

Figure 6: Plant length of Paspalum and Bermuda grasses after 10 days of planting

In the third sampling for plant length, 30 days after planting the Paspalum grass grown by the stolons on Jute Fabric and Rock wool combination showed the highest length of 47.67 ±1.45 cm. The least length recorded for the grasses produced from Paspalum seeds on both Jute fabric+Rock wool (36.83±2.43 cm) and for Rock wool alone (36.83±1.92 cm). In this parameter there is no significant difference between the two substrates.

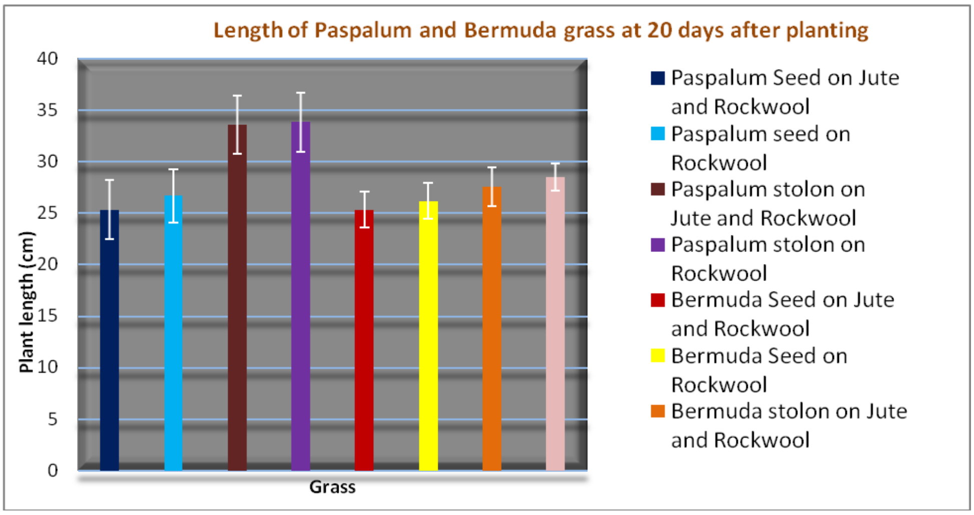

Figure 7: Plant length of Paspalum and Bermuda grasses after 20 days of planting

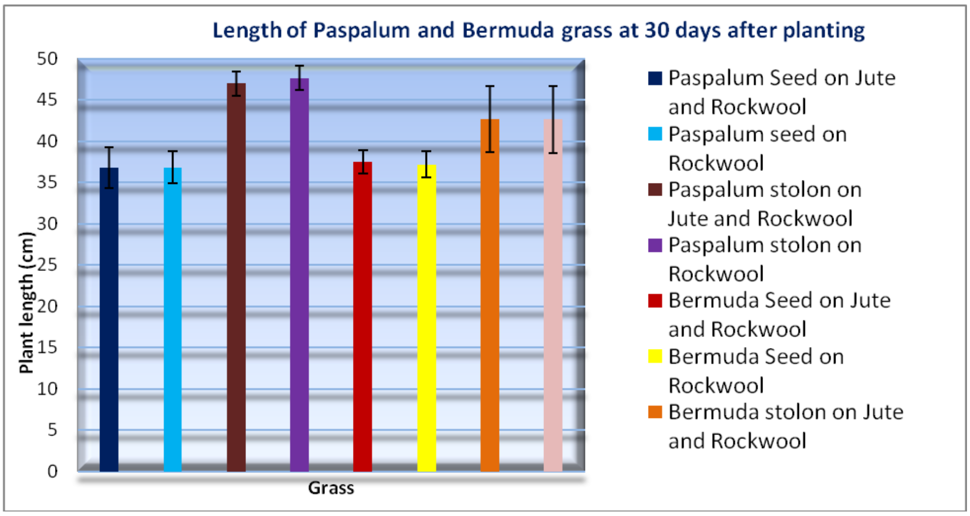

Figure 8: Plant length of Paspalum and Bermuda grasses after 30 days of planting

4.4 Dry Weight of Paspalum and Bermuda Grasses

One month after the growth, the surface area of the grass was pruned and fresh weight was observed. This green matter was then kept in the sunlight and allowed to dry and the dry weight was calculated and expressed in gm.

The dry weight of the studied grasses ranged from 0.21 to 84.53 g as well. A very significant difference could be noticed among the dry weight values calculated. The highest dry weight of biomass (84.53 gm) was noticed in the Bermuda grass grown from the seeds on Rock wool alone as a substrate followed by Bermuda grass grown on Jute fabric and Rock wool combination (44.51 gm).

Table 6: Dry weight of Paspalum and Bermuda grass on different substrates

	Dry Weight* (gm)			
	Paspalum		Bermuda	
Substrate	**Seeds**	**Stolon**	**Seeds**	**Stolon**
Jute Fabric and Rockwool	0.21(±0.08)**	15.68(±0.51)**	44.51(±1.83)**	34.43(±1.46)**
Rockwool	4.43(±0.33)**	12.07(±0.40)**	84.53(±1.09)**	40.45(±4.52)**
Soil	4.70[a]	16.50[a]	84.70[a]	30.66[a]

***Results are mean of three replicates and their standard errors are given in brackets

**Significant at P value 0.05; [a]- Pessarakli and Hayat. (2006)

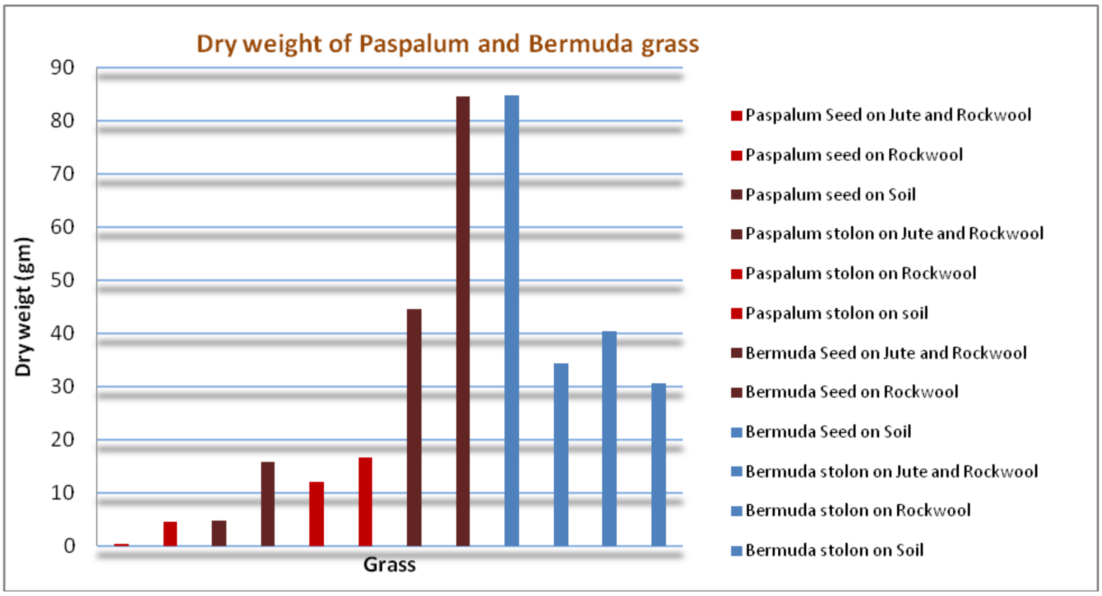

Figure 9: Dry weight of Paspalum and Bermuda grasses on different substrate

The dry weight of both Paspalum grass produced from seeds and stolons was found lower on both substrates compared to the dry weight of Bermuda grass. The overall results indicate that the Bermudagrass found significantly higher percentage of fresh and dry weight of biomass than Paspalumgrass. However only a marginal difference could be noticed in the height of the plant between Paspalum and Bermuda grass. In case of the substrates used, the Jute fabric in combination with Rock wool promoted the germination and generation percentage. The Rock wool alone promoted the fresh and dry weight of the investigated plant biomass. In terms of length of plant, both grasses showed only a slight variation in the two substrates studied.

4.5 Soil Hardness Test

The soil hardness of the lawn established in field by hydroponically produced sods from different substrates and also the lawn at the soccer field in Islamic institute are given in the Table 7 and Figure 8.

Table 7: Soil hardness of the lawns established through hydroponically produced sods

Nature of Lawn	**Soil Hardness (Kg/cm^2)***
Soccer Field	14.67(±1.76)
Paspalum Seeds on Rockwool and Jute Fabric	14.33(±1.67)
Paspalum Seeds on Rockwool	11.67(±0.33)
Paspalum Stolon on Rockwool and Jute Fabric	12.0(±1.0)
Paspalum Stolon on Rockwool and Jute Fabric	13.33(±1.20)
Bermuda Seeds on Rockwool and Jute Fabric	12.67(±1.86)
Bermuda Seeds on Rockwool	14.0(±0.57)
Bermuda Stolon on Rockwool and Jute Fabric	14.33(±3.52)
Bermuda Stolon on Rockwool and Jute Fabric	12.33(±1.20)

* Mean of three replicates; ± Standard error

The hardness of the lawn established by sods from Paspalum seeds, Bermuda stolons grown on Rockwool and Jute Fabric (14.33(±1.67, 14.33±3.52 Kg/cm^2) and Bermuda seeds grown on Rockwool (14.0±0.57 Kg/cm^2) showed only a slight difference than the lawn tested for hardness in the soccer field (14.67±1.76 Kg/cm^2).

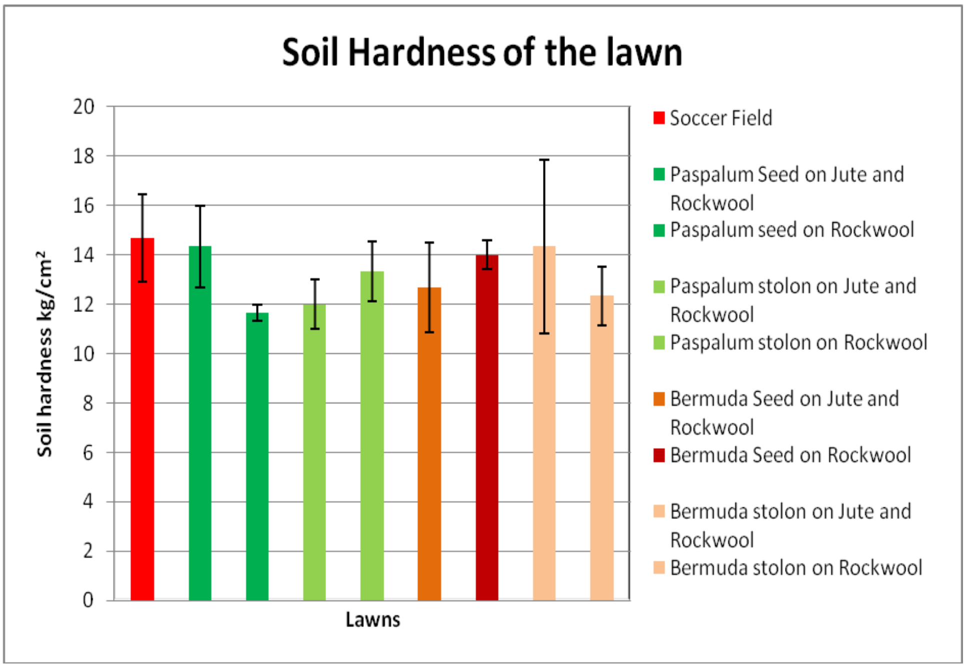

Figure 10: Soil hardness of the lawn established by hydroponically produced sods

The soil hardness of the lawn established by the sod grown Paspalum seeds on Rockwool showed the hardness of 11.67 (±0.33) which was found the lowest value among the all the hardness data. However these data on soil hardness are only a marginal differences compared to soccer field hardness.

Chapter 5: Discussion

In the present research work, two grass species namely Paspalum and Bermuda grasses were compared by growing on hydroponic system amended with nutrient solution. Seashore paspalum, Tifway and Common Bermuda grasses can be managed well in arid zones (Alshehh *et al.,* 2010). The *Cynodon* species produce well on both acid and alkaline soils, but perform best on soils with a pH of 5.5 or higher (Burton and Hanna, 1995). In addition to choosing drought-tolerant plants, select plants compatible with the design of your landscape and well suited to your site and local environment. Also, the use of drought-tolerant grasses such as Bermuda or Paspalum should be a standard practice in all parks that contain turf. These warm-season grasses need less water than the commonly planted turf mixes (Zureikat and Husseini, 2007).

The results showed that the fresh weight of the biomass produced from the seeds of Paspalum on Jute fabric and Rock wool was significantly lower. The turf management has been carried out with conventional practice as well as with recent research tools. For example Caturegli *et al.* (2016) found the growth parameters like plant growth (in cm) and fresh weight as important parameters in tall fescue turf research and used unmanned medium to study the reflectance and correlated the nitrogen requirement of three turf grasses namely Bermuda, Paspalum and Korean grasses. Landscape and turfgrass irrigation have been identified as sources of high water consumption and for this reason, alternative but saline water sources such as recycled water or low-quality groundwater are becoming increasingly attractive for irrigating recreational turf areas such as parks, athletic fields, and golf courses. These characteristics can be very beneficial for turfgrass growth in arid and semi-arid regions where the soils are usually saline/sodic and water is limited for irrigation and other agricultural uses (Pessarakli *et al.,* 2005).

The germination of seeds of both Paspalum and Bermuda grasses as well as the regeneration percentage of the stolons of the grasses were studied on two different substrates namely Jute Fabric combined with Rockwool and Rock wool alone. After one week of irrigation of the seeds and stolon, the germination commenced. Rock wool culture has many advantages namely ease in handling, installation and media removal, high water holding capacity, more precise control of nutrients and good air circulation (Sengar *et al.,* 2014). The rock wool slabs showed significantly highest easily available water (EAW) among all examined substrates such as sheep wool and hemp by Dannehl *et al.* (2015). The use of horticultural rock wool as the growing medium in open hydroponic systems is increasing rapidly. In the present study, the dry weight of the studied grasses ranged from 0.21 to 84.53 gm as well. A very significant difference could be noticed among the dry weight calculated. The highest dry weight of biomass (84.53 gm) was noticed in the Bermudagrass grown from the seeds on Rock wool alone as a substrate followed by the same on Jute Fabric and Rockwool combination (44.51 gm). The dry weight of both Paspalumgrass produced from seed as well as stolon was found lower on both substrates compared to the dry weight of Bermudagrass. The overall results indicate the Bermudagrass was found showed higher percentage, fresh and dry weight of biomass than Paspalumgrass. However only a marginal difference could be noticed in the height of the plant between Paspalum and Bermuda grass. In the present study, different parameters of the growth of grass like germination percentage of seeds, regeneration percentage of stolon, fresh weight, plant length and dry weight tested on two different types of growing substrate namely Rock wool, Rock wool and Jute fabric combination. It has a high tensile strength and high chemical resistance. Jute is one of the natural fibres and it has many advantages over man-made fibres due to low density, low cost, recyclability, biodegradability and moreover, they are renewable and possess relatively high strength and stiffness (Shah and Lakkad, 1981).

In our study the germination of seeds both Paspalum and Bermuda grasses as well as the regeneration percentage of the stolons of the grasses were studied on two different substrates namely Jute fabric combined with Rock wool and Rock wool alone. Öztürk, 2010 observed many natural fibres and among all the natural fibre reinforcing materials, jute appears to be a promising materials because it is relatively inexpensive and commercially available in the required form. The jute fibre was found to increase its tensile strength and hardness when it was combined with rock wool, rather than when it was alone. It has higher strength and modulus than plastics and is a good substitute for conventional fibres in many situations (Shah and Lakkad, 1981). Jute fibre was found to be suitable growing media in soil-less culture for growing squash (Suvo *et al.*, 2016a; 2016b).

In the present study, between the two substrates the Jute fabric combined with Rock wool showed better results in terms of germination percentage and regeneration percentage except the seeds of Paspalumgrass. The highest germination percentage of 95.67 ±0.67 % was recorded with the seeds of Bermudagrass in Jute fabric combined with Rock wool as a substrate. It is interesting to note that germination percentage in medium with rice hull and sand was higher than other treatments of pure sand medium (Golestani *et al.*, 2014). The principal reason for this result may be due to high water retention capacity of rice hull and also it has higher aeration than others. Sod produced on full mixed treatment (sand + rice husk + compost tea + compost leaf) showed acceptable quality than other treatment and appeared to handle well when harvested. In this experiment, the lowest uniformity was related to growing sod on sand beds. One reason for this may be that sand requires special care and regular watering, and usually does not provide under field conditions (Golestani *et al.,* 2014). The total soilless crop area in Southern East Spain is about 5000 ha; half of this area is under rock wool media and the other half is under perlite, sand, and coir using other minor soilless systems (Mazuela *et al.,* 2005). Wettability increases and the water retention is possible drastically at the time of wettability. It means that the application in the nutrient solution of wetting agent improved significantly the wettability of new coir waste and reused ones (Blodgett *et al.,* 1993; Reinikainen and Herramen, 1997). Wettability of growing medium in horticulture is an important practical factor of this industry. With a proper choice and a right application, wetting agent in the nutrient solution would improve wettability and some other physical properties of growing media (Urrestarazu *et al.,* 2008).

Between the two substrates the Jute fabric combined with Rock wool showed better results in terms of germination percentage and regeneration percentage except the seeds of Paspalumgrass. The highest germination percentage 95.67 ±0.67 % was recorded with the seeds of Bermuda grass in Jute fabric combined with Rock wool as a substrate. However, the germination percentage of Paspalum on the same substrate was recorded as only 64.67±0.88%. The highest regeneration percentage was noticed in the stolons of Bermudagrass in Jute fabric combined with Rock wool substrate. Between the two seeding materials the stolons were found to be better except for the stolon of Bermuda grass in Rock wool. Germination studies conducted in controlled environments appeared to be poor predictors of turfgrass establishment under field conditions (Serena *et al.,* 2012). The present automation system in hydroponics can minimize fertilization and irrigation, labour inputs, continuous monitoring of system is important (Sengar *et al.,* 2014).

The overall results indicate the Bermudagrass was found better in terms of germination percentage, fresh and dry weight of biomass. However only a marginal difference could be noticed in the height of the plant between Paspalum and Bermuda grass. In case of the substrates used, the Jute fabric in combination with Rock wool promoted the germination and regeneration percentage. The Rock wool alone promoted the fresh and dry weight of the plant biomass studied. There is a significant difference among the length of grasses during these three different periods of samplings. After the 10th day of planting the plant length ranged from 1.17 ± 0.09 cm to 5.30 ± 0.06 cm. After the 20th day it was from 25.33 cm to 33.83±2.85 cm. In terms of length of plant, both grasses showed only a slight variation between the two substrates studied. Pessarakli *et al.* (2008) found that the bermudagrass and seashore paspalum, when grown in silica sand the highest values for shoot lengths were obtained when the whole plants were used, while the lowest ones were resulted when the rhizomes were used. This shows that difference in growth characteristics such as plant length and dry weight may occur with the type of planting or seeding material used. In a study by Brosnan and Deputy (2008), compared to Bermudagrass, seashore Paspalum can form a higher quality turf in reduced light conditions, in soils ranging in pH from 3.6 to 10.2, under waterlogged soils, and with fewer applications of nitrogen fertilizer

Pessarakli *et al.* (2008) found that the Paspalum leaf was 2.5 times larger than the Common Bermuda grass, but they had similar shoot fresh and dry weight production. The fast weight gain and higher production of dry matter of seedlings of lettuce produced in substrates containing rock wool may be attributed to the high degree of aggregation provided by this substrate (Tapia and Caro, 2009). They also confirmed that the rock wool substrate, alone or in combination with expanded perlite, allows for the production of high-quality lettuce seedlings that optimally respond to their establishment in a nutrient film technique-modified hydroponic system.

In our experiment nutrient solutions are added automatically in hydroponics using separate tank. Nadeem *et al.* (2012) used soft sponges in testing the saline resistant of four cultivars of Bermudagrass using different growth parameters in open tank floating culture. But they used only the stolons as planting material. They also changed the nutrient solution once in fifteen days. This disturbance at middle of the experiment may cause physical stress. Our results do not show this problem in our hydroponic model. Of all nutrients, N has the strongest effect on grass growth and an adequate N fertilization can reduce the time required for the formation of high-quality mats. Increasing N rates increased the soil cover rate of Bermudagrass by reducing the formation time of the mat (Lima *et al.*, 2010).

The rapid rate of establishment of turf grass can be attributed to the increase in the availability of essential nutrients, especially N and P and have the advantage of increasing the number of sod harvests per season by speeding up the rate of turfgrass growth (Tesfamariam *et al.*, 2009). Many advantages make hydroponics a specific technique for plant biology researches. In plant nutrition research, hydroponics allows researchers manage nutrients and control pH, EC, macro and microelements concentrations in nutrients media (Torabi *et al*., 2012).

Schiavon *et al.,* (2014) reported that only limited potable or saline water is available to irrigate turf areas, physiological drought and reduced quality may be observed on turf stands. Under field conditions, additional environmental stresses such as drought, cold, or heat can worsen turf quality to a greater extent than a single stress would. This would suggest that much lower salinity levels than those reported from greenhouse studies might be sufficient to cause a 50% reduction in shoot growth under field conditions.

To meet the increased quality expectations during a labor shortage, labor saving equipment and chemicals will become more important. Recycling waste for sod production plays an important role in reducing the potential source of waste and preserving agricultural soils (Cisar and Snyder, 1992). The hydroponics method of cultivation also allows containment of plant diseases, particularly viruses, and problems associated with insect pests, particularly in tropical regions where infestations are a major concern (Premanandh, 2011). So the hydroponics systems for sod development are a modern way technology that reduces the risk of weeds, fertilization, diseases. The present research work is first of its kind in which the hydroponics were carried out using controlled environment, using rock wool, rock wool and jute as substrate so as to improve the quality of sod production.

Chapter 6: Summary

Turf sod is also very helpful in enhancing aesthetics of the surroundings as well as in making the clean environment. The turfgrasses are cultivable grass species of the class monocot. It is the only landscape plant material that can overcome the stresses of traffic and mowing. The UAE is characterized by a bi-seasonal Mediterranean climate with high temperatures and low rainfall. Like in any desert dominated regions, soils are poor in organic matter, with relatively low biological activities. In the present research experiment two warm season grasses namely Bermudagrass and Paspalumgrass were selected for sod production using Rock wool, Rock wool and Jute fabric combination in automated hydroponic system with separate tanks for different substances i.e. water (Tank 1), pH adjustment (Tank 2), Iron Chelate and Calcium (Tank 3) and Nutrient solution (Tank 4).

The overall results indicate the Bermudagrass was found better in terms of germination percentage, fresh and dry weight of biomass. In case of the substrates used, the Jute fabric in combination with Rock wool promoted the germination and generation percentage. The Rock wool alone promoted the fresh and dry weight of the plant biomass studied. In terms of length of plant, both grasses showed only a slight variation between the two substrates studied.

The soilless production system is very suitable for UAE socio-economic and agro-ecological status. However, growers' acceptance of this new system represents one of the key issues that must be addressed to ensure the successful dissemination of the technology and sustainability of the achievements.

The turfgrass cultivation using the hydroponic system can prove instrumental in greening the country side as well as in urban landscaping for climate modification. This research is being conducted with the purpose to provide a sustainable and effective alternative method of turf grass production. This system can provide a breakthrough for farming and agriculture in the UAE, once the method of turf grass production in hydroponics system is standardized.

Conclusions and recommendations

1. Turf performed better in rock wool than the combination of rock wool and jute substrate when Bermuda seeds was used while it was not different in the other cases.
2. There was no significant difference between typical turf field and the developed rock wool and jute sod according to soil conditions.
3. Still the rock wool and jute combination is preferred because it is more convenient in handling and usage.
4. Hydroponically produced sods should be evaluated according to its water and energy use efficiency.

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