PERFORMANCE EVALUATION OF TURF GRASS SPECIES IN THE HUMID TROPICS

By

ABDUL RAZIQ
(2010-12-120)

THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Pomology and Floriculture
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2014

DECLARATION

I hereby declare that the thesis entitled **"Performance evaluation of turf grass species in the humid tropics"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara ABDUL RAZIQ

CERTIFICATE

Certified that the thesis entitled **"Performance evaluation of turf grass species in the humid tropics"** is a bonafide record of research work done independently by **Mr. Abdul Raziq** under my guidance and supervision and that it has not formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Vellanikkara

Dr.P.K.Valsalakumari
Chairperson, Advisory Committee
Professor and Head
Department of Pomology & Floriculture
College of Horticulture, Vellanikkara

CERTIFICATE

We, the undersigned members of the advisory committee of **Mr. Abdul Raziq.,** a candidate for the degree of **Masters of Science in Horticulture** with major field in **Pomology and Floriculture,** agreed that the thesis entitled **"Performance evaluation of turf grass species in the humid tropics"** may be submitted by **Mr. Abdul Raziq** in partial fulfilment of the requirement of the degree.

Dr.P.K.Valsalakumari
(Chairperson, Advisory Committee)
Professor and Head
Department of Pomology & Floriculture
College of Horticulture, Vellanikkara

Dr.P.K.Sudhadevi
Professor (Hort.) AICFIP
Department of Pomology & Floriculture
College of Horticulture,Vellanikkara
(Member)

Dr.C.K.Geetha
Professor
Department of Pomology & Floriculture
College of Horticulture,Vellanikkara
(Member)

Dr.K.Nandini
Professor & Head
Department of Plant Physiology
College of Horticulture,Vellanikkara
(Member)

ACKNOWLDMENTS

First and foremost I humbly bow my head before the Almighty God, who blessed me with will power and courage to complete this endeavour successfully.

*I humbly express my indebtedness and deep sense of indelible gratitude from the core of my heart to my major adviser, **Dr. P.K Valsalakumari** Associate Dean, college of horticulture, Professor and Head, Department Pomology and Floriculture KAU, for her valuable guidance, incessant inspiration and wholehearted help and personal care throughout the course of this study and in bringing out this thesis.*

*I would like to take this wonderful opportunity to express my sincere thanks and gratitude to my former major adviser, **Dr. P.K, Rajeevan**, Registrar, Kerala Agriculture University, Professor and Head, Department of Pomology and Floriculture for his guidance, immense support, patience and encouragement shown throughout my M.Sc programme and research work. I felt proud to be his student. He always provided the time and patience for me to grow, learn, and apply that knowledge. His door was always open for my help.*

*Profound thanks to **Dr.P.K, Sudha Devi** Professor, Department Pomology and Floriculture and member of advisory committee for her invaluable support, suggestions and constructive criticism which helped in the finalization of my thesis. She always welcomed me with smile. Surely I am going to miss her.*

*I am deeply indebted to **Dr.C.K,Gheetha,** Professor, Department Pomology and Floriculture and member of advisory committee for her whole hearted co operation, critical comments and valuable suggestion during the preparation of this manuscript.*

*Heartfelt pleasure automatically arising to mention **Dr.K,Nandini**, Professor and Head, Department of plant Physiology and member of advisory committee for her patience and care showed towards me throughout my thesis works. Help offered by **Ms. Shina** (Research Assistant), Dept. of plant Physiology is also gratefully acknowledged.*

All of my advisers invested a tremendous amount of time to ensure that I did not stray too far from the path of creating an approachable story-like performance evaluation of the turf grass species under humid tropics. I am very lucky to have such great mentors who care so much about my success.

*I wish to express my indebted thanks to **Dr. N.K, Parameswaran, Dr, K, Ajith Kumar, Dr. T. Radha, Dr. Lila Mathew, Dr. Simi, Dr. Saradha** and other faculty of the Department of Pomology and Floriculture, College of Horticulture for their unbounded support and valuable suggestions offered at different stages of the study.*

*My heartfelt thanks are expressed to **Shri. S. Krishnan**, Associate Professor & Head, Department of Agricultural Statistics, College of Horticulture for his whole hearted co-operation and immense help extended for the statistical analysis of the data.*

*I express sincere and heartfelt gratitude to **Dr. F. M. H. Kaleel**, Professor and Head, Department of Agricultural Extension, College of Horticulture for his scholarly advice, sumptuous guidance and constant encouragement during the entire programme.*

*I take this opportunity to express my respectful gratitude to **Professor Ghulam Rasool Samadi,** and **Professor Masood Saeed,** Department of Horticulture, Faculty of Agriculture, Kabul University, Afghanistan, for their valuable advices and suggestions which helped me a lot.*

*I express my sincere gratitude towards **Dr.Abdul Rahim Abidi** teacher at Kunduz University, Afghanistan, for his valuable suggestions, moral support and encouragement throughout my study.*

*I wish my heartful acknowledgment to **Ministry of Agriculture Irrigation and Livestock, Afghanistan** and **ICAR for** providing scholarship and providing financial support throughout the study via India Afghanistan fellowship programme. I wish to mention about Mr. Godwin, Mr. Kunjunny and other office staff for their timely help to get my fellowship money without any struggle and I was overwhelmed about their friendliness and care.*

*Words are insufficient to express my deep sense of gratitude to **Mrs. Shakila Begum** who gave valuble suggestion, moral support, encouragement and mother's love throughout my study. She was always ready to help me, whatever the problem I had and was always there to share happy and sad moments of my life. I am really going to miss her.*

*I extend my thanks also to my best friends and classmates, **Mr. Narender Nagi, Mr. Pawan Saini, Mr. Najeeb Naduthodi , Mr, Ajay Bhardwaj Mr. Rohit, Mr. Amar, Mr. Ashok, Mr. Ningaraju G.K, Mr. Pramod, Ms Nimmy Varghese, Ms, Manjusha, Ms swathi, Ms Tess Joseph, Ms. Binisha and Ms. Priya, Ms. Aun Raman, Ms. Airiana C .K, Ms.Deepthi Radha** for their constant support and encouragements and words of wisdom.*

They were always ready to help me, whatever the problem I had and were always there to share happy and sad moments of my life.

I am ineffably happy to place on my sense of gratitude and thanks my best Afghan friends ***Noor Jan Zazai, Muhammad Wali Dawlathzai, Khalil Rahman Jahid, Shams Rahman Rahmani*** *students at Purdue University, Indiana, USA.* ***Abdul Satar and S hukrullah Sherzad*** *students at ISA, Lille, France,* ***Mr. Tariq Salari*** *student at Szent Istvan University, Godollo, Hungary for their eminent guidance, motivation and moral support rendered during my post graduate programme.*

I am extremely thankful to my juniors, ***Samrithika Takur, Saveen Takur, Asha Yadav, Priyanka Singh, Sadhana Kapoor, Nithu, Parimal, Ravindra,*** *and* ***Subba Reddy.***

I wish to extend my special mention to my other Afghan friends here in Thrissur, ***Mr. Ahmad Omar Zazai, Mr. Ghulam Sarwar, Mr. Faizan Quraishi, Mr. Wahidullah Rahimi, Mr. Hamed Afzali, Mr. Quwat Ali Fekrat, Mr. Ahjaz Ahmad Sherzad, Mr. Shekib, Mr. Ahmad Mustafa, Mr, Malik and Mr, Zakir*** *for their heartfelt helps, timely suggestions and back-up which gave me enough strength to get through all mind numbing circumstances.*

I am sincerely thankful to have been involved with such a wonderful group of International students, ***Mr. Abdu Ibrahim, Mr, Hilario, Mr. Shifiraw, Mr, Charles, Mr. Aston, Mr. Thomas Arcadius, Mr. Emmanuel , Mr. Clement, Mr. Donzo , Ms. Taresa and Ms. Jocelyn ,*** *for their companionship, thank you for making my stay more enjoyable.*

The journey I took was made easier because friends and family have made the duration of the study more bearable with their friendship and support. For the useful informal conversation, I would like to thank all the friends that I have met in the course of my education in India.

I have great pleasure and exultation in acknowledging the gratitude towards all office staff of Department of Pomology and Floriculture for the care and support. I wish to express my gratitude to all garden labourers for their help and kindness.

*I am extremely thankful to **Mr.Arvind Kongot,** for his friendliness and support throughout the study.*

I am highly exhilarated to dedicate my thesis with deep sense of love to my family members for their endless love, meticulous care, boundless prayers, constant encouragement, moral support, sacrifices and inspiration.

Abdul Raziq

I dedicate this work to my entire family, for unfailing support, patience, and sacrifice.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

APPENDIX

Introduction

1. INTRODUCTION

Turfing practices were developed by modern man in order to enhance the aesthetic value of his environment. Lawns were an integral part of the Persian pleasure garden carpet and later of the Arabian gardens. Low growing flowering plants were the basic constituents of these garden lawns. Subsequently, the Greeks and then the Romans adapted the Persian lawn gardens to their cultures. The culture of mowed lawns is a relatively recent development in the history of man. References to "lawn garden" are found in the English literature of medieval times. Lawns of this period were composed of low growing grasses interplanted with flowers similar to the vegetation found in a meadow. Some gardens of the thirteenth century had turfs composed of grass monostands. Turfed seats were a feature of this period. The thirteenth century literature also contains references to the sport of lawn bowling that utilized turf.

Turfs are important in human activities from the functional, recreational and ornamental standpoint. A turf has numerous, important functional purposes as well as being attractive. Turfs control winds and water erosion of soil and are essential in eliminating dust and mud problems in areas surrounding homes, factories, schools etc. More recently, the importance of turfs in climate control has been to reduce pollution problems. It removes smoke and dust from the atmosphere and it releases oxygen in the air (Beard, 1980). Greenhouse gases absorbed by lawn can be more than offset by earth-unfriendly maintenance practice (Roosevelt, 2010).

Lawn is basic feature for home ground development and an essential feature for any other type of garden in a home garden. A lawn improves the appearance of the house, enhances its beauty, increases conveniences and usefulness, thus adding monetary value to the real estate. The lawn provides a perfect setting for a flowerbed, a border, a shrubbery or a specimen tree or a shrub. Besides the material value, a lawn has its spiritual value too. A lawn is the source of charm and pride and reduces tension of the mind after a day's hard work in the materialistic world.

Many outdoor sports and recreational activities, including baseball, cricket, croquet, field hockey, football, golf, hiking, lawn bowling, lawn tennis, lacrosse, polo, racing, rugby, shooting, skiing and soccer utilize turf. Turfs provide a cushioning effect that reduce injuries to the participants, particularly in the more active sports such as football, rugby, and soccer. The enjoyment and benefits to physical health derived from recreational and leisure activities on turf are a vital part of modern man's activities (Couch and Bedford, 1966).

Grass is one of the hardiest perennial herb and it is not very difficult to maintain a lawn, although one has to take necessary care. A garden lover should do well to remember that the beauty of a garden mainly depends on a properly maintained lawn (Randhawa and Mukhopadhyah, 1994). For landscaping, the turf grass should fulfil the visual and functional qualities. The visual quality depends on the colour, texture, density, uniformity. Functional quality depends on the rigidity, elasticity, resilient, yield, and recuperative capacity (Paramanguru, 2010).

A turf provides beauty and attractiveness for human activities. Cities can be very dismal without green turfs surrounding homes and businesses, in parks, and beside boulevards. The clean, cool, natural greenness of turfs provides a pleasant environment in which to live and work. Such aesthetic values are of increasing importance to the mental health of modern man because of the rapid life style and increasing urbanization.

Evaluating of turf grass species is a complex and difficult problem. Turf grass quality is a relative term that varies with the type of turf, the time of year, the individual making the evaluation, and the purpose for which the turf is to be used. The degree of detail involved in evaluating turf grass quality varies with the need and objective of the individual making the evaluation. For example, the turf grass quality observation of a homeowner would be rather simple in comparison to the detailed criteria used by turf grass researcher.

Turf grass quality is difficult to measure quantitatively since it is a composite of many characteristics and factor. The characteristics of high quality turf have been established over the years by the personal preference and needs of the user like uniformity, density, texture growth habit, smoothness and colour. The relative importance of these components varies, depending on the purpose for which the turf is used. For example, smoothness is very important on putting and bowling greens, but is much less important for a home lawn (USGA. 1933).

Turf grasses are fine-textured grass species that form a uniform, persistent population of plants and that tolerate traffic and low mowing heights (Pennsylvania State University, 2009). Although there are thousands of varieties of turf grass, turf grass typically falls into one of two categories, warm season grasses and cool season grasses. Warm season grasses only start growth at temperatures above 10 °C (50 °F), and grow fastest when temperatures are between 25 °C (77 °F) and 35 °C (95 °F), with one long growth period over the spring and summer. They often go dormant in cooler months, turning shades of tan or brown. Many warm season grasses are quite drought tolerant, and can handle very high summer temperatures. Zoysia grass (*Zoysia* spp.), Bermuda grass (*Cynodon* spp.),St. Augustine grass (*Stenotaphrum secundatum)*, Bahia grass (*Paspalum notatum)*, Centipede grass (*Eremochloa ophiuroides)*, Carpet grass (*Axonopus affinis* or *Axonopus compressu*s), Buffalo grass (*Buchloe dactyloides*), Grama grass (*Boutela oligostachya*) are examples of warm season grasses.

Cool season grasses start growth at 5 °C (41 °F), and grow at their fastest rate when temperatures are between 10°C (50 °F) and 25°C (77 °F), in climates that have relatively mild/cool summers, with two periods of rapid growth in the spring and autumn. They retain their colour well in extreme cold and typically grow very dense, carpet like lawns with relatively little thatch. They require considerable irrigation to prevent them from going dormant during the hot summer months. Bluegrass (*Poa* spp.), Bentgrass (*Agrostis* spp.), Ryegrasses (*Lolium* spp.), Fescues (*Festuca* spp, hybrids, and cultivars) are other examples of cool season grass.

The study is planned to evaluate the performance of tropical turf grass species with respect to growth parameters, establishment rate, Incidence of pest and diseases, identification of weeds, tolerance to shade, plant characters and Air Pollution Tolerance Index in order to introduce new grass species for the tropical lawns.

Review of Literature

2. REVIEW OF LITERATURE

Salient literature available on the present study performance evaluation of turf grass species in the humid tropics is categorized and summarized below.

2.1 Common lawn grass species

Bermuda grass (*Cynodon* species) is one of the most widely used turf grasses in tropical and subtropical regions (Brosnan and Deputy, 2008). Although bermuda grass can now be found on 6 of the 7 continents, the center of origin of the genus *Cynodon* is believed to be Africa or Southeast Asia (Taliaferro *et al*., 2003). It is adapted to the humid and semi-arid tropical, sub-tropical and warmer temperate regions in the world. In certain countries bermuda grass is also known by the common name of couch grass (Beard, 1973). Other names for bermuda grass are couch grass, quick grass, wire grass, and devil grass. Usually, the growth of the grass stops when temperatures are below 60˚F (16˚C) and turns brown at 45˚F - 50˚F (7˚C – 10˚C). Low temperature tolerance varies significantly among cultivars. (Emmons, 1995).

Bermuda grass is very wear resistant among the warm season turf grasses and has an excellent recuperative capacity (Turgeon, 2005). It has a good tolerance to wear and compaction but also requires high nitrogen (N) for good quality turf (Christians and Engelke, 1994). The heat and drought tolerance of bermuda grass was appreciated by early golf course superintendents because it required little or no irrigation during summer (Dunn and Diesburg, 2004). Regarded as drought tolerant, bermuda grass requires less water than most other grasses (Keeley and Fagerness, 2001). The ability to become semi dormant during severe drought and to recover from stolons and rhizomes when water becomes available makes them drought tolerant (Duble, 1996).

With potential for water savings and many desirable qualities fitting today's turf grass needs and environmental concerns, use of bermuda grass has increased considerably (Keeley and Fagerness, 2001). Common bermuda grass [*Cynodon dactylon* (L.) Pers.] is a highly variable warm season turf grass species, containing considerable variation in color, texture, density, vigor and environmental adaptation (Turgeon, 2005).

They have a very fast growth rate and therefore are quick to establish and recover from injury due to their ability to spread rapidly by stolons (aboveground stems) and rhizomes (underground stems) (Higgins, 1998). Common bermuda grass establishes a deep root system with vigorous rhizomes making it a troublesome weed in adjacent flowerbeds (Wiecko, 2006). They are relatively resistant to many herbicides and chemicals as well as many adverse environmental conditions (Wiecko, 2006). Because of their prostrate growth habit they have good tolerance to close mowing (Beard, 1973).

Improved fine textured bermuda grasses are used for golf courses, athletic fields, and high profile residential and commercial landscapes where fine textured, dense ground cover is desired. Common bermuda grass verities are often found as pasture and roadside grasses. These coarse leaved varieties do not provide the high quality nor do they require the high maintenance of the fine – textured types (Trenholm *et al.,* 2012)

Bermuda grass produces a vigorous, medium green, dense turf that is well adapted to most soils and climates. It has excellent wear, drought, and salt tolerance. It establishes rapidly and is able to outcompete most weed species. It is readily available as sod or plugs, and some improved cultivars are available as seeded varieties. Common varieties are available as seed, sod, or plugs (Trenholm *et al.,* 2012).

(Jenning *et al.,* 2012) reported that bermuda grass is adapted to a wide range of soil conditions but is best suited to a well-drained site. Plants may survive in poorly drained soils, but production potential is limited. Bermuda grass is not adapted in areas that frequently become waterlogged. It is extremely drought tolerant; however, it is not as productive in arid conditions.

Hybrid bermuda grasses are the product of interspecific crosses of *Cynodon dactylon* and *Cynodon transvaalensis*. These hybrids do not produce viable seed and must be propagated by sprigs, stolons, or sodding. Hybrid bermuda grasses offer improved levels of quality, density, and color, as well as improved tolerances to the stresses of traffic, heat, and drought. In addition, hybrid bermuda grasses can tolerate mowing heights less than one inch and they produce very few unsightly seed heads (Brosnan and Deputy, 2008). Bermuda grass hybrids are the highest quality warm season grasses and require the highest level of maintenance (Emmons, 1995).

Bermuda grass hybrids are essentially sterile. They may produce seed heads but little viable seed and must be propagated vegetatively (sprigs and/or green tops). Compared to Common bermuda grass and many seeded varieties, properly managed hybrids generally offer greater drought tolerance, and greater cold tolerance (Corriher and Redmon, 2001)

Some of the hybrid bermuda grasses are Celebration, GN-1, Tifway (also referred to as 419), Tifgreen (also referred to as 328), Tifdwarf, Tifsport (also referred to as Tift 94), Flora Dwarf, and Tif Eagle (also referred to as TW-72) (Brosnan and Deputy, 2008).

Zoysia, one of the earliest grass species to be used as turf, is native to Australia, China, Japan, Korea, New Zealand and the Philippines where climate and rainfall vary greatly depending on season (Samples and Sorochan, 2007). It was named for an eighteenth century Austrian botanist named Karl von Zois (Double, 1989).

There are ten species within Zoysia genus. Three of these are used as turf. They include Korean (or Japanese) lawngrass (*Z. Japonica* Steud), manilagrass (*Z. matrella* [L.] Merr.), and mascarenegrass (*Z, tenuifolia* Willd.) (Christians and Engelke, 1994).

Zoysia produces seed, but germination of the seed is poor. It is usually established by plugging, sodding, or strip sodding (Yeam et al., 1980; Yu and Yeam, 1968). Zoysia grasses are grown primarily in the humid and transitional regions. Three species of zoysia are utilized for turf purposes: *Z. Japonica* , *Z. matrella* and *Z. tenufolia*. All three are native to tropical eastern Asia (Beard, 1973). This slow growing, sod-forming species forms a dense, uniform turf in full sun and light and open shade. When propagated from sprigs or plugs, many varieties may require two or more years for total turf coverage (Samples and Sorochan, 2007). Zoysia is relatively free from disease problems, although rust, leaf spot, brown patch, and dollar spot have been reported, Insect damage is also rare on zoysia grass, but it may be attacked by billbugs, white grubs, sod webworms, and mole crickets.

Zoysia matrella has a finer leaf texture than *Z. japonica* (Christians and Engelke, 1994). *Zoysia tenuifolia* has the finest leaf texture of the three species. It is intolerant of cold temperatures and its distribution is limited to tropical and subtropical climates. There is a hybrid of *Z. Japonica* and *Z. tenuifolia* called Emeralad, presently being tested in the United States (Unruh and Trenholm, 2000).

Dichondra is a warm season, perennial, broad leaved species that can be maintained by mowing in lawns. It is known for its kidney-shaped leaves and spreading stolons that roots from the nodes. It is best adopted to tropical area. It does not tolerate freezing and is easily killed by cold temperatures. It shows good resistance to diseases. (Christians, 2004).

Dicrondra is a broad leaved plant that produces an attractive, low, dense ground cover. It has poor growth under low temperature. The plant has soft, pale green leaves and grows close to the ground. It is tolerant to partial shade. In the sun dichondra seldom grows taller than 3 inches (7.6 centimeter). Maximum height in the shade is 6 inches (15.2 centimeters)

A small leaved, dense stand occurs when dichondra is mowed to a height of 0.5 -1 inch (1.3 to 2.5 cm). A mowing height of 1.5 to 2 inches (3.8 to 5.1 cm) results in lower density, larger leaves and increased drought tolerance. It has poor wear tolerance and should be planted only on sites where traffic is limited.

Dichondra does not grow well on wet, compacted soils. Moderate fertility is required. Establishment is by seeds and plugs. Dichondra is a dicot and injured by broadleaf weed killers such as 2 4.D.

Pest problems include nematodes, cutworms, two spotted mites, flea beetles, vegetable weevil, slugs, snails and several diseases caused by fungi (Emmons, 1995).

Dichondra is mowed and maintained similarly to most turf grasses. It belongs to convolvulaceae family. Dichondra can be established vegetatively or from seed which should be mechanically scarified due to an impressive seed coat. Dichondra is adapted to fine textured, slightly acidic, moist soils of relatively low fertility. The tolerance to compacted wet soil condition and salinity is poor (Beard, 1973).

St. Augustine grass is native to the coastal regions of both the Gulf of Mexico and Mediterranean Sea, St. Augustine grass (*Stenotaphrum secundatum* [Waltz] Kuntze) is widely adapted to both tropical and subtropical regions. This highly stoloniferous species produces a very dense, dark blue-green, coarse-textured turf with better shade tolerance than most other warm-season turf grasses. (Brosnan and Deputy, 2008).

St. Augustine grass is best suited for areas that receive little use and consequently little maintenance. The species tends to be shallow-rooted and therefore does not withstand drought conditions as well as some other turf grasses. It is prone to excessive thatch build up when given large amounts of nitrogen fertilizer and frequent irrigation. St. Augustine grass has poor tolerance of wear (Brosnan and Deputy, 2008).

This species spreads by stolons that can grow to several feet long. It forms a dense turf but has a very coarse texture. It has excellent shade tolerance and can produce a relatively high quality lawn turf. It is too coarse to be used on golf course greens, tees, or fairways, but it has been used in roughs in some locations.

Most cultivars are either poor seed producers or do not produce seed at all. As a result, St. Augustine grass is usually vegetatively propagated. The stolons are often damaged during harvesting, and the species does not lend itself well to establishment by stolonizing. Establishment is usually by sod or plugs (Christians and Engelke, 1994)

St. Augustine grass produces heavy thatch layers when it is managed as a turf grass and generally requires regular mechanical thatch removal. The large stolons may be damaged with verticutting and verification equipment, and the best time to “dethatch” is in the spring at the first sign of green up (Christians and Engelke, 1994).

Improved cultivars of this species include Floratam, which was selected for its better resistance to chinch bugs. It has relatively poor cold tolerance and is limited to the warmer regions of the St. Augustine range (Double and Novsad, 1973; Riordan *et al.,* 1980). Seville is another improved variety released in 1980 by the O.M. Scott and Sons Company (Riordan *et al.,* 1980).

Paspalum is a diverse genus of 320 species. *Paspalum notatum* is the most widely used as a turf grass. It has a medium texture with thick rhizomes. It forms a relatively open turf. Bahia grass readily forms a thick thatch layer and thatch control may be an important part of the management of this species. Pensacola is a fine textured cultivar used on roadside, while Argentine is used for lawns (Christian, 2004).

Bahia grass is a popular, low-maintenance lawn grass that does well with limited water and fertilizer inputs. Although bahia grass does not produce a carpet-like, dense lawn compare to other warm-season lawn grasses, it does provide a good, low-maintenance lawn where slightly reduced visual quality is acceptable (Trenholm *et a*l., 2011).

Bahia grass forms an extensive, deep root system. It sustains better than other grasses in infertile, sandy soils and does not require high inputs of water or fertilizer. This makes it a good choice for home sites on large lots or acreage or for anywhere without irrigation system. Bahia grass can be established as sod or seed. Plugging or sprigging bahia grass is not typically recommended. Because of the slow growth habit of bahia grass, the plugging method leaves open areas of soil that can be taken over by fast-growing weed species (Trenholm *et al*., 2011).

Kentucky blue grass (*Poa pratensis*) is a multipurpose species planted throughout the cool season zone, and is also used at higher elevations in the subtropical zone. Kentucky blue grass spreads by strong rhizomes and produces a turf of medium to high density. Kentucky blue grass spreads by strong rhizomes and produces a turf of medium to high density. It is used on athletic field because the vigorous rhizomes allow good recovery (Emmons, 1995).

The reason for its widespread use is that it has a number of advantages over alternative grasses. Kentucky blue grass has excellent recuperative and reproductive capacity. Kentucky bluegrass develops a dense turf grass stand, has excellent colour, and mows more cleanly than tougher bladed grasses. It has a greater tolerance to cold temperatures than either perennial rye grass or tall fescue, when mowed at the correct mowing height of 1.5 to 3 inches. It is very competitive with weeds. When properly managed (Double, 1989).

The grass is best adapted to well drained, fertile soils with a pH in the range of 6 to 7. Germination and establishment rates are slow for many cultivars, but some, such as Baron and Mystic, establish fairly rapidly. Drought tolerance is good. The grass is fairly disease resistant. Leaf spot, summer patch, necrotic ring spot, and stripe smut are the most common problems. Thatching tendency is medium (Emmons, 1995).

The genus Agrostis is composed of about 220 species. As with the other genera, only a few species are suitable for use as turf. They include creeping bent grass (*Agrostis palustris* Huds.) velvet bent grass (*A. canina* L.), colonial bentgrass (*A. tenuis* or *capillaries* Sibth.), dryland bent grass (*Agrostis castellana*), and redtop (*Agrostis alba* L.) (Gould and Shaw, 1969; Hansen et al., 1969; Ward, 1969).

Creeping bent grass is native to Eurasia but has been distributed throughout the world for use in close cut, fine textured turfs (Beard, 1973). When mowed closely, creeping bent grass forms a fine textured turfs with superior shoot density, uniformity, and turf grass quality. (Holt and Payne, 1952). The turf grass color varies among the cultivars from greenish yellow to dark green or blue green. The root system is dense, fibrous, medium to shallow in depth, and annual in nature. Creeping bent grass is one of the most hardy cool season turf grasses to temperature extremes ((Beard, 1973).

Creeping bent grass tolerates partial shading but grows best in full sunlight. The wear tolerance is poor (Beard, 1973). The creeping bent grass is susceptible to a wide range of disease including dollar spot, brown patch, *Helminthosporium* spp., *Fusarium* blight, *Fusarium* patch, *Phythium* blight, red thread, stripe smut, and *Typhula* blight (Gaskin, 1965).

The rye grasses are a group of eight species in the genus *Lolium.* The rye grasses are closely related to the grasses in the gunus *Festuca* (Pohl, 1968). The rye grasses are best known for their rapid seed germination and establishment. Many cultivars of perennial rye grass will form a dense, high quality turf (Christian, 2004). Perennial rye grass (*Lolium perenne* L.) is known for its rapid germination and establishment. The primary limitation of perennial rye grass is its poor tolerance to cold temperatures. It is often lost to winter kill. It known for its tolerance to traffic. Perennial rye grass is best adapted as a permanent turf grass where winters and summers are moderate and where there is sufficient moisture. It thrives well on fertile, well drained soils with moderate fertilization (Christian, 2004).

Perennial rye grass is a non creeping, bunch type grass. It forms a turf of medium density. Leaf texture is fine to medium. Best adaptation is to moist, moderately fertile soils with a pH of 6.0 to 7.0, although it tolerates a wide range of soil conditions. Shade tolerance and recuperative potential are relatively poor. Wear resistance is good (Emmons, 1995).

Disease susceptibility of perennial rye grass are medium. Red thread, dollar spot, brown patch, leaf spot, and *pythium* blight are the most common disease problems. Thatching tendency is low (Emmons, 1995).

2.2 Methods of Planting

There are four methods of turf grass establishment– seeding, sodding, sprigging, and plugging. The latter three methods are types of vegetative propagation. Almost all cool season grasses and some warm season grasses are propagated by seed, which is the cheapest method of establishment. Sodding is expensive, but provides an instant turf. Sprigging and plugging are the common ways of propagating some grasses that produce little or no seed, or poor quality seed.

Seeding is the preferred method of establishment because it is the least expensive (Emmons, 1995). The timing of seed application will depend upon whether the grass is a cool- season or a warm season species. The amount of seed to be used will vary with species. Seeding rates are determined by two primary factors, growth habit and seed size (Christian, 2004).

Any method that will uniformly distribute the seed is appropriate. This includes simply spreading the seed by hand on smaller areas. There is a variety of equipment that can be used to spread grass seed. Broadcast spreaders and drop spreaders are the two most common types for smaller areas. For larger areas, tractor drawn equipment, such as cultipackers, should be used to place he seed at the proper depth (Leuthold and Fry, 1994).

Sodding is a practice which involves transplanting large pieces of established turf. The entire site is covered with three pieces of mature, high quality turf, which can be composed of many different cultivars. Sodding is providing instant turf. Three months to two years are required to produce good sod. The exact length of time depends upon the species and cultivar used, the soil, the climate, the sod production method, and the maintenance program (Emmons, 1995).

Sprigging is a modification of stolonizing that involves placing the stolons in narrow furrows spaced, 6 to 8 inches apart (McCarty, 1994). Sprigging takes more time but uses less plant material. From 4 to 5 bushels of stolons are required to sprig a 1000ft^2, whereas 5 to 10 bushles are required for stolonizing (Leuthold and Fry, 1994; Leuthold et al., 1994).

Plugging is the process of using small pieces of sod transplanted in the soil at intermittent intervals. The plugs may be formed by cutting up sod strips or removing plugs of turf from an intact sod. Only part of the soil surface is covered, unlike sodding. Bare soil areas are left uncovered, and the plugs are allowed to spread and fill in the openings (Leuthold, 1988).

The plugs usually measures from 2 to 4 in. and are placed 6 to 16 in. centers. The 100 ft^2 of sod can be used to establish more than 1000 ft^2 of area with 4 in. plugs. A square yard of sod can be cut into 324 2-in. plugs. Approximately 2,250 of the 2-in. plugs are needed to establish 1000ft^2 when they are placed on 8-in. spacings (Leuthold, 1998).

Basically, any spreading grass can be established by plugging. Grass like Kentucky blue grass and creeping bent grass that have readily available seed sources are generally seeded if sodding is not practical (Christian, 2004).

Bermuda grass is easily stolonized, and that procedure is preferable for its establishment. The two species most commonly established by plugs are zoysia grass and St. Augustine grass. Zoysia is marketed as plugs for both commercial and home markets. Plugs are often used to establish lawns and even larger areas, such as golf course fairways (Christian, 2004).

Bermuda grass is readily available as sod or plugs, and some improved cultivars are available as seeded varieties. Common varieties are available as seed, sod, or plugs (Trenholm *et al.,* 2012).Hybrid bermuda grass may produce seed heads but little viable seed and must be propagated vegetatively (sprigs and/or green tops) (Corriher and Redmon, 2001).

Zoysia produces seed, but germination of the seed is poor. It is usually established by plugging, sodding, or strip sodding (Yeam et al., 1980; Yu and Yeam, 1968).

Dichondra can be established vegetatively or from seed which should be mechanically scarified due to an impressive seed coat (Beard, 1973). Establishment of St.Augustine grass is usually by sod or plugs (Christians and Engelke, 1994). Bahia grass can be established as sod or seed. Plugging or sprigging bahia grass is not typically recommended (Trenholm *et al*., 2011).

2.3 Lawn establishment

The quality of a new lawn is directly related to the success of establishment. Turf establishment begins with careful planning, knowledge of soil conditions, and an understanding of the environmental and cultural requirements. Neglecting any of these elements can result in poor establishment, and correcting the problem will cost more time, money, and efforts than if proper procedures had been followed.

Turf can be established from seed or vegetative plant parts. There are four basic methods of vegetative establishment: (a) sodding (b) plugging (c) stolonizing, and (d) sprigging. Each procedure can be used as advantageous under certain situations with certain turf grass species. Creeping bent grass, bermuda grass, zoysia grass and St. Augustine grass are the turf grasses, most commonly propagated by the latter three methods. No matter which method of turf grass establishment or propagation is used, it is imperative that adequate soil preparation is accomplished prior to planting.

Determining the lawn establishment method is the first important step in the establishment process. Lawns are normally established by seeding or sodding. In zoysia grass, plugging is also used occasionally. The common method of establishing a lawn is seeding, which involves planting grass seed on a prepared seedbed. There are both advantages and disadvantages in seeding a lawn. Seeding has a low initial cost for seeded turf grass species and varieties. The best temperature range for seed germination of warm-season grasses is from 70°F to 95°F (Chalmers *et al.,* 2004). Centipede grass is the only one that will reach its optimum potential from seed. Bermuda grass and zoysia grass have seeded varieties, but none of them will produce a lawn that looks as good as their hybrid varieties (Deputy, 2009). All grasses do not produce viable seeds. Also, if they produce they may not be true to type. According to Patton *et al*. (2004) seeding bermuda grass or zoysia grass instead of sprigging or sodding will help to establish these turfs quickly and at minimal cost too.

Sowing advanced or germinated seeds is most likely to be useful where management of newly sown turf is a problem, competition from weeds is expected, cosmetic repairs are needed urgently, an important and slow germinating component of a seed mix is expensive or rare, seeds are dormant, or the weather is cold (Lush and Birkenhead, 1987). Studies by Danneberger *et al.,* (1992) reveal that osmo-conditioning of perennial rye- grass seeds may be of benefit for turf establishment under salinity or temperature stress.

Turf grasses that spread by rhizomes or stolons can be grown and harvested as sod. Sod costs more than seeding. Although costing 10–20 times more than plugging and over 50 times more than seeding, sodding eliminates most of the problems that come with other methods of establishment, mainly frequent watering and weed prevention during the grow-in period (Deputy, 2009). Usually more irrigation, fertilization, weed control, and time are required to successfully establish turf from seed than from sod (Deputy, 2009). Compared to seeding, sodding has advantages like, establishes quickly, provides immediate soil erosion control, eliminates issues with dust and mud, minimizes any need for weed control during establishment. The best time to sod is when the turf grass is actively growing. This means that the sod will root or knit down as quickly as possible (Chalmers *et al.,* 2004). Some turf grasses that spread by stolons may be harvested and used to establish new turf. This process is referred to as sprigging, and it is used primarily for establishing hybrid bermuda grasses. Sprigging costs more than seeding but less than sodding. Turf should be sprigged in the active growing season (Chalmers *et al.,* 2004). Sprigs are perishable and must be planted as soon as possible after harvest. In addition, the sprigs should be kept moist so that they will not dry out. This requires a good irrigation system and diligent irrigation practices. Bermuda grass sprigged at 5 bushels per 1,000 square feet should cover within two months; zoysia grass may require an entire growing season and for that reason is rarely sprigged. After sprigging, the sprigs may be covered with a thin layer of top soil or mulch. Since the sprigging is initially sparse, weed control will likely be necessary once the planting is mature enough to tolerate herbicides labelled for this use (Deputy, 2009). According to Wang (2003) the best way to establish bermuda grass is spreading stems before covering with sand, the second was flowing and burying stems, followed by spaced sod laying, dibbling stems and direct seed sowing.

Relatively small areas can also be established or repaired using plugs of grasses that spread by stolons such as bermuda grass, St. Augustine grass, centipede grass, or zoysia grass (Chalmers *et al.,* 2004). Turf sites may be plugged at any time during the growing season when adequate moisture is available. The proper distance between plugs depends on the rate of growth and on how soon a cover is desired. St. Augustine grass plugs 2 to 4 inches in diameter planted on 2-foot centers should completely cover within three months if adequately watered and fertilized (Chalmers *et al.,* 2004). Plugs are pressed firmly into the soil, and roll the planted site to give a smooth surface for mowing.

Jizhou (1997) observed that stolonizing followed by top dressing was the best method for establishing turf, and direct stolonizing could be adopted only under good irrigation condition. He also observed that plugging and strip sodding were not often recommended because of its slow turf formation, poor turf quality and high cost of establishment.

Daily growth rates were calculated as the logarithm of the quotient final/initial fresh weights, divided by the number of days between planting and harvest. By means of this criterion an elemental biological concept was demonstrated as a measure of rapidity of vegetative propagation and as a predictor of sod production time (Busey and Myers, 1979). A comparison of growth rates for various durations of growth periods suggested that for zoysia grass and St. Augustine grass growth was not strictly exponential, but was sigmoidal. Maximum growth rates of turf grass species ranged from l.8 per cent per day for centipedegrass (*Eremochloa ophiuroides)* to 9.2 per cent for common bermuda grass (*Cynodon dactylon*). These rates were larger than growth rates in commercial sod production, that were estimated to be not more than 2.6 per cent per day (Busey and Myers, 1979).

Establishment rates of lawn grass have been measured by several different methods including visual estimation, line intersect methods, plant counts, and most recently, digital image analysis (Reynolds, 2002). Visual estimation has been the most commonly used method of measuring turf grass establishment. This involves trained evaluators observing plots of turf grass and subjectively rating them for percent cover at given intervals over time. Visual estimation can produce accurate results, although the data can be highly variable and difficult to repeat by other investigators. However, this method is still commonly employed and is generally considered to be an adequate means of measuring turf grass establishment (Reynolds, 2002).

Line-intersect and line transect methods have also been used to measure bermuda grass establishment. The line-intersect method involves setting up a grid over an entire plot and counting the number of plants that touch each intersection of the grid. The number of intersections is then multiplied by the area of each grid section and divided by the total area of the entire grid to determine the percent of a species that is present (Richardson *al et*., 2001). The line transect method is somewhat different in that it involves sprigging in rows and setting lines on each side at known distances from the center of the sprigged row. Counts are then periodically taken to see how many stolons have crossed each line (Mueller *et al*., 1992). One drawback to this method is that the sprigs need to be planted in rows. Although sprigs are commonly row-planted on athletic fields it would be difficult to accurately measure their lateral growth using the line transect method. This method is more suitable in forage situations. Digital Image Analysis is a relatively new technology that can be used to measure turf grass cover. It involves taking the digital picture of a given area, which is then downloaded onto a computer and analyzed using a software program called Sigma Scan Pro (v.5.0, SPSS, Inc., Chicago, IL). The software calculates the number of green pixels, or total number of pixels representing turf, present in a given area. This number is then divided by the total number of pixels in the picture to yield percent cover.

Dichondra seed needs a warm soil before it can sprout. The best time to seed dichondra is when the temperature is around 70˚F. This is usually mid to later spring of late summer to early fall in most of the areas. When soil temperatures are too low, seed sprouting and lawn establishment are too slower and more care is required during the establishment period. Seed should be sown at the rate of 1 pound per 500 to 1,000 square feet. The heavier rates will give a solid stand faster. Rake in the seed to cover it lightly. A very shallow covering of peat moss or similar weed free organic matter will help to hold moisture while the seed sprouts (Cal West, 2012).

The seeds germinate in one or two weeks, the first two leaves being opposite and sharp-pointed. After the plant has developed twelve leaves, runners begin and the plant spreads rapidly. Weeding at this time is advisable to aid plant growth and reduce later labour. Seed will grow into a beautiful lawn in 5 months. It grows in sun or part shade and is a good cover between pavings. While it can make a casual cover among native shrubs, it will not remain an immaculate lawn without proper aftercare (Zanthorrea, 2012).

Bermuda grasses can be established by vegetative propagation such as plugging, sprigging, or sodding. Some bermuda grass varieties can be established from seed. Bermuda grasses can be sodded at any time of the year. The optimum time for their establishment by sprigging, plugging or seeding is from March through August. The successful establishment of bermuda grass depends greatly on properly preparing the soil and seedbed. Under ideal conditions, full coverage is attained at 6 to 10 weeks after seeding. If planting is early or late in the season, more time may be needed for establishment (Han and Huckabay, 2008).

Soil fertility at establishment is essential to obtain a healthy and vigorous stand of bermuda grass. Good fertility at establishment will help reduce the time required for coverage and may allow for limited grazing or hay production during the first growing season.

According to Hansen *et al*. (2011), typically, bermuda grass is established between 1st of April June. Later plantings are successful only if adequate moisture is available. Bermuda grass should be planted into a well tilled, level and firm seed bed. Seeded varieties can be either broadcast or drilled. The desired seeding depth is ¼ inch. Seeding rates are 4 to 8 pounds of pure live seed per acre. The faster the stand is desired the more sprigs that must be planted. A rate of 20 bushels per acre (one bushel is 1.25 cubic feet) gives an acceptable rate of ground cover in southwest Missouri.

Sprigs, consisting of underground rhizomes, plant crown and stolons, should be planted at a depth of one to two inches in 20- to 40- inch rows. Planting deeper will delay the establishment. Rolling after planting will help to ensure good soil contact and enhance soil moisture retention during dry weather. Sprigs should be kept moist but not wet, cool, and in the shade to ensure survival. As a rule of thumb, sprigs should be planted within 24 hours of digging (Hansen *et al*., 2011).

Giant and common bermuda grass varieties produce viable seeds that can be used to establish the crop. Hybrid varieties, which do not produce fertile seeds, must be established from sprigs or top growth (Mueller *et al*., 2011).
The stoloniferous-rhizomatous growth habit of bermuda grass [*Cynodon dactylon* (L.) Pers.]is a key feature for fast turf establishment and effective recovery from wear and divots. (Volterrani *et al,* 2012).

St. Augustine grass is established vegetative by sodding, sprigging or plugging. Sodding is the most expensive method of vegetative propagation; however, it provides instant turf grass cover. The process involves simply laying pieces of sod over moist soil.

Sprigging is a modification of traditional stolonizing.The process involves planting St. Augustine grass stolons end-to-end in 1–2 inch deep furrows spaced 6–12 inches apart. In the furrow, stolons should be placed (Brosnan and Deputy, 2008)

Plugging is the most common method of establishing St. Augustine grass. The sod is cut into small pieces (2–4 inches in diameter; square or circular) called Plugs. The plugs are planted into the soil on 6–14 inch centers. Increasing plug diameter and decreasing plug spacing will increase the rate of establishment.

Narrower the spacing between furrows and between sprigs within furrows, faster will be the establishment rate. While sprigging does not provide instant turf grass cover (as with sodding), establishment rates after sprigging are greater than plugging (Brosnan and Deputy, 2008).

A well-prepared weed-free plant bed is desirable when establishing zoysia grass. Vegetative material may be planted as sprigs or plugs. One square foot of sod may provide as many as 500 sprigs or 36 two inch plugs. A plug is a round or square piece of sod usually two to four inches in diameter with a core of about 2 to 2.5 inches in depth. The term sprig applies to a vegetative portion of the grass plant and usually includes the leaves, a stolon (runner) and some roots. Zoysia grass is best planted during its early growing season from mid May through June. Later plantings fail to cover the soil before frost and they will experience more winterkill (Murphy *et al*., 2004).

Sprigging into an existing lawn is not as desirable as plugging. Sprigs should be planted in well-prepared, weed-free plant beds. Sprigs are obtained by tearing a piece of sod apart. Each sprig should be at least three inches in length and contain one or two nodes. Sprigs are planted with one end below the soil and the other end with the leaf shoots above the soil. Fresh sprigs are planted 4 to 12 inches apart in rows and 8 to 12 inches between rows.

According to Murphy *et al.* (2004), in the method of plugging place plugs 2.5 inches in diameter (preferred over 2 inches) at 8 to 12 inch intervals.
In bermuda grass under ideal conditions, full coverage is attained 6 to 10 weeks after seeding. If planting is early or late in the season, more time may be needed for establishment (Forest, 2012).
Normally, if plugs are placed in 12-inch rows, it will take about 3 to 6 months for the lawn to grow in 24 inch rows take 6 to 9 months. The row spacing also affects the amount of sod needed to plug a given area. Plugging 2 inch square plugs in a 12 inch

row requires about 3 square yards of bermuda grass sod to establish a 1,000 square foot area (Han and Huckabay, 2008).

2.4 Growth Parameters

Maintaining a rough lawn requires only occasional cutting with a suitable machine, or grazing by animals. Maintaining a smooth and closely cut lawn necessitates more organized and regular treatments like, mowing regularly with a sharp blade at an even height, dethatching and raking (to remove dead grass, leaves, and other debris, and to prevent tufting), rolling, to encourage tillering (branching of grass plants) and to firm the ground (for sports use only), top dressing with sand, soil or other material, aeration with a spike aerator or plug/core aerator (to relieve compaction of the soil and allow greater absorption of nutrients) and seeding to cover patchy areas and maintain thick turf.

Mowing is the most basic and frequently practiced of all lawn care operations. Proper mowing is essential in the maintenance of quality turf. Close mowing reduces the amount of leaf area available for photosynthesis, reducing plant vigour. As cutting height is reduced, lawns become less tolerant to environmental stresses and more prone to invasion by weeds than a lawn maintained at a higher cutting height. In addition, root systems of grasses usually become shorter and less prolific as cutting height is reduced (Toler *et al.,* 2007). Although a closely-cut lawn can be successfully maintained, its shorter root system will result in a need for more frequent watering and fertilization to compensate for its reduced ability to obtain water and nutrients from the soil. It is therefore desirable to maintain your lawn at the highest cutting height acceptable for its intended use and aesthetic value. A cutting height of 5.0 to 7.5 cm is best for most lawns (University of Massachusetts, 2012).

How fast a lawn grows determines how frequently it requires mowing. Frequency of mowing is also an important consideration in the maintenance programme. Infrequent clipping allows the grass to grow to such a degree that any subsequent clipping removes too much leaf surface. In order to avoid stressing turf, no more than one third of existing shoot growth should be removed at any one mowing. If a lawn is being mown at 5.0 cm, it should not be allowed to grow higher than 7.5 cm before it is mown again (University of Massachusetts, 2012). If a lawn grows excessively high for some reason, the mowing height should be gradually reduced to the proper height over a span of several mowing rather than all at once. This will minimize excessive build up of clippings as well as prevent physiological shock to the plant which may occur when the grass is severely defoliated after being allowed to grow too high (University of Massachusetts, 2012).

At no time should clipping should be in excess of 1/4 to 1/3 of the total leaf surface at one mowing (Harper, 2000). Removal of larger amounts of leaf surface will result in a physiological shock to the plant, cause excessive greying or browning of the leaf tips, and greatly curtail the photosynthetic production of food, thus depleting root reserves. In addition, the accumulation of excessive clippings may smother the grass and provide excellent environmental conditions for disease organisms and insects. Excessive clippings should be removed promptly. Some grasses, especially Merion Kentucky blue grass and red fescue, produce clippings that are highly resistant to decomposition. To prevent excessively fast build up of thatch it is recommended that the clippings from normal frequency mowing be removed at least by 50 per cent of the time (Harper, 2000).

The height at which a given perennial grass can be cut and still survive for extended periods is directly related to its ability to produce enough leaf surface to keep up photosynthetic production of food. Basically this ability is related to the type and habit of growth found in the grass, i.e. the length of internodes, the number of stolons or rhizomes, and the number of basal buds all influence the amount of leaf mass produced by a given grass; hence, its ability to withstand low heights of cut (Harper, 2000).

Creeping type plants, such as bent grass, when properly fertilized and watered are able to produce adequate leaf surface at very low heights of cut. Kentucky blue grass and fine leaf fescues must be cut relatively high (1.5 to 2 inches) because they cannot produce enough leaf mass at low heights to sustain the plants. If bunch type grasses, such as tall fescue or rye grass, are cut close, too much leaf surface is removed and the plant no longer can carry on enough food making activity to maintain satisfactory growth. Bunch type grasses should be cut 2 to 3 inches in height (Harper, 2000).

Thatch buildup that occurs in warm season grasses should be removed. Thatch is the layer of undecomposed leaf blades, stolons, roots, and crowns intermingled with soil. Thatch development is greatest in grass that is over fertilized or overwatered. An excessive thatch layer reduces water penetration and can bind up fertilizer or pesticides. In severe cases, roots may be seen actually growing aboveground and rooting into the thatch layer. This is a very unhealthy condition and leaves the lawn vulnerable to many stresses (Trenholm et. al 1997). Chemical analysis of the thatch gave an average lignin content 10 per cent higher than that reported for cereal straws and 12 to 13 per cent greater than for live top growth (Ledeboer and Skogley, 1967). An investigation into the physical thatch structure showed that sclerified vascular strands of stems and leaf sheaths were more resistant to decay than clippings or sloughed leaves. Nodes and crown tissues were most resistant. Intact fibrous roots were numerous in the upper thatch layer; only few extended through the thatch into the soil(Ledeboer and Skogley, 1967).

Excessive thatch accumulation is a serious problem in maintenance of turf grasses. Several turf grass management practices have been shown to influence thatch accumulation.

Mechanical aeration provides an excellent means of correcting or alleviating soil compaction which may be quite serious in many lawn areas. Compaction occurs primarily in the surface area of the lawn. A compacted layer as thin as ¼ to ½ inch can greatly impede water infiltration, nutrient penetration, and gaseous exchange between the soil and the atmosphere (Meinhold *et al.,* 1973). Compaction of this type in the surface layer of soil can be corrected or reduced by the use of suitable aerating equipment. Aerating machines remove plugs of soil from the turf area, thereby creating an artificial system of large or noncapillary pores by which moisture and plant nutrients can be taken into the soil (Meinhold et. al. 1973). They also provide a breathing system through which carbon dioxide can escape from the soil and oxygen can enter. A rapid intake in movement of water and air is recognized as a prime necessity in correcting damages to the turf caused by compacted soils. If the thatch layer exceeds one inch, it may be removed by vertical mowing or verticutting in early spring to midsummer (Trenholm et. al 1997).

The type of equipment recommended will depend upon the size and use of the area. Equipment varies in size, from the small, hand, tubular-tine forks to large, tractor-drawn units capable of aerating large areas in relatively short time. Power-driven, home-owner-sized units are available. Many lawn and garden supply houses have aerating equipment available on a rental basis, and many landscape agencies will do the job on a custom basis. Equipment having solid tines or spikes should not be mistaken for aerating equipment. Aerators always remove a soil core whereas solid tine spikers do not. Spikers actually increase soil compaction as the movement of the soil to all sides by the penetration of the solid tine forces the soil into a denser mass.

2.5 Morphological Characters

Grasses commonly grow in tufts or tussocks, each plant consisting of a cluster of leafy shoots, each shoot being termed a tiller. In a tuft the tillers are joined at the base by very short stems and this growth habit is known as tufted. In mat grasses, shoots are attached to long, often branched, stems growing along the ground. A grass tiller consists of roots, stem and leaves (Wheeler *et al.,* 2001).

The upright stems of grass tillers are termed culms. They are solid at the nodes and often hollow throughout the internode region. But the internodes of many grasses are pithy while those of many aquatic grasses have a series of inter connected air chambers in addition to the central cavity. The cylindrical leaf sheaths are attached to the stem nodes with very short internodes in between. The older leaves encircle and protect the younger leaves and the apical bud. An axillary bud may arise in some lower leaf axils which are immediately above where the leaf sheath joins the node. Such buds can develop into new tillers, as has the bud in a leaf axil on the right of the diagram. Roots arise from the lower nodes of grass tillers. Shoots with very short internodes at or near ground level, with leaves rising high above them and acting as a protective sheath, are characteristic of the vegetative stage of most grasses (Wheeler *et al.,* 2001).

Culms grow up from the base or crown of the plant and are rounded or angled in cross-section. In most grass species, stems are hollow, except where leaves attach to the stem *i.e.* at nodes. Nodes may be useful distinguishing features. They may be relatively inconspicuous, enlarged, pigmented or fringed with hairs (NCSU, 2005).

Turf grass identification is an important, but sometimes difficult, aspect for correct management of the turf. Seed heads are the main feature in identifying grasses, but they are not present in mowed turf, so it is necessary to learn identification by vegetative characteristics (K-State, 2001).

The leaf of a grass is an elongated structure arising at a node and consisting of a basal cylindrical sheath that encircles the stem or younger leaves. Above this is a flattened blade or lamina with parallel venation (Wheeler *et al.,* 2001).The parallel veins are drawn on the right hand side of the blade. Each leaf is attached to a specialised portion of the stem, a node, where the veins of the leaf are integrated with the vascular system of the stem. Between the nodes are internodes. Leaf blades may be parallel sided, needle-like, tapering, constricted at base, twisted. In some leaf blades the midrib is prominent and often pale coloured, while in others the veins are equally conspicuous or inconspicuous. Leaf blades are often flat but may be rolled or folded, and some are so narrow as to be bristle like. A band of mechanical tissue, often pale, occurs at the blade/sheath junction, the abaxial portion of which is termed the collar. Leaf tips are either pointed, boat shaped and blunt or round (University of California, 2014). Leaf surface may be smooth, ridged, hairy or sparsely hairy. Sheaths green, compressed smooth in Kentucky blue grass (K-State, 2001) and in perennial rye grass it is prominently veined above, very glossy, and smooth beneath (NCSU, 2005). Though the shape, texture, folding, hairiness etc. of the leaf blade may be useful diagnostic features, they are often variable within a species or even on the same plant (NCSU, 2005).

Grasses vary in vernation, the arrangement of the youngest leaf in the bud shoot, either rolled or folded. Leaves are folded in the bud in Bermuda grass Leaves are rolled in the bud and long in rye grass (University of California, 2014) in *Zoysia japonica* laves are rolled in the bud (K-State, 2001).

The lower portion of the leaf blade that encircles the stem is the sheath. Leaf sheaths are hollow cylinders split down one side with the margins usually overlapping. Leaf sheath features useful in identification are the degree of flattening or compression, hairiness, and sometimes the colour and prominence of the veins or nerves (NCSU, 2005). At the base of the leaf sheath and the blade are intercalary meristems that, for all but old leaves, allow the leaf to elongate after removal of the blade by mowing (Wheeler *et al.,* 2001).

. A ligule is an outgrowth from the sheath. Because they vary in size, shape, and texture, they are used in the identification process (Gardner, 1997). Ligule may be absent, membranous or with fringe of hairs. Bermuda grass have ligules made up of a fringe of hairs (University of California, 2014)) Ligule membranous in Perennial Ryegrass, *Lolium perenne* (K-State, 2001).

Auricles are small, clasping outgrowths that may or may not be present on the leaf collar. Because they vary in size and shape, they are used in the identification process (Gardner, 1997). Auricle- Claw-like appendages occurring in pairs at the base of the leaf blade or at the apex of the leaf sheath. Claw like, small or absent. Bermuda grass varieties lack auricles (University of California, 2014). Auricle is absent in Kentucky Blue grass (NCSU, 2005).

Stoloniferous and many rhizomatous grasses are termed mat grasses. St. Augustine grass has a creeping growth habit and is propagated by stolons that form shoots at every node. Bunch type growth observed in fine-fescue (Bigelow, 2005). Kentucky blue grass has rhizome (Bigelow, 2005) (NCSU, 2005).

Spike inflorescence is present in St.Augustine grass (Bigelow, 2005), panicle in orchard grass (Bigelow, 2005) and 2-3 branched raceme in bermuda grass (Bigelow, 2005) (NCSU, 2005).

2.6 Commercial aspects

The improved bermuda grass form a very dense, uniform turf of high quality when gown under proper climatic and cultural condition. It is utilized in the warm humid and warm semi arid regions in lawns, parks, cemeteries, institutional grounds, fairways, greens, tees, roughs, roadsides, airfields, athletic fields and other comparable general purpose lawn areas (Beard, 1973).

The zoysia grasses are widely used on lawns, sports fields, horse racing tracks, and golf courses fairways and tees. Zoysia grass has also been used on golf course greens in the Asian countries (Christians and Engelke, 1994).

St. Augustine grass is utilized primarily in the warmer portions of the warm humid regions for lawns and similar turf grass areas where a fine texture is not required. It is widely utilized under shaded conditions. St. Augustine grass is also one of the main warm season turf grass species grown for commercial sod production. It is normally not utilized on playgrounds or athletic fields (Beard, 1973).

Bahia grass forms a relatively low quality turf that is satisfactory for use on low quality, nonuse, turf grass areas. It is particularly well suited for use on road sides, air fields, and similar extensive, low quality turf grass areas where minimum maintenance costs are more important than turf grass quality. Cultivar of bahia grass, Pensacola is a fine textured cultivar used on road sides, while Argentine is used for lawns (Christian, 2004).

Dichondra is a broadleaf plant which is used to produce an attractive, low, dense ground cover (Emmons, 1995). Kentucky bluegrass I the most widely used cool season grass. It can be found on lawns, golf courses, cemeteries, parks, school grounds, athletic fields, and other areas where dense grass cover is desired (Emmons, 1995).

Creeping bent grass is an excellent turf for golf course fairways and tees when mowed at 0.5 in. Creeping bent grass is not well adapted to a lawn use. It requires an intense management regime, specialized mowing equipment, and a high level of turf management skill to maintain it in a quality condition. Kentucky bluegrass is much easier to maintain under lawn conditions (Christian, 2004).

Perennial rye grass is a common constituent of seed mixtures used on home lawns, parks, cemeteries, institutional grounds, fairways, roughs, roadsides, air fields, and other general use turf grass areas (Beard, 1973).

2.7 Air pollution Tolerance Index (APTI)

Different plant species vary considerably in their susceptibility to air pollutants. The identification and categorization of plants into sensitive and tolerant groups is important because the former can serve as indicators and the latter as sinks for the abatement of air pollution in the indoors and proper care can be provided to those sensitive plants from the effect of pollution (Alex, 2012). To screen plants for their sensitivity/tolerance level to air pollutants, a proper selection of plant characteristics is of vital importance. Singh and Rao (1983) has computed a formula to obtain an empirical value signifying the Air Pollution Tolerance Index (APTI) of species using four parameters namely ascorbic acid, total chlorophyll content, relative water content and leaf extract pH.

Symptoms of pollution toxicity are found especially on leaves. The symptoms of acute damage (SO_2 >1 ppm) according to Kovács (1992b) are necrosis on the upper and lower leaf surfaces, at the apices, margins and between the veins. The tissues around the stomata may also decompose. Taylor et al. (1990) also reported water soaked appearances on leaves in many species. Necrosis on awns of grasses and cereals has been reported. The extent of chlorosis, necrosis, red pigmentation and growth parameters such as height, leaf area and stem diameter in clover and Egyptian mallow plants was generally related to pollution load (Mulgrew and Williams, 1998). To test the suitability of a variety of plant species as bioindicators,

With the APTI values, Singh *et al*. (1991) evaluated 69 plant species, including herbs, shrubs and trees and categorised them into sensitive, intermediate, moderately tolerant and tolerant classes. Chauhan (2010) also evaluated some tree species grown in Dehradun city to test the effect of automobile pollution on plants and found pollutants emitted from automobiles adversely affecting the ambient air and tree pigments and thus creating adverse impacts on human health. He emphasized the use of trees as bio-indicators for such pollution. Investigation done in plants growing along the roadside of Vishrambag and Shashtri Chowk, Sangli city for APTI showed that plants were affected by increased atmospheric pollution and it was found that plants can be used as bio-indicators to assess the accumulation of autoexhaust pollutants like SO_2, NO_2 and particulate matter (Gaikwad *et al.,* 2006).

Sulistijorini *et al.* (2008) examined the combination of the relative growth rate (RGR) and physiological responses (APTI) in determining tolerance levels of plant species to air pollutants. Among the eight roadside tree species tested, *Lagerstroemia speciosa* was categorised as a tolerant species and *Pterocarpus indicus, Delonix regia*, *Swietenia microphylla* as moderately tolerant and *Gmelina arborea, Cinnamomum burmanii* and *Mimusops elangi* as intermediate tolerant species. They concluded that the combination of RGR and APTI values would be better to determine tolerance level of plants to air pollutants than merely from APTI values.

Liu and Ding (2008) have collected 23 plant species growing near a Beijing steel factory and estimated their APTI values. From the results, they highlighted the need for APTI measurements to be conducted throughout the growing season, when evaluating pollution tolerance of individual species and they stressed that the APTI of species was indicated as an ideal candidate for landscape planting in the vicinity of polluting industry.

Lakshmi *et al.* (2008) estimated the APTI values of tree species grown in industrial area of Visakhapatnam city and found that among 24 species tested, 20 were having low values of APTI and remaining species identified as moderately tolerant. Thus they suggested that estimation of APTI values help to identify tolerant species to air pollution and which may further help in proper selection of species in urban plantation programme. Singh (1993) also suggested that the APTI can be used as a good indicator of the impact of pollution on plants.

In Moradabad city, Tripathi *et al.* (2009) evaluated ten different plant species from residential, industrial and commercial area for their APTI values. They found that as the city is meant for Brass and allied industries, they are the prominent sources responsible for the elevated level of air pollutants at the industrial site. Highly significant results were obtained by them in this industrial site. They proposed that analysing such parameters would be useful for the better understanding and management of air quality as well as in selection of suitable plant species for plantation in industrial areas as well as roadside and this may become the main strategy for the abatement of city's air pollution.

Jyothi and Jaya (2010) conducted an evaluation study to find out the air pollution tolerance as well as sensitivity of the plant species growing adjacent to NH-47 passing through Thiruvananthapuram during different seasons. The study identified different species of trees and shrubs tolerant and sensitive to air pollutants as bio-accumulator and bio-indicator respectively to be planted along the highways.

Till date, the research about APTI was mainly concentrated around trees and other shrub species and the pollution tolerance level of grass species were least studied.

Lawns can also detoxify air pollutants. Their capacity to do this is comparable to that of the same leaf surface area contained in trees, and it can provide cooling effects as well (Leslie and Knoop, 1989).Turf grass can serve as a sink for CO2. Grass is estimated to trap some 12 million tons of dust and dirt from the air annually. Just one acre of grass will absorb hundreds of pounds of fossil fuel created sulfur dioxide in a single year. A well maintained lawn traps smoke particles more than 12 million tons of dust and dirt annually (Anonymous, 1999).

2.8 Tolerance to Shade

Shade is a common detrimental factor in landscape with turf grasses. Home and school lawns, golf courses, cemeteries, parks and many other landscapes with turf grasses are either partially or fully shaded by trees or buildings. Maintaining turf grasses under shaded conditions is a daunting task for golf course superintendents and home lawn turf grass managers because shade affects the turf grasses' physiological, morphological, nutritional, and anatomical responses.

The amount of sunlight needed by lawn grasses varies by species and, in some cases, by cultivar within the species. The amount of shade present in a landscape varies over time as trees mature and can also vary seasonally. Sunlight also varies within a yard, so portions of a lawn may be in full sunlight all or most of the time, while other portions may be shaded throughout part or most of the day. Grass that does not receive enough sunlight has long, spindly leaf blades and stems, because it is working hard to obtain sunlight. This tissue elongation depletes the plant's carbohydrates, which can reduce the lawn's overall health and vigour.

A survey conducted by University of Florida in 1996 reported that 75% of all turf acreage in Florida is planted in residential lawns; and, a high percentage of this turf grass is grown under shade (Hadyu et al., 1996 and Hodges et al., 1994). According to Beard (1973), 20-255 of the total turf grass grown under some degree of shade.From their studies, they found that St. Augustine [*Stenotaphrum secundatam* (walt.)Kuntze] is highly shade tolerant while bermuda grass (Cynodon dactylon (L.) Pers.] exhibits poor shade tolerance. Other warm season turf grasses like centipede grass [Eremochloa ophiuroides (munro) Hack.], carpet grass [*Axonopus affinis* Chase], zoysia grass [zoysia sp.], and bahia grass [*paspalum notatum* Fluegge (Bogdan)] show varying degrees of shade tolerance.

According to Trenholm (2011), zoysia grass cultivars such as 'Empire' have moderate shade tolerance, performing best with six to eight hours of sunlight per day. Centipede grass tolerates moderate shade. Bahia grass, seashore paspalum, and bermuda grass are sun-loving species that do not come up well in shaded conditions.

An efficient approach for growing turf grasses under shade is choosing turf grass cultivars that are tolerant to shade. Different cultivars show different variations in growth rate under shade. Barrios *et al*., (1986) and Beard (1973) classified the warm season turf grasses on the basis of their shade tolerance as following.

Classification of warm season turf grasses based on shade tolerance

Degree of Tolerance	**Warm season turf grasses**
Excellent	St. Augustine grass
Good	Zoysia grass
Fair	Bahia grass, Carpet grass, Centipede grass
Poor	Bermuda grass

St Augustine grass is originated in the coastal regions of Gulf of Mexico and the Mediterranean. It is well adapted to warm, tropical, and subtropical regions of the world (Sauer, 1972). In the United States, it is grown in USDA classified hardiness zones 9 and 10. St. Augustine grass is suitable for home lawns due to several reasons such as low maintenance costs, shade tolerance, salt tolerance, growth in a wide range of soils, and competence with weeds (Busey and Davis, 1991).

St. Augustine grass has the best tolerance for shade of any of the warm-season grass species and also grows well in full sunlight. The most shade-tolerant cultivars are

‘Seville’, ‘Delmar’, and ‘Captiva’, all of which can sustain with five to six hours of sunlight (Trenholm, 2012).

St. Augustine grass is the most common residential lawn grass grown in Louisiana, Florida, and the southern portion of the Gulf Coast states. Hodges et al. (1994) evaluated the contribution of the turf grass industry to Florida’s economy in 1991-92 and reported that 600,000 ha is maintained in St. Augustine grass, accounting for 36% of the total turf area. Haydu et al. (1996) reported that St. Augustine grass was grown on 72% of the total sod acreage in Florida, which confirms the fact that it is the most popular grass for expanding residential lawn acres and urban landscapes. Even in Louisiana, St. Augustine grass is the most common turf grass used for home lawns after centipede grass. It is propagated vegetatively by sodding, sprigging, and plugging (Beard, 1973). Nearly 28 cultivars of St. Augustine grass have been released currently. Several experiments have been conducted to evaluate the shade tolerance of different St. Augustine grass cutlivars. Barrois et al. (1986) and Peacock and Dudeck (1993) found that the cultivar, ‘Floratam’ had poor shade tolerance while ‘Seville’ was found to be highly shade-tolerant.

Shade-tolerant grasses exhibit some morphological and physiological traits for survival in shade in order to compensate for low light levels (Bjorkmann, 1981; Givnish, 1988). This study looks at distinguishing a shade-tolerant grass by identifying the morphological and physiological characters that assist its survival. Differences can be noticed by comparing the performance of turf grasses under both shade and sun. The effects of shade on all plants are similar and this applies to turf grasses as well. Some research has been conducted to study the effects of shade on growth of turf grass. Knowledge of such previous investigations helps to narrow down the response of turf grasses to shade from other plants, which is useful for the present study.

In the low light stress, turf grass has various morphological changes, such as decline in root numbers, shorter rhizome, tilling decline, higher and thinner stem, longer internodal length, lighter color and thinner leaf, flatter leaf angles and slower growth (Beard, 1997; Bell and Danneberger, 1999).

Most of the nutritional responses of turf grasses are a result of nitrogen uptake and its interaction with shade. Shoot dry matter yields and N concentration in the shoot increase under shaded and low N conditions (Eriksen and Whitney, 1981). Under heavily fertilized conditions, growth and shoot dry matter yields are reduced in low lights (Burton et al., 1959).

.

Epidermis morphological structure turn out to be cell convex thoroughly, with reduced layers, increased size, thinner cell walls, thinner epidermis cutin membrane or no cutin membrane (Roacaas and Scarano, 2001).The leaf anatomical structure changes enhance the cell ability to capture light, which is an advantage of the light penetrating leaf epidermis reaching mesophyll, or the photochemical reaction process in the leaf epidermis that directly improves photosynthetic capacity.

Specific responses of turf grasses to shade can be noticed with respect to rhizome growth, tillering capacity, and root and shoot growth. Rhizomes grow actively under normal light intensities. Shading causes a greater reduction in root and rhizomal growth than shoot growth (Burton et al., 1959; Eriksen and Whitney, 1981; Patterson, 1980a). New tiller production and leaf number are also reduced to a greater extent under full shade (Patterson, 1980a). However, moderate shade favors shoots growth (Eriksen and Whitney, 1981).

Beard (1973) presented a brief summary of morphological changes of turf grass under low light intensities. The y are reduced shoot density, increased leaf length and plant height, reduced leaf width, thinner leaves with less weight, longer internodes, reduced tillering, reduced stem diameter, reduced appearance rate of successive leaves on the stem, and more upright growth habit.

Boardman (1977) summarized the responses of plants under shade that are commonly found in turf grasses. Higher chlorophyll content, lower respiration rates, lower compensation points, lower carbohydrate reserves, lower C/N ratio, higher tissue moisture content, reduced transpiration rates, and lower osmotic pressure are common plant responses of turf grasses. According to Allard et al, (1991a, b), turf grasses growing under low light intensities have larger leaves in order to compensate lower carbon dioxide exchange rates (CER) per unit area.

Physiological and biochemical characteristics of the turf grass will change accordingly in low light conditions. For example, those who have scavenging function will be changed, such as superoxide dismutase, catalase, peroxidase, ascorbate peroxidase, glutathione reductase and low molecular weight antioxidants such as ascorbate (ASC), glutathione (GSH), α-tocopherol and flavonoids (Shainberg et al.). These changes will further affect the photosynthesis of plants, and this influence shows differences under different growing habitats.

Low light also led to nitrate reductases activity reduction in the blade, and activity of nitrate reductases in the root decreased in greater manner, which makes plants to absorb more nitrate in order to satisfy the demand of nitrogen (Gouia et al., 2000).

Plants gain limited light quantum in the low light adversity, so leaf temperature is reduced, stomata limitation increased, stomata conductance decreased, intercellular carbon dioxide concentration decreases, and photosynthetic rate decrease (Philip and Knapp, 1998). Non-structural carbohydrates and photosynthetic efficiency of the turf grass are greatly reduced in the low light conditions (Qian and Engelke, 1999).Low light has significant effect on plant metabolism and membrane protection. In low light, the plant leaves protective enzymes SOD and POD in plant leaves increased their activity and the activity of CAT was decreased (Huang et al., 2002).

2.9 Incidence of pest and diseases

The control of injurious insects is one of the constant problems of turf establishment and maintenance. It has been conservatively estimated that the damage of turf due to insects is around 5% of its vaued and amounts to several hundred million dollars annually (USDA, 1995). All the common kinds and varieties of turf grasses are attacked by insects and more than 60 species of which are recorded as pests. According to App and Kerr (1965) the insect pests of turf can be roughly divided into three groups- those they feed below the surface of the soil, those that eat the leaves and stems, and those that suck plant juices.

Insects that feed on turf grass have two different types of mouthparts. Some, such as grubs, caterpillars, and maggots, chew plant tissue. Their jawlike mouthparts tear, chew, and grind grass shoots and roots. Others such as chinch bugs, scales and aphids, have piercing- sucking mouthparts. They pierce plant tissue with their beaks and then suck juices from the stems, leaves, or roots, both types of feeding can result in serious injury to turf grass plants (Emmons, 1995).

Kerr and App (1965) reported that mites are closer relatives of insects, and several species suck the sap of grasses and cause a blotching or stripping of the leaves. Continued feeding may cause severe chlorosis and death of the leaf. In severe infestations, brown and dead stolons are common and entire plants may be killed. *Oligonychus Stickneyi* was reported to infest grasses in Florida (Wolfenbarger, 1983) and in Arizona (Bibby and Tuttle, 1959).Banks grass mite *oligonychus stickneyi* is widely distributed and feeds on many plants. Malcolm (1995) reported that it was a serious pest in grass seed field in Washington but it was not an important pest of well managed lawn in that area. Bibby and Tuttle (1959) recorded this species from bermuda grass. In 1959, an exiophyid mite, now called the bermuda grass mite, *Acceria neocynodonis*, was found seriously damaging bermuda grass turf in Arizona (Butter and Tuttle, 1969).

Grass hoppers are chewing insects that commonly feed on range and pasture grasses, as well as grasses growing in waste areas. They are seldom a threat to well maintained turf unless their number are quite large and food is scare (Emmons, 1995). Many species of leaf hoppers infest lawns. They are tiny wedge shaped insects about 1/5 inch long ranging in colour from yellow to green and grey and are often mottled or speckled. Both nymphs and adults can retard grass growth by sucking the sap from the stems and leaves. (App and Kerr, 1965).

App and Kerr (1965) reported that several species of ants nest in turf, and, when they are numerous, the mounds excavated by them are unsightly and may smoother grass and cause much damage. Their tunnels may allow the soil to dry out around the roots of plants, which often causes the death of the plants. Also, ants prevent grass seeds from germination by feeding on them or storing them in their nests. Schread (1964) listed four species three of which commonly nest in lawns. The red ant, *Formica palliedefulva* lateille, cornified ant, *lasius alienus* (Forester), and the pavement ant, Tetramorium caespitum (L.). A fourth species, the alleghency mound ant, *Formica exectoides* forel, is capabale of nesting in lawns.

Several kinds of catterpillars, such as sod webworms, army worms, and cut worms, damage truf grasses. The sod webworms are the most important, found more in lawn grass species (App and Kerr, 1965). There are many species of sod webworms found in lawns belonging to the genus *Crambus.* Bohart (1947) listed *C.bonifattellus* and *C. Sperryellus* klots as important species in California. The bluegrass webworm, *C . teterrellus*, is widely distributed in the eastren U.S. (Ainglie, 1930). Johson (1944) reported about *C. Laqueatellus* Clemens and *C. trisectus* damage turf areas. Crawford and Harwood (1964) listed several species that are trouble in some grass seed fields but reported *C. topiarius*, the cranberry gridler, as most destructive. The fall army worm, *Spodoptera fruiperda* (J.E. Smith), is the most common army worm found in turf.

Army worms and cutworms are immature moths that feed on turf grass leaves and stems. These caterpillars chew off young plants just above the ground and can be highly destructive. Golf courses are especially attractive places for females to lay eggs, and for the caterpillars to feed. Young armyworms skeletonise turf grass or chew leaf blade margins at night. Armyworms are gregarious and prefer cool-season turf grasses, and will often feed and migrate in large groups. Large masses of caterpillars will cause widespread damage of irregular brown patches (Erin, 2007). Several species of cut worms are occasionally found in turf. They are usually minor pests that feed on the leaves and cut off the grass near the soil surface. Turf areas may also serve as a reservoir for cutworms that migrate into flower beds and cut the plants (Schread, 1964).

Chinch bugs, Blissus Spp., feed on grasses, and some species of these are serious pests of lawn grasses. The hairy chinch bug, *Blissus hirtus*, is frequently injurious to bent grasses. *B. insularis* Barber is a major pest of St. Augustine grass in the southeastern part of U.S (APP and Kerr, 1965). A few species of bugs and wasps (Hymenoptera) may damage lawns by their nest building habits. Kelsheimr and kerr (1957) mentioned the unsightly mounds of a mound building bee, *Nomia heteropoda* (Say).

Plant diseases are disorders caused by microorganisms such as fungi, bacteria, and viruses. Almost all common turf grass diseases are caused by fungi (Emmons, 1995).The species that most commonly live in and damage warm season turf grasses include the tropical sod webworm (*Herpetogramma phaeopteralis*), fall armyworm

(*Spodoptera frugiperda*), striped grass loopers (*Mocis* spp.), and the fiery skipper (*Hylephila phyleus*).

Gray leaf spot is an important infectious disease of warm season St. Augustine grass (*Stenotaphrum secundatum*), it can also occur on some cool-season turf grasses such as perennial rye grass (*Lolium* sp.) and tall fescue (*Festuca* sp.). Gray leaf spot is caused by the fungus *Pyricularia grisea*. It is a seasonal disease problem in St. Augustine grass that becomes noticeable during hot and steamy weather (Vann, 2013). Newly sprigged, sodded, or rapidly growing grass is more susceptible than well established grass (Henn, 2012).

Gray leaf spot tends to be more problematic on intensively managed turf grasses that are fertilized with high nitrogen applications during the summer months. Over fertilization is a key factor in disease onset and severity. Soil compaction and improper irrigation practices also contribute to disease activity. Periods of extended leaf wetness periods from overhead or late evening irrigations increase disease susceptibility (Vann, 2013). This infectious disease can spread rapidly, especially under hot, humid weather conditions. Shady locations with poor air circulation also favour the disease. Gray leaf spot is active under conditions of high relative humidity or persistent rainfall or irrigations during July through September when temperatures are upwards of 85° F (Vann, 2013).On St. Augustine grass, the symptom of gray spot shows distinctive spots. Tiny lesions enlarge rapidly into spots that are first round, then round to oval, and later elongate across the entire leaf blade. The leaf spots are tan to gray, often depressed at the center, with irregular purple to brown margins (Ki Jo *et al*., 2010).

Dollar spot is caused by *sclerotinia homeocarpa*. On kentucky blue grass lawn, dollar spot generally appears as blighted areas about the size of soft ball. Bermuda grass, bahia grass, zoysia grass, Fescu and rye grass lawn may also be damaged by this disease (Nick Christian, 2004).

Dollar spot is more prevalent on grass that is deficient in N, and fertilizing is one of the cultural practices that can reduce its severity (Cough, 1995). Hanson and juska (1969) reported that dollar spot diseases are hosted by annual blue grass, bahia grass, bermuda grass, centipede grass, colonial bent grass, creeping bent grass, Italian reyegrass, Kentucky bluegrass, red fescu, red top, sheep fescu, St. Augustine grass, valvet bent grass, and zoysia grass. It is a common disease of bent grass putting greens and kentucky blue grass and fine leaf fescu lawns (Cough and bloom, 1960; Cough and Moore, 1960).

Bermuda, zoysia, and bahia grass, are severely affected by dollar spot (Freeman, 1967). Damage caused by *S.homeocarpa* is readily distinguished from most other turf grass disorder by the presence of characteristics lesions on the leaf blades of plants at the margin of the affected areas.

Damage caused by *S. homeocarpa* is readily distinguished from most other turf grass disorders by the presence of characteristics lesions on the leaf blades of plants at margin of the affected areas. The lesions are light tan and have a reddish brown border. Some extende downward from the leaf tip, and may be an inch or so in length. They are usually completely across the blades of Kentucky blue grass. The lesions tend to occur along the margin of blades of coarser grasses (Freeman, 1967). Infection of culms and leaves of unmowed bermuda grass and bahia grass has been reported (Bain, 1962; Gudauskas and Mc Glohon, 1964).

Brown patch (*Rhizoctonia solani*) disease rarely occurs in regions with cool summers (Gould, 1963). It is particularly destructive to bent grass (Moneith and Dahl, 1932). Kentucky bluegrass is seldon damaged severly, and for some time was thought to be immune (OoKley, 1924; Monteith, 1926; Pipper and Oakley, 1921).

Brown patch is a summer disease of cool season grasses, but is more common on warm season grasses in the spring and fall. Annual bluegrass, rough bluegrass, the various fescues, and the ryegrass are moderately susceptible than bermuda grass, centipede grass and bahia grass (Zummo and Plakidas, 1984). Emmons, (1995) reported that brown patch occurs on all the major turf grass species, with the bent grasses, perennial rye grass, St. Augustine grass, and annual blue grass usually most seriously affected.

Powdery mildew disease occurs most commonly on Kentucky blue grass, bermuda grass, redtop, fine-leaved fescues, and zoysia grasses. The disease is much more severe where air circulation is reduced and the grass is growing in shaded areas (on north and east sides of buildings, under dense trees and shrubs), (University of Elliniois, 1995). Cooler temperatures, 55-70F (12- 21˚C), and low light intensities are necessary for its development. The pathogen is inhibited by sunlight, so the disease is commonly found in the shade (Emmons, 1995).

This growth rapidly becomes more dense and may cover the entire leaf, giving the leaf a gray-white appearance. In severe outbreaks, entire portions of the turf stand may be dull white, rather than green. Individual leaves look as though they are covered with flour or white powder (Penn State University, 2013).Kentucky blue grass, when planted in shaded areas, is particularly susceptible to this disease.

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled "Performance evaluation of turf grass species in the humid tropics" was carried out at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara from 2011 to 2012. The studies were conducted to find out the new grass species for the tropical lawns and their tolerance to shade condition. Ten turf grass species were evaluated in the open field and under various (0%, 25%, 50%) shade levels.

3.1 Major aspects of the study

The following were the major aspects of the study.

1. Time taken for the establishment of turf grass species and total coverage of the area by grass
2. Plant shoot, leaf and root characters and nature of growth
3. Growth parameters like time taken for first mowing, frequency of mowing, volume and biomass removed at each moving, time for first verticutting and time for use as sod/planting material.
4. Estimation of air pollution tolerance index (APTI) of the turf grass species
5. Tolerance of turf grass species to different shade levels
6. Incidence of pests and diseases
7. Identification of different types of weeds in turf grass species

3.2 Plant material

Ten species were collected from various sources. This included four local species (zoysia, bermuda, St. Augustine and hybrid bermuda grass) and six species brought by the Directorate of Floriculture, New Delhi from the United States of America. Turf grass species, used for the study are given in Table 1.

Plate 1. General view of field study

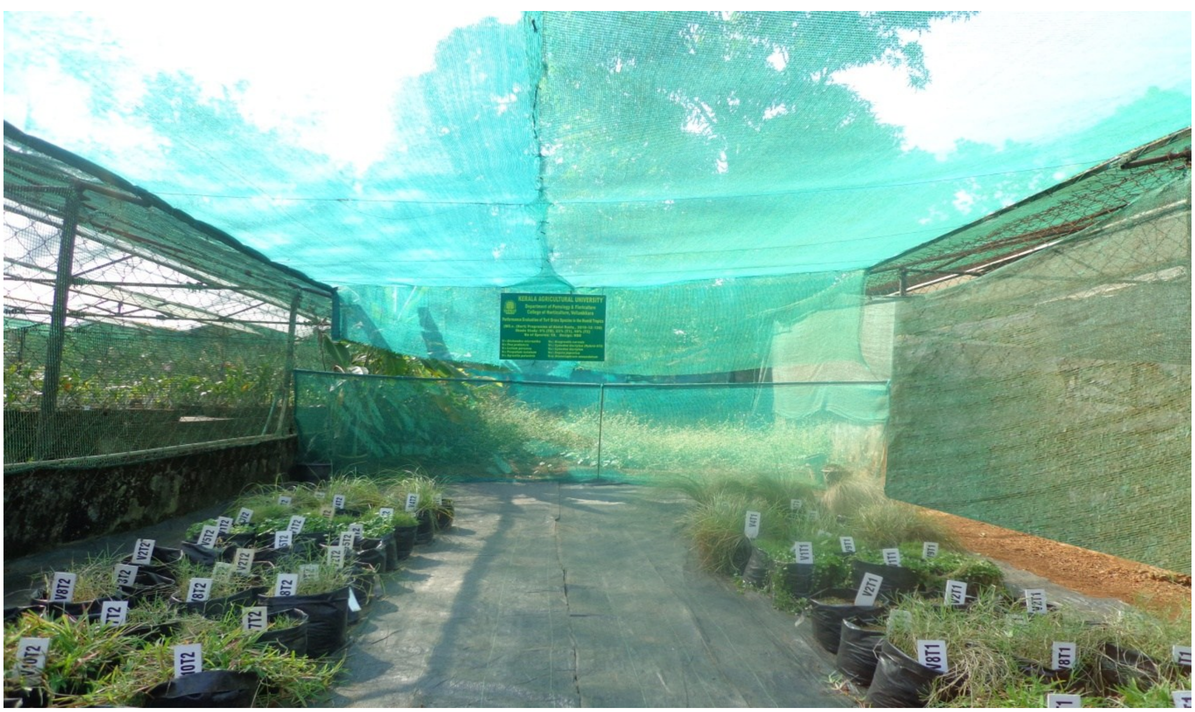


Plate 2. General view of shade study

Table 1. Turf grass species used for study

No	Scientific name	Common name	Family
1	*Cynodon dactylon*	Bermuda grass	Poaceae
2	*Stenotaphrum secundatum*	St.Augustine grass	Poaceae
3	*Zoysia japonica*	Korean grass	Poaceae
4	*Eragrostis curvula*	Love grass	Poaceae
5	*Cynodon dactylon 419*	Hybrid bermuda grass	Poaceae
6	*Poa pratensis*	Kentucky blue grass	Poaceae
7	*Lolium perenne*	Perennial rye grass	Poaceae
8	*Agrostis palustris*	Bengal creeping bent grass	Poaceae
9	*Paspalum notatum*	Bahia grass	Poaceae
10	*Dichondra micrantha*	Dichondra	Convolvulaceae

3.3 Methods

3.3.1 Establishment

Duration (days) for complete coverage of area of each turf grass species, taken from the day of germination/ planting.

3.3.2 Characterization

Turf grass species selected for the study were morphologically described based on nature of growth and shoot, leaf, root characters.

3.3.3 Growth parameters

In growth parameters duration (days) was recorded for first mowing, first verticutting and time for use as sod/planting material. The weight (g) of biomass removed at first mowing was recorded for each turf grass species.

3.3.4 Estimation of air pollution tolerance index of the turf grass species

Air pollution tolerance index (APTI) of selected turf grass species under shade and open field conditions were computed by the values obtained from the estimation of ascorbic acid content, chlorophyll a and b, relative water content and leaf extract pH.

Cynodon dactylon

Stenotaphrum secundatum

Zoysia japonica

Cynodon dactylon 419

Eragrostis curvula

Paspalum notatum

Plate 3. Turf grass species - I

Dichondra micrantha

Plate 3. Turf grass species - II

3.3.5 Tolerance to shade

Turf grass species were grown under various (0%, 25% and 50%) shade levels, to find out shade tolerant species. All selected species were grouped as good, medium or poor, based on tolerance to shade, by observing plant characters.

3.3.6 Design of the experiment

For field experiments randomized block design and for shade studies completely randomized block design were laid out.

3.3.7 Location

Vellanikkara is situated at latitude of 10°31' N and longitude of 76°13' E. The area lies 22.25 m above MSL. The area enjoys humid tropical climate. Meteorological data during the period of investigation are presented in Appendix 1.

3.4 Observations

The following observations were recorded for the performance evaluation of turf grass species.

3.4.1 Establishment

3.4.1.1 Time taken for total coverage of area

Time taken from the day of germination upto total coverage of the field was observed, recorded and expressed in days.

3.4.2 Plant characters:

3.4.2.1 Plant height (cm)

Plant height was measured from ground level to tip of leaves held together and expressed in cm.

3.4.2.2 Shoot height (cm)

Height of the shoot was measured from the base to the tip of the shoot and expressed in cm.

3.4.2.3 Arrangement of unfurled leaves in shoot

For observing the arrangement of unfurled leaves, magnifier glass was used. The arrangement of unfurled leaves was observed in each turf grass species after cutting the top portion of the stem. Observations were taken both in open field and shade conditions and classified, as folded or rolled.

3.4.2.4 Leaf length (cm)

Length of the leaf was measured from ligule to the tip and expressed in centimeters.

3.4.2.5 Leaf width (cm)

The width of the leaf was measured at the broadest region and expressed in cm.

3.4.2.6 Leaf texture

Turf grass texture is a measure or estimate of leaf width. The visual rating of texture is based on a 1 to 9 rating scale with 1 equalling coarse and 9 equalling fine.

3.4.2.7 Leaf colour

Leaf colour was observed based on a visual rating scale with 1 being light green and 9 being dark green. Species categorized as green, light green and dark green, both in the open field and shade condition.

3.4.2.8 Root length (cm)

Length of the root was measured from the base to the tip of root and expressed in cm

3.4.2.9 Number of root

Total number of roots was counted and recorded for each plant

3.4.2.10 Root shoot ratio

Roots and shoots of selected turf grass species were collected at the end of experiment. Weight of shoots was divided by the weight of roots to arrive at the ratio. According to following formula root shoot ratio was recorded.

R/S = Weight of roots (g) / Weight of shoots (g)

3.4.2.11 Nature of growth

Nature of growth of the plants was visually observed and categorized as erect, slanting and creeping.

3.4.3 Growth Parameters

3.4.3.1 Time for first mowing

Number of days taken for the first mowing was counted for each turf grass species and expressed in days.

3.4.3.2 Weight of biomass removed at first mowing

The biomass collected after first mowing of each grass species form one square meter area was weighed and was recorded in gram.

3.4.3.3 Time for first verticutting

This observation was not taken since none of the grass species was not ready for verticutting.

3.4.3.4 Time for use as sod /planting material

The time taken by each grass species for use as planting material was observed and recorded in days

3.4.3.5 Relative mowing height

All turf grass species were mowed at different mowing height. Coarse turf grass species were mowed at 5cm and fine turf grass species at 2.5 to 3cm.

3.4.3.6 Recuperative ability

Recuperative ability is a visual estimate of plant density in the area. Recuperative ability of different turf grass species was visually evaluated after mowing both in open field and under different shade conditions. A visual rating of 1 to 9 was used with 9 equalling maximum recuperative ability.

3.4.3.7 Frequency of mowing

Frequency of mowing depend upon seedling vigor or establishment like plant height, etc. Seedling vigor was rated on a 1 to 9 scale with 9 equalling maximum vigour.

3.4.3.8 Mowing Quality/ Tolerance

Mowing quality/ tolerance, reflects the uniformity and cleanness of cut exhibited by turf grass species. The rating scale was 1 to 9 with 1 equal to poorest mowing quality/ tolerance.

4.4.4 Air Pollution Tolerance Index

Air pollution tolerance index (APTI) of turf grass species was computed once during the period of study. After estimating the four parameters, viz, ascorbic acid, total chlorophyll, relative water content and leaf extract pH, the air pollution tolerance index (APTI) was computed using the following formula.

APTI= [A (T+P) +R /10]

Where

A = Ascorbic acid content (mg/g)

T = Total chlorophyll (mg/g)

P = pH of leaf extract and

R = Relative water content of leaf (%)

Fully mature physiologically active leaves (third from above) were collected in the morning hours and the fresh samples were analyzed for total chlorophyll, ascorbic acid, leaf extract pH and relative water content. The Turf grass species were categorized by the method and values suggested by Singh *et al*., (1991) using the equation.

4.4.4.1 Ascorbic acid content:

Ascorbic acid content of leaves is estimated and recorded. For the determination of ascorbic acid content, a homogenate was prepared by using 4% oxalic acid and was dehydrogenated by bromination. The dehydroascorbic acid was then treated with 2,4 nitro phenyl hydrazine to form osazone and dissolved in sulphuric acid to give an orange red colour solution which was measured at 540nm (Sadasivam and Manickam,1996).

4.4.4.2 Chlorophyll content

Chlorophyll a, Chlorophyll b and total chlorophyll content of leaves were estimated and recorded as mg/g. Chlorophyll was extracted in DMSO (dimethyl sulfoxide) and the absorption at 663nm and 645nm were read in a spectrophotometer. Using the absorption coefficients, the amount of chlorophyll was calculated.

4.4.4.3 Leaf extract pH

Relative water content of leaves was estimated using fresh weight and dry weight. Fresh leaf sample of 0.5g weight was homogenized using 50 ml distilled water and the supernatant liquid was fed into digital pH meter for detection of pH (Varshney, 1992).

4.4.4.4 Relative water content

. The percentage of relative water content was calculated by using the fresh weight, turgid weight ad dry weight for leaf samples (Beadle *et al.,* 1993). Relative water content was computed using the following formula and expressed in per cent.

RWC = (FW – DW/ TW – DW) 100

4.4.5 Tolerance to shade

The grass species were grown under the 0%, 25%, and 50% shade and were categorized according to their performance under shade.

4.4.6 Incidence of pests and diseases

Pests and diseases problems were observed both in shade and open field conditions. For pest problem invader, description, symptoms, identification and solution were recorded. For diseases problem disease, description, symptoms and solution were also noted down.

4.4.7 Identification of weeds

Weeds were identified and their names were listed, under shade and open field condition.

4.4. 8 Statistical tool used

All the tabulated data were statistically analysed using SPSS version 11.5.

Results

4. RESULTS

The results of the studies “Performance evaluation of turf grass species in the humid tropics” conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period 2011-2013 are presented in this chapter. The turf grass species were compared with respect to different characters under open field condition as well as under different shade levels, viz., 0, 25, 50 per cent.

4.1 Evaluation of turf grass species under open field conditon

4.1.1 Nature of growth

All the turf grass species were evaluated with respect to their nature of growth. It was observed that all the grass species had spreading habit of growth, except *Eragrostis curvula.*

4.1.2 Time taken for total coverage of area

Data on the time taken for total coverage of area are given in Table 2. The data showed significant differences. The maximum duration for total coverage of area was recorded by *Paspalum notatum* (189 days) and the minimum by *Eragrostis curvula* (100 days), which was significantly lower as compared to other species.

4.1.3 Plant characters

The turfgrass species showed significant differences for plant height, shoot height, leaf length and leaf width (Table. 3).

4.1.3.1 Plant height

The data presented in Table 3 indicated that turf grass speceis, compared with respect to their plant height, showed significant differences. Height varied from 108.7 cm in *Eragrostis curvula* to 4.6 in *Dichondra micrantha*.

4.1.3.2 Shoot length

The data indicated that all the species of grass varied significantly with respect to their shoot length (Table. 3). Highest value for shoot length was in *Cynodon dactylon* (44.4 cm) and the lowest in *Zoysia japonica* (4.6 cm), which was on par with all other grass species, except *Eragrostis curvula.*

Table.2. Time taken from planting to total coverage of area in different grass species in open field conditions

Sl.No.	Grass species	Duration for complete coverage (days)
1	*Dichondra micrantha*	130[d] (11.42)
2	*Paspalum notatum*	189[a] (13.79)
3	*Eragrostis curvula*	100[f] (10.02)
4	*Cynodon dactylon* 419	163[b] (12.80)
5	*Cynodon dactylon*	146[c] (12.11)
6	*Zoysia japonica*	170[b] (13.21)
7	*Stenotaphrum secundatum*	112[e] (10.60)

Table.3. Shoot characters of turf grass species in open field conditions (after six months of establishment)

Sl.No.	Grass Species	Growth habit	Plant height (cm)	Shoot length (cm)
1	*Dichondra micrantha*	Spreading	4.6[d]	*
2	*Paspalum notatum*	Spreading	70.6[b]	6.7[c]
3	*Eragrostis curvula*	upright	108.7[a]	21.5[b]
4	*Cynodon dactylon* 419	Spreading	7.1[e]	6.1[c]
5	*Cynodon dactylon*	Spreading	47.8[c]	44.4[a]
6	*Zoysia japonica*	Spreading	6.8[e]	4.6[c]
7	*Stenotaphrum secundatum*	Spreading	29.4[f]	6.2[c]

*** No Shoots**

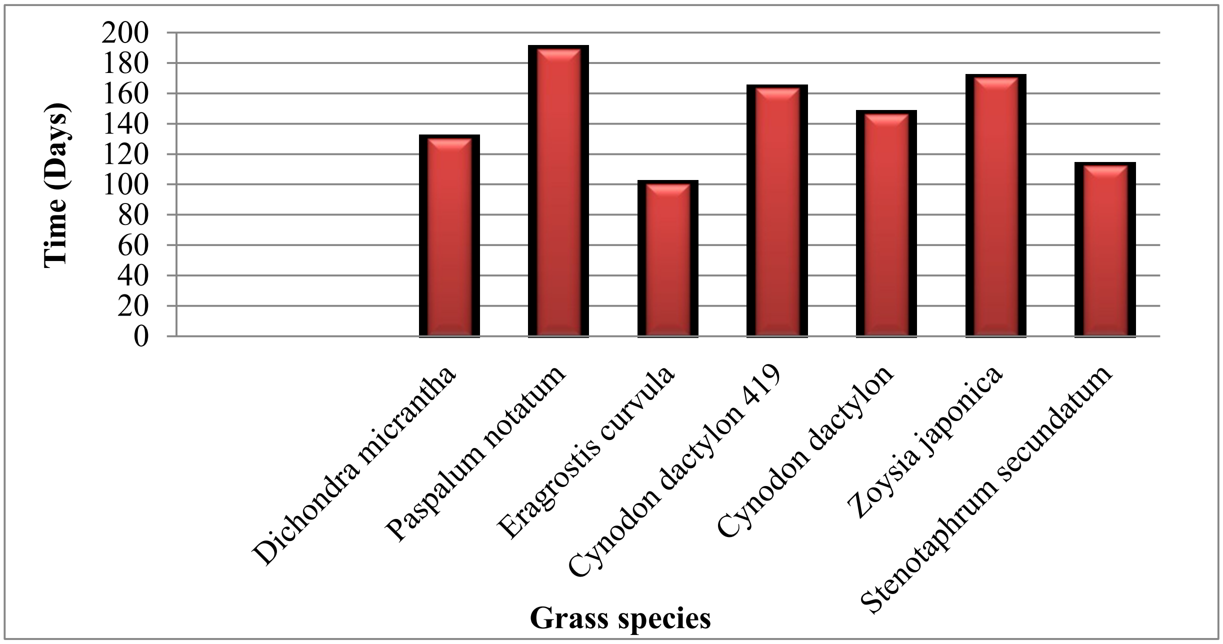


Fig.1. Time taken for total coverage of area

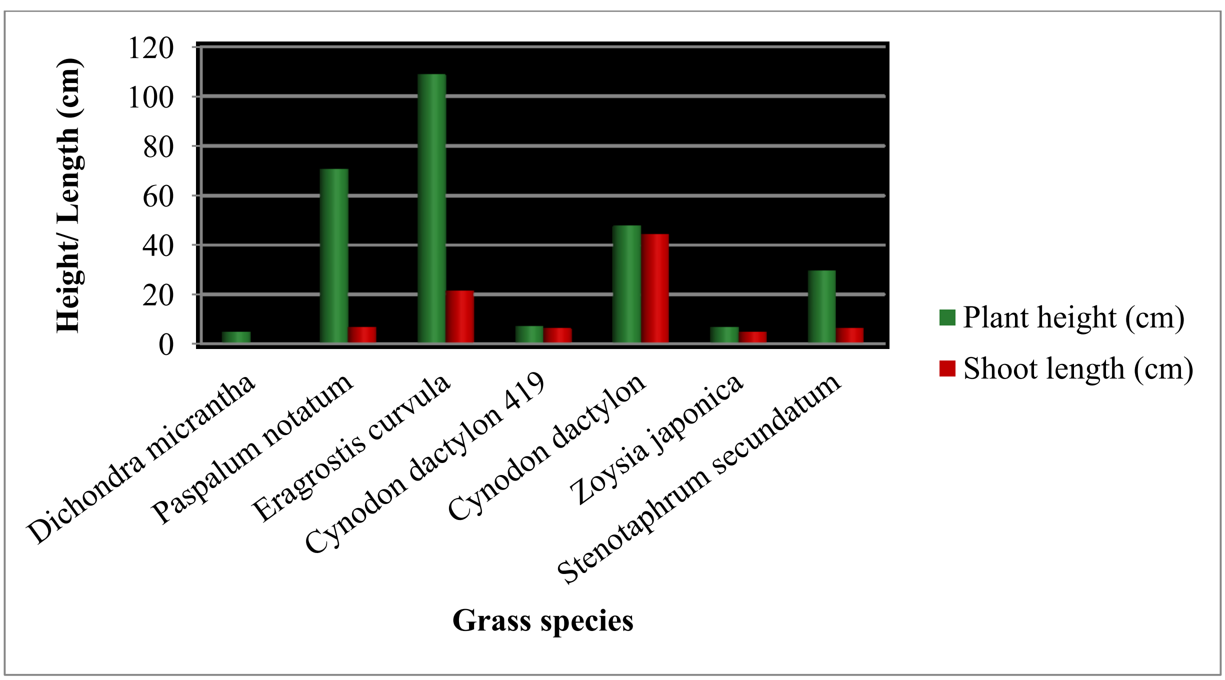


Fig. 2. Plant characters of different turf grass species in open field after six months of establishment

4.1.4 Leaf characters

The quantitative and qualitative characters of the leaves of turf grass species studied under open field condition are given in Table 4.

4.1.4.1 Leaf length

The turf grass species showed significant differences with respect to their leaf length (Table. 4). It ranged from 71.6 cm in *Eragrostis curvula* to 3.7 cm in *Zoysia japonica*.

4.1.4.2 Leaf width

Turf grass species showed significant differences with respect to leaf width (Table. 4). The Maximum leaf width was shown by *Dichondra micrantha* (20.0 mm) and the lowest was in *Cynodon dactylon* 419 (1.6 cm), which was on par with *Zoysia japonica* (1.7 mm).

4.1.4.3 Leaf texture

Turf grass species were compared with respect to their leaf texture in open field condition and the obsevervation are furnished in Table 6.

Dinchondra micrantha, Paspalum notatum and *Stenotaphrum secundatum* species were included in the category of coarse textured species, because these species showed the maximum leaf width compared to all other grass species in the study. *Eragrostis curvula* and *Cynodon dactylon* were in the category of medium textured grass species. *Cynodon dacylon* 419 and *Zoysia japonica* species were included in the category of very fine textured grass species characterizsed by their minimum leaf width.

4.1.4.4 Leaf colour

Lawn grass species were visually compared with respect to their leaf colour in open field condition. There are significant difference in colour of different grass species (Table. 5). Light green colour was observed in *Paspalum notatum* , *Eragrostis curvula*. Both in *Cynodon dacylon* 419 and *Cynodon dactylon* the colour was green. Dark green colour was observed only in *Zoysia japonica*, *Stenotaphrum secundatum* and *Dihondra micrantha.*

4.1.4.5 Arrangment of unfurled leaves

The arrangment of unfurled leaves differed significantly with respect to species (Table.4). In *Paspalum notatum*, *Cynodon dactylon* 419 and *Stenotaphrum secundtatum,* the unfurled leaves were folded and in all other s they were rolled.

Plate 4. Leaf textures of different turf grass species

Table 4. Leaf characters of turf grass species in open field conditions (after six months of establishment)

Sl.No.	Grass Species	Quantitative characters		Qualitative characters
		Leaf length (cm)	Leaf width (mm)	Arrangement of unfurled leaves
1	*Dichondra micrantha*	1.6[d]	20.0[a]	Rolled
2	*Paspalum notatum*	55.5[b]	5.7[c]	Folded
3	*Eragrostis curvula*	71.6[a]	2.8[d]	Rolled
4	*Cynodon dactylon* 419	4.3[d]	1.6[e]	Folded
5	*Cynodon dactylon*	8.1[d]	2.9[d]	Rolled
6	*Zoysia japonica*	3.7[d]	1.7[e]	Rolled
7	*Stenotaphrum secundatum*	13.6[c]	6.9[b]	Folded

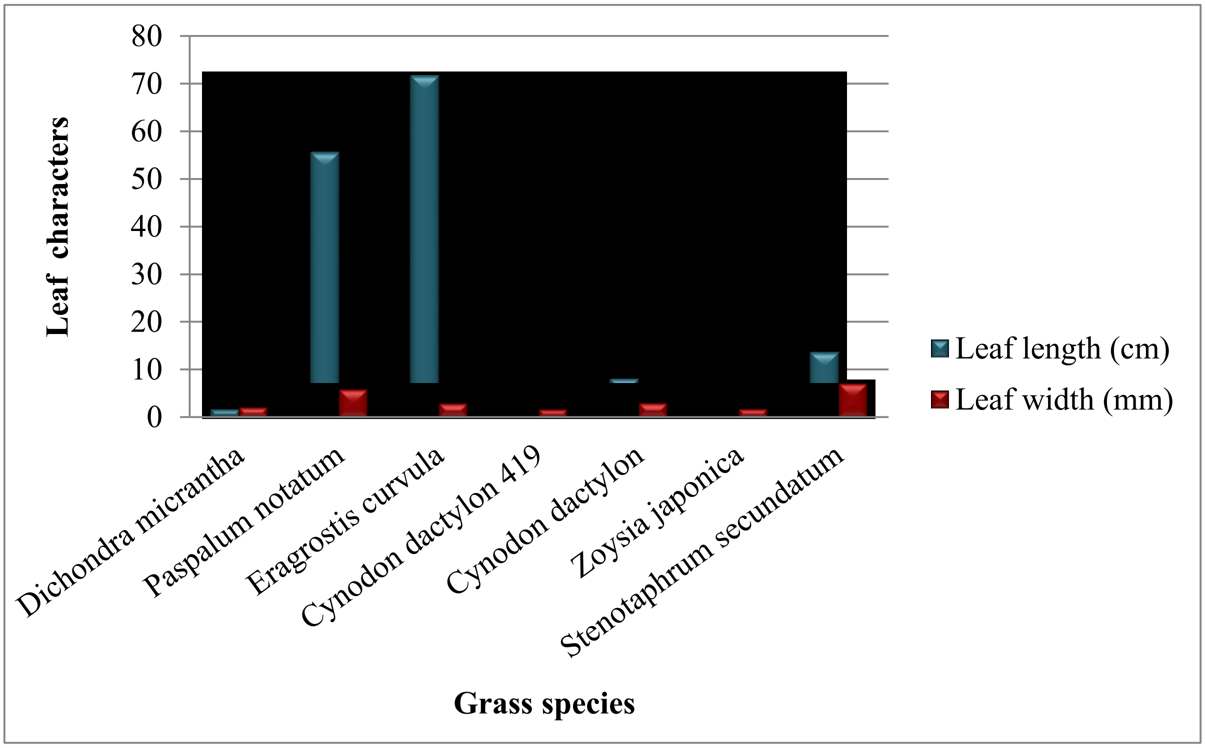


Fig. 3. Leaf characters of different turf grass species in open field after six months of establishment

Table 5. Turf grass species colour rating, based on 1 to 9 rating scale

Sl.No.	Grass species	Colour	Visual rating
1	*Dichondra micrantha*	Light green	1
2	*Paspalum notatum*	Light green	1
3	*Eragrostis curvula*	Light green	1
4	*Cynodon dactylon* 419	Green	7
5	*Cynodon dactylon*	Green	7
6	*Zoysia japonica*	Dark green	9
7	*Stenotaphrum secundatum*	Dark green	9

Table 6. Turf grass species texture rating, based on 1 to 9 rating scale

Sl.No.	Grass species	Leaf texture	Visual rating (1-9)
1	*Dichondra micrantha*	Coarse	1
2	*Paspalum notatum*	Coarse	1
3	*Eragrostis curvula*	Medium	7
4	*Cynodon dactylon* 419	Very fine	9
5	*Cynodon dactylon*	Medium	7
6	*Zoysia japonica*	Very fine	9
7	*Stenotaphrum secundatum*	Coarse	1

4.1.5 Root characters

Data on root characters of the turf grass species studied under open field condition, six months after establishment are given in Table 7.

4.1.5.1 Number of roots

The number of roots in different species differed singnificantly. The maximum number was observed in *Eragrostis curvula* (316.7) and the minimum in *Zoysia japonica* (34.7).

4.1.5.2 Root length

Data on the variation in root length showed a range of 9.7 cm (*Dichondra micrantha)* to 34.8 cm in *Eragrostis curvula*, all the species were significantly different.

4.1.5.3 Root shoot ratio

The root shoot ratio was significantly high in *Cynodon dactylon* (0.2647), followed by *Dichondra micrantha* (0.1580). It was minimum in *Eragrostis curvula* (0.0097).

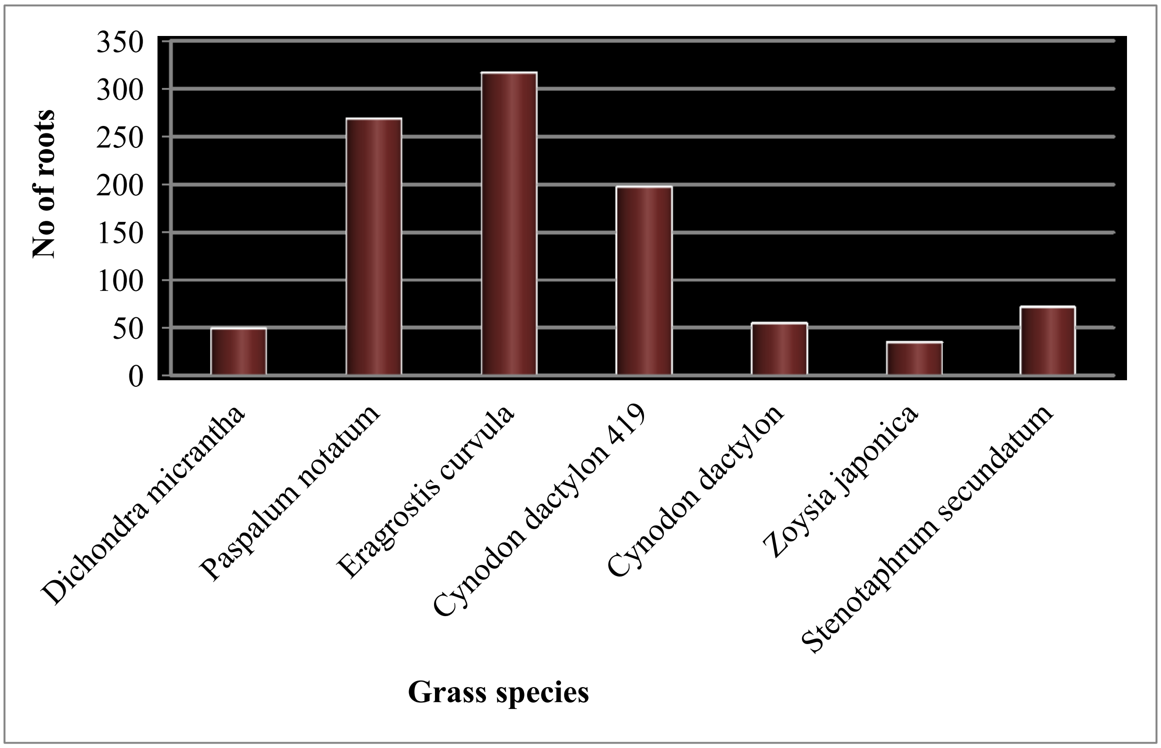


Fig. 4. Number of roots in turf grass species in open field condition

Table 7. Root characters of turf grass species under open field condition (after six months of establishment)

Sl.No.	Grass species	No of roots	Length of roots (cm)	Root shoot ratio
1	*Dichondra micrantha*	49.3^{d}	9.7^{d}	0.1580^{b}
2	*Paspalum notatum*	268.7^{b}	31.4^{ab}	0.0500^{e}
3	*Eragrostis curvula*	316.7^{a}	34.8^{a}	0.0097^{f}
4	*Cynodon dactylon* 419	197.7^{c}	19.4^{c}	0.1033^{c}
5	*Cynodon dactylon*	54.7^{d}	23.7^{bc}	0.2647^{a}
6	*Zoysia japonica*	34.7^{d}	19.2^{c}	0.0770^{d}
7	*Stenotaphrum secundatum*	71.7^{d}	24.5^{bc}	0.0393^{e}

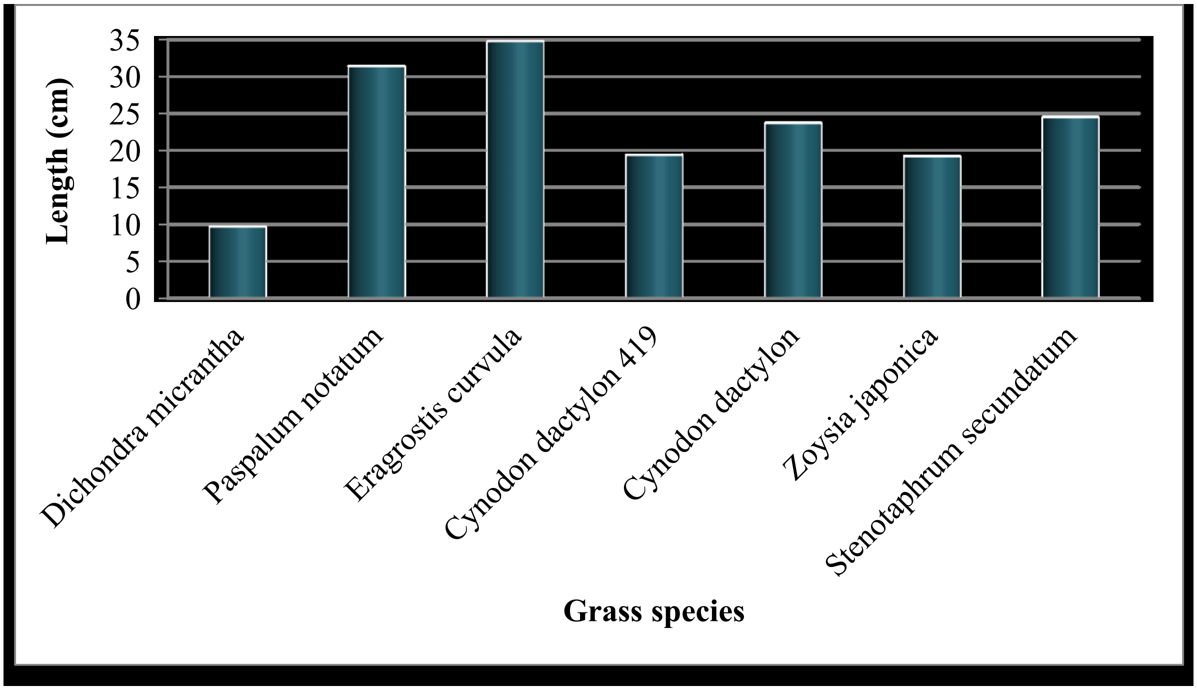


Fig. 5. Root length of different turf grass species in open field

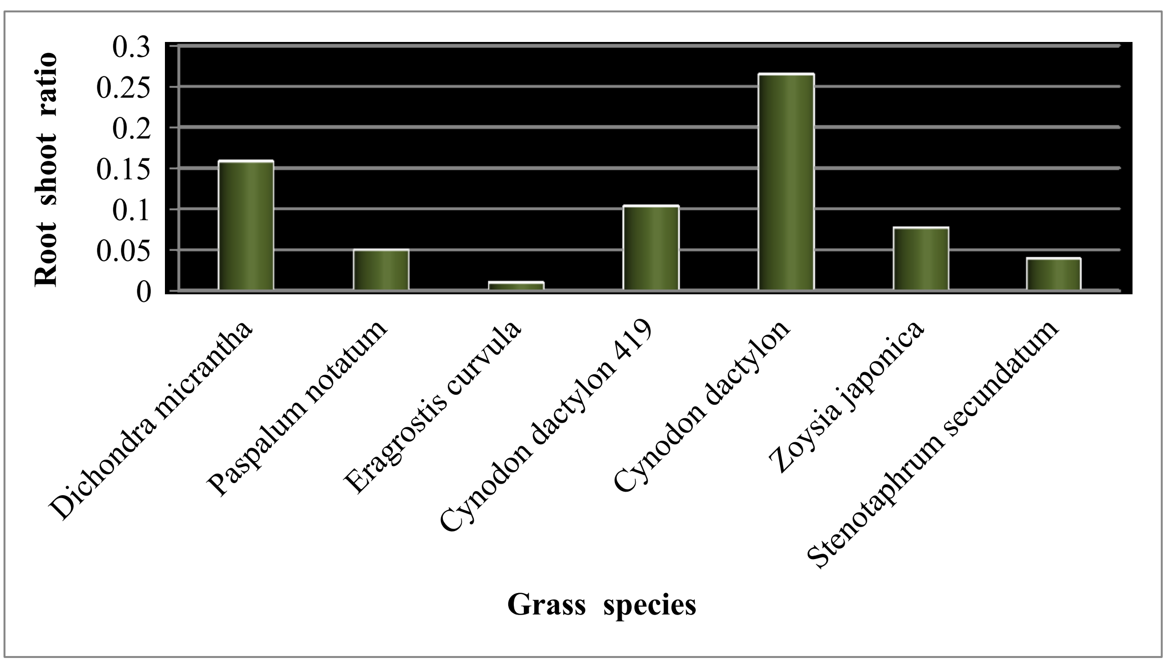


Fig. 6. Root shoot ratio of turf grass species in open field

4.1.6 Mowing effectiveness of turf grass species

Data on the mowing effectiveness in different grass species under open condition are given in Table 8.

4.1.6.1 Time taken for first mowing

Data pertaining to the duration (days) up to first mowing are given in Table 8, which showed significant differences. The maximum duration showed by *Dichondra michrantha* (174.7 days), followed by *Cynodon dacylon* 419 (146.7 days) and *Zoysia japonica* (126.3 days). The minimum duration was shown by *Eragrostis curvula* (57.7 days). All the value were significantly different.

4.1.6.2 Weight of biomass removed at first mowing

Values for weight of biomass removed at first mowing showed significant differences (Table. 8). *Eragrostis curvula* showed the highest value (3330.7g) for biomass collected from the selected area, followed by *Stenotaphrum secundatum* (2733.3 g) and *Paspalum notatum* (1815.0 g). The lowest value for biomass removed was in *Zoysia japonica* (30.0 g).

4.1.6.3 Time for first verticutting

As most of grass species did not attain the required stage for verticutting during the period of study, this observation could not be taken.

4.1.6.4 Relative mowing height

The relative mowing height was high in *Paspalum notatum, Eragrostis curvula* and *Stenotaphrum secundatum* and medium in *Dichondra micrantha, Cynodon dactylodon.* It was very low in *Cynodon dactylodon* 419 and *Zoysia japonica.*

Table 8. Influence of different grass species on mowing effectiveness under open field condition

Sl.No.	Grass species	Time taken for first mowing (days)	Relative mowing height	Mowing height (cm)	Biomass removed (g)
1	*Dichondra micrantha*	174.7^{a} (13.23)	Medium	up to 3.0	238.3^{f} (15.42)
2	*Paspalum notatum*	63.7^{f} (8.00)	High	3.5-5.0	1815.0^{c} (42.51)
3	*Eragrostis curvula*	57.7^{g} (7.62)	High	3.5-7.0	3330.7^{a} (57.70)
4	*Cynodon dactylon* 419	146.7^{b} (12.13)	Close	up to 2.5	516.7^{e} (22.69)
5	*Cynodon dactylon*	86.3^{d} (9.31)	Medium	3.0-5.0	778.3^{d} (27.9)
6	*Zoysia japonica*	126.3^{c} (11.26)	Close	up to 2.5	30.0^{g} (5.51)
7	*Stenotaphrum secundatum*	76.3^{e} (8.76)	High	3.5-7.5	2733.3^{b} (52.16)

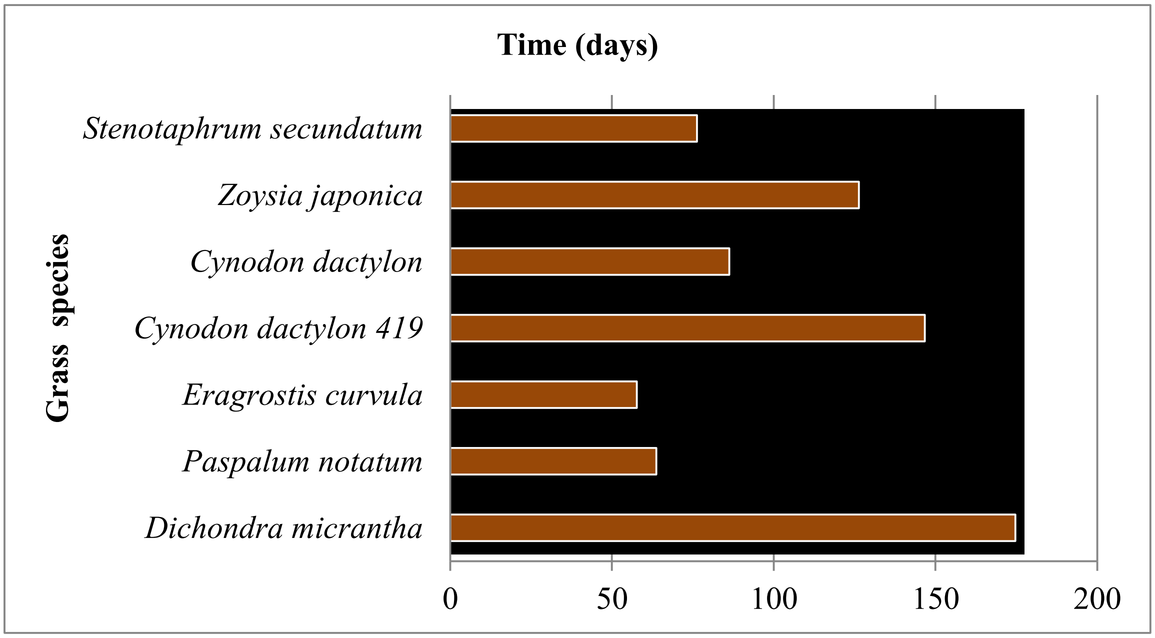


Fig. 7. Time taken for first mowing

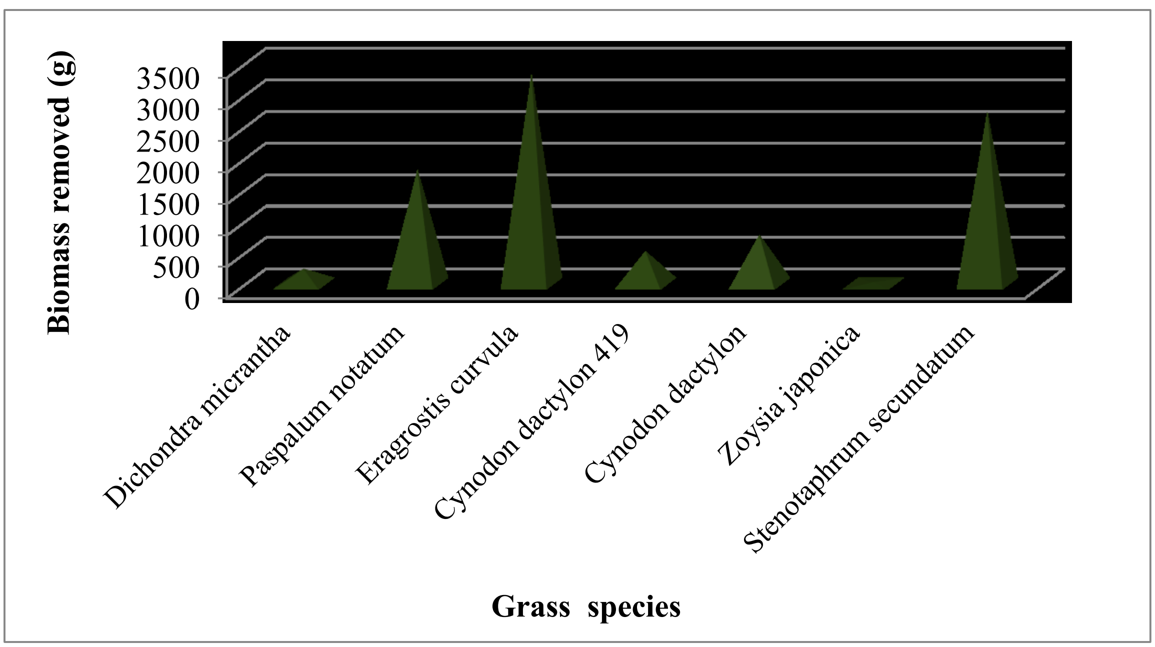


Fig. 8. Quantity of biomass removed at first mowing

4.1.6.5 Recuperative ability

Data on recuperative ability after mowing in different turf grass species are given in Table 9. Recuperative ability after mowing was poor in *Dichondra micrantha, Paspalum notatum* and *Eragrostis curvula.* It was high in *Cynodon dactylon* and *Cynodon dactylon* 419. Recuperative ability was good in *Zoysia japonica* and *Stenotaphrum secundatum*.

4.1.6.6 Mowing frequency

Data on mowing frequency of different turf grass species are given in Table 10. Mowing frequency was high in paspalum notatum and *Eragrostis curvula*. It was medium in *Cynodon dactylon* and *Stenotaphrum secundatum*. Mowing frequency was less in *Dichondra micrantha*, *Cynodon dactylon* 419 and *Zoysia japonica.*

4.1.6.7 Mowing quality/ tolerance

Data on mowing quality/tolerance in different turf grass species are given in Table 11. The mowing quality/tolerance was high in *Cynodon dactylon*, *Cynodon dactylon 419* and *Zoysia japonica*. Cleanness of cut and mowing tolerance was medium in *Stenotaphrum secundatum*. *Paspalum notatum* and *Eragrostis curvula* showed poor mowing quality but their mowing tolerance was high. Mowing quality and tolerance were poor in *Dichondra micrantha.*

Table 9. Turf grass species recuperative ability rating, based on 1 to 9 rating scale

Sl.No.	Grass species	Plant density (1-9)	Recuperative ability
1	*Dichondra micrantha*	1	Poor
2	*Paspalum notatum*	1	Poor
3	*Eragrostis curvula*	1	Poor
4	*Cynodon dactylon* 419	9	High
5	*Cynodon dactylon*	9	High
6	*Zoysia japonica*	5	Good
7	*Stenotaphrum secundatum*	5	Good

1= Poor density
9= High density

Table 10. Turf grass species mowing frequency rating based on 1 to 9 rating scale

Sl.No.	Grass species	Plant vigour	Mowing frequency
1	*Dichondra micrantha*	1	Less
2	*Paspalum notatum*	8	More
3	*Eragrostis curvula*	9	More
4	*Cynodon dactylon* 419	1	Less
5	*Cynodon dactylon*	5	Medium
6	*Zoysia japonica*	1	Less
7	*Stenotaphrum secundatum*	5	Medium

1= Minimum vigour
9= Maximum vigour

Table 11. Turf grass species mowing quality/ tolerance rating, based on 1 to 9 rating scale

Sl.No.	Grass species	Uniformity and cleanness of cut (1-9)	Mowing tolerance
1	*Dichondra micrantha*	9	Low
2	*Paspalum notatum*	9	Low
3	*Eragrostis curvula*	9	Low
4	*Cynodon dactylon* 419	1	High
5	*Cynodon dactylon*	1	High
6	*Zoysia japonica*	1	High
7	*Stenotaphrum secundatum*	3	Medium

1 = High mowing quality
9 = Poorest mowing quality

4.1.7 Plant characters under open field condition, two months after mowing

The plant characters were observed two months after mowing and the data are presented in Table 12. There was significant difference among species with respect to the plant characters like height, shoot length, leaf length and leaf width. Plant height was significantly maximum in *Eragrostis curvula* (78.1 cm), followed by *Paspalum notatum* (50.9 cm), and the minimum in *Dichondra micrantha* (3.4 cm). Shoot length was significantly high in *Cynodon dactylon* (27.3 cm) followed by *Eragrostis curvula* (15.0 cm). It was the lowest in *Zoysia japonica* which was on par with all the remaining species. Leaf width was the maximum in *Dichondra micrantha* (15mm) and the minimum in *Zoysia japonica* (1.2mm) which was on par with Cynodon dactylon 419 (1.4 mm).

Plate 5. General view of field study after mowing

Table 12. Plant characters of turf grass species under open field condition (after two months of mowing)

Sl.No.	Grass species	Plant height (cm)	Shoot length (cm)	Leaf length (cm)	Leaf width (mm)
1	*Dichondra micrantha*	3.4[e]	*	1.0	15.0[a]
2	*Paspalum notatum*	50.9[b]	5.5[c]	38.92[b]	5.2[c]
3	*Eragrostis curvula*	78.1[a]	15.0[b]	61.3[a]	2.8[d]
4	*Cynodon dactylon* 419	4.9[e]	4.3[c]	1.5[e]	1.4[e]
5	*Cynodon dactylon*	30.2[c]	27.3[a]	5.8[d]	2.6[d]
6	*Zoysia japonica*	4.1[e]	3.3[c]	2.2[e]	1.2[e]
7	*Stenotaphrum secundatum*	16.2[d]	5.8[c]	9.9[c]	7.1[b]

* No shoots

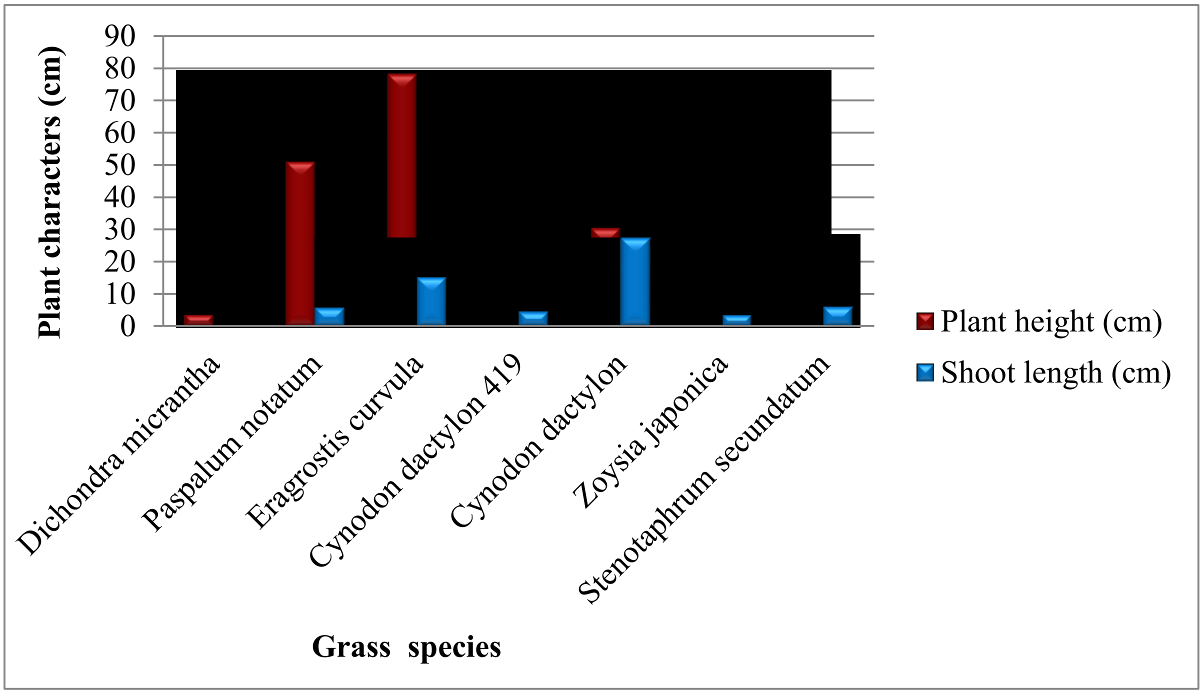


Fig. 9. Plant characters of turf grass species in open field condition at two months

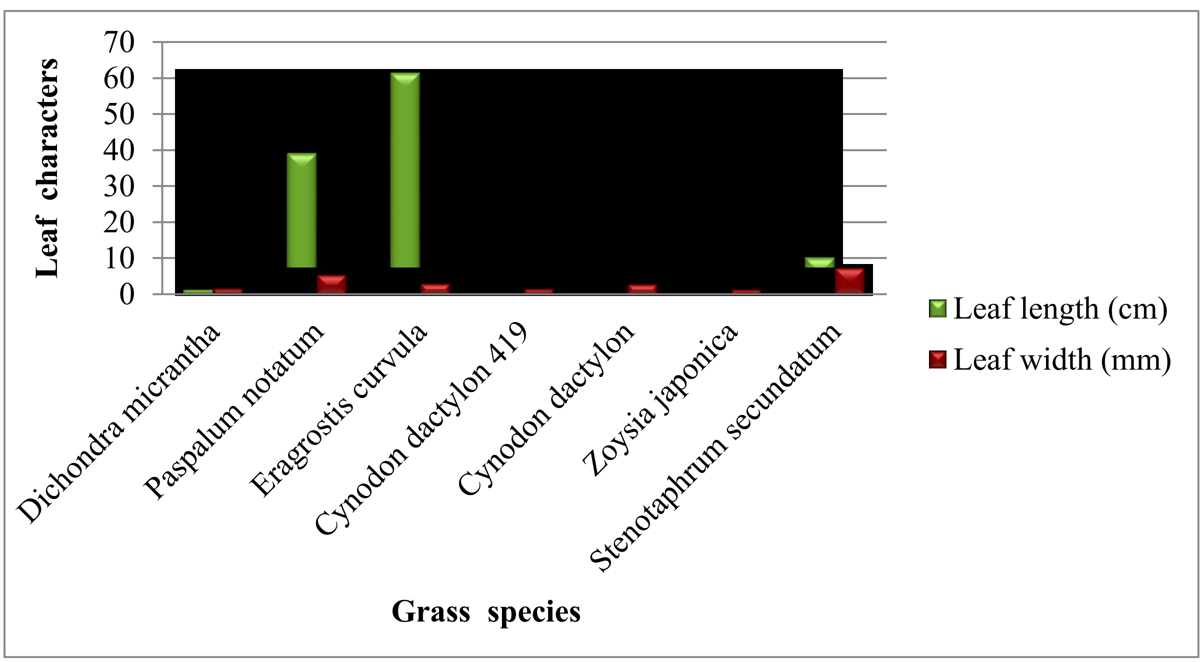


Fig. 10. Leaf characters of turf grass species in open field condition after two months after mowing

4.2 Evaluation of turf grass species under different shade levels

All turf grass species were compared under various (0%, 25%, 50%) shade levels with respect to their plant height, shoot height, leaf length and leaf width after six months of establishment and the data obtained for various parameters are presented in Table 13 &14.

4.2.1 Growth habit

Irrespective of the shade level, all grass species had spreading habit except in *Eragrostis curvula*, which grew up right. Growth habit of different turf grass specis is given in Table 13.

4.2 .2 Plant characters

All turf grass species were compared under various (0%, 25%, 50%) shade levels with respect to their plant height, shoot lenght and the data obtained for various parameters are presented in Table 13.

4.2.2.1 Plant height

Among different grass species evaluated at different levels of shade *Eragrostis curvula* recorded the maximum plant height at 0 per cent shade (102.2 cm) which was on par with the height at 25 per cent shade level (99.2 cm), followed by the height at 50 per cent shade (85.4 cm). The minimum height was for *Cynodon dactylon* 419 at 0 per cent shade (7.0 cm). This was on par with the height at 25 per cent and 50 per cent shade levels (7.7 cm and 8.1 cm respectively) for the same species. *Stenotaphrum secundatum* and *Zoysia japonica* did not record any significant variation in plant height at different shade levels.

Dichondra micrantha under 0 percent shade level

Paspalum notatum under 0 per cent shade level

Dichondra micrantha under 25 percent shade level

Paspalum notatum under 25 per cent shade level

Dichondra micrantha under 50 percent shade level

Paspalum notatum under 50 per cent shade level

Plate 6. Turf grass species grown under various shade levels - I

Eragrostis curvula under 0 percent shade level

Cynodon dactylon under 0 percent shade level

Eragrostis curvula under 25 percent shade level

Cynodon dactylon under 25 percent shade level

Eragrostis curvula under 50 percent shade level

Cynodon dactylon under 50 percent shade level

Plate 6. Turf grass species grown under various shade levels - II

Zoysia japonica under 0 percent shade level

Cynodon dactylon 419 under 0 percent shade level

Zoysia japonica under 25 percent shade level

Cynodon dactylon 419 under 25 percent shade level

Zoysia japonica under 50 percent shade level

Cynodon dactylon 419 under 50 percent shade level

Plate.6 Turf grass species grown under various shade levels - III

Stenotaphrum secundatum under 0
percent shade level

Stenotaphrum secundatum under 25
percent shade level

Stenotaphrum secundatum under 50
percent shade level

Plate.6 Turf grass species grown under various shade levels - IV

4.2.2.2 Shoot length

Cynodon dactylon recorded significatly long shoots at 0 per cent shade level, followed by the length at 25 per cent and 50 per cent shade levels in the same species. This was followed by *Eragrostis curvula*.

The minimum shoot length at all the shade levels was observed in *Stenotaphrum secundatum* and *Cynodon dactylon* 419, which were on par with each other.

Table 13. Plant characters of turf grass species as influenced by shade levels (after six month of establishment)

Sl.No.	Grass species	Levels of shade (%)	Growth habit	Plant height (cm)	Shoot length (cm)
1	*Dichondra micrantha*	0	Spreading	11.9[g]	*
		25	Spreading	13.7[f]	*
		50	Spreading	14.0[f]	*
2	*Paspalum notatum*	0	Spreading	62.9[d]	6.3[h]
		25	Spreading	77.2[c]	6.0[h]
		50	Spreading	77.1[bc]	5.4[h]
3	*Eragrostis curvula*	0	Upright	102.2[a]	21.4[d]
		25	Upright	99.2[a]	18.4[e]
		50	Upright	85.4[b]	17.7[e]
4	*Cynodon dactylon* 419	0	Spreading	7.0[j]	6.2[h]
		25	Spreading	7.7[ij]	6.6[h]
		50	Spreading	8.1[ij]	6.9[h]
5	*Cynodon dactylon*	0	Spreading	37.8[e]	35.1[a]
		25	Spreading	32.7[ef]	28.9[b]
		50	Spreading	28.7[f]	24.4[c]
6	*Zoysia japonica*	0	Spreading	16.7[g]	9.7[g]
		25	Spreading	16.7[g]	10.5[g]
		50	Spreading	19.4[g]	13.7[f]
7	*Stenotaphrum secundatum*	0	Spreading	9.6[hij]	6.8[h]
		25	Spreading	10.7[hi]	6.3[h]
		50	Spreading	11.2[h]	6.1[h]

* No shoots

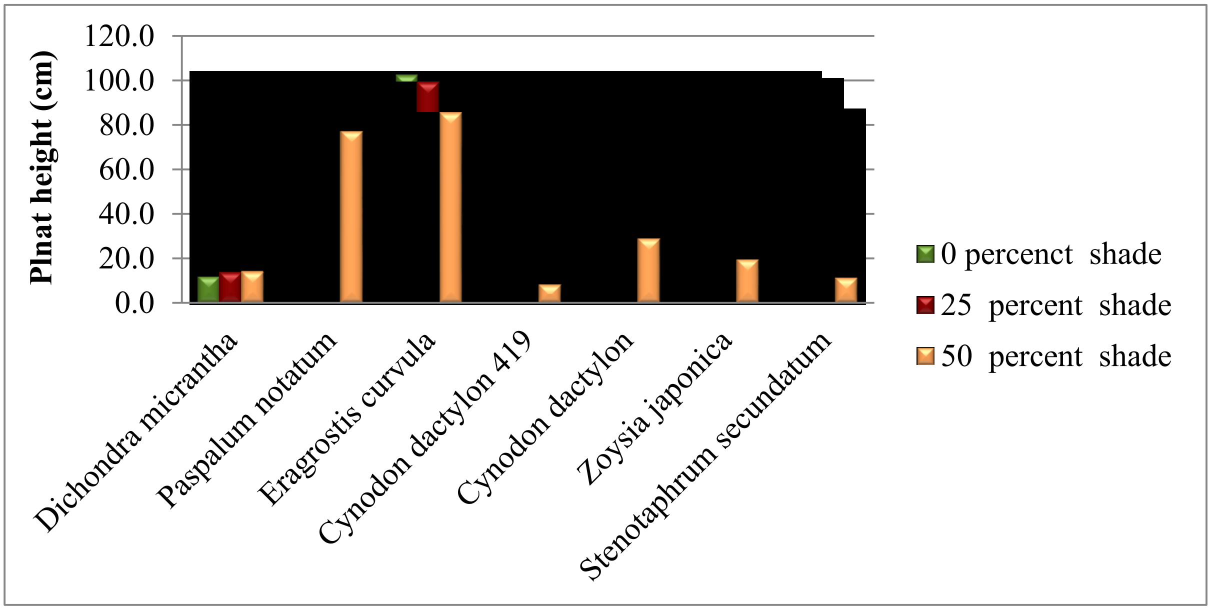


Fig. 11. Influence of various shade levels on plant height (cm) in different turf grass species after six months of establishment

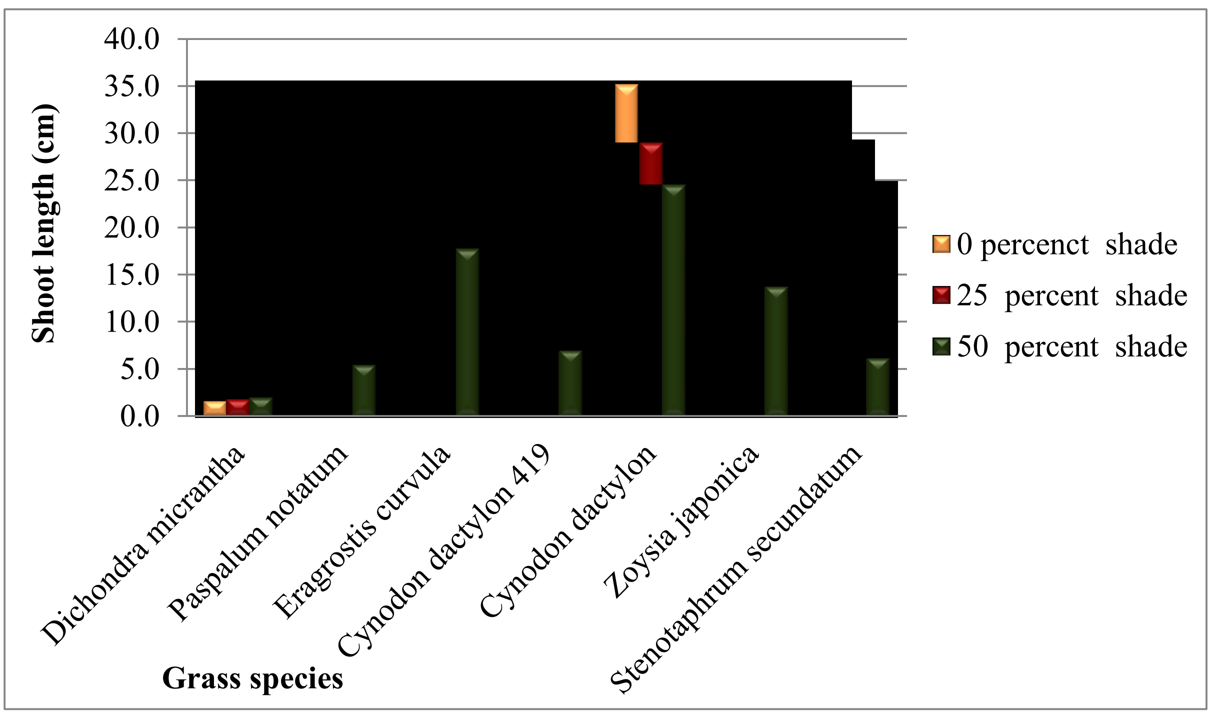


Fig. 12. Influence of various shade levels on shoot height (cm) in different turf grass species after six months of establishment

4.2.3 Leaf characters

The quantitative characters of the leaves of turf grass species studied are given in Table 14.

4.2.3.1 Leaf length

Leaf length was significantly less in *Cynodon dactylon* 419 and *Dichondra micrantha* at all the shade levels and range between 1.56 cm and 2.99cm . It was the maximum in *Paspalum notatum* (65.97 cm) at 25 per cent shade level and *Eragrostis curvula* (66.40 cm) at 0 per cent shade level. In *Zoysia japonica, Stenotaphrum secundatum* and *Cynodon dactylon* the leaf length was medium (5.85 to 8.60 cm) and did not differ significantly with respect to different shade levels.

4.2.3.2 Leaf width

Cynodon dactylon 419 and *Zoysia japonica* recorded recorded the minimum leaf width (1.24 to 1.50 cm) under all levels of shade. This was followed by *Eragrostis curvula* where the leaf width varied from 2.19 to 2.33 cm in accordance with light intensity. Maximum leaf width showed by *Dichondra micrantha* in 50 per cent (25 mm) followed by in 25 (23 mm) and 0 per cent (21 mm) shade condition.

Table 14. leaf characters of turf grass species as influenced by shade levels (after six month of establishment)

Sl.No.	Grass species	Levels of shade (%)	Leaf length (cm)	Leaf width (cm)
1	*Dichondra micrantha*	0	1.56[f]	21.0[a]
		25	1.75[f]	23.0[a]
		50	1.92[f]	25.0[a]
2	*Paspalum notatum*	0	52.33[c]	4.55[b]
		25	65.97[a]	4.56[b]
		50	60.72[ab]	4.11[b]
3	*Eragrostis curvula*	0	66.40[a]	2.33[cde]
		25	58.12[bc]	2.26[de]
		50	53.39[c]	2.19[e]
4	*Cynodon dactylon* 419	0	2.91[f]	1.48[f]
		25	2.97[f]	1.30[f]
		50	2.99[f]	1.24[f]
5	*Cynodon dactylon*	0	8.60[d]	2.83[cd]
		25	8.08[de]	2.43[cde]
		50	6.51[de]	2.130[e]
6	*Zoysia japonica*	0	5.85[e]	1.50[f]
		25	6.72[de]	1.26[f]
		50	6.80[de]	1.22[f]
7	*Stenotaphrum secundatum*	0	6.87[de]	4.67[b]
		25	8.08[de]	4.00[b]
		50	8.30[de]	3.00[c]

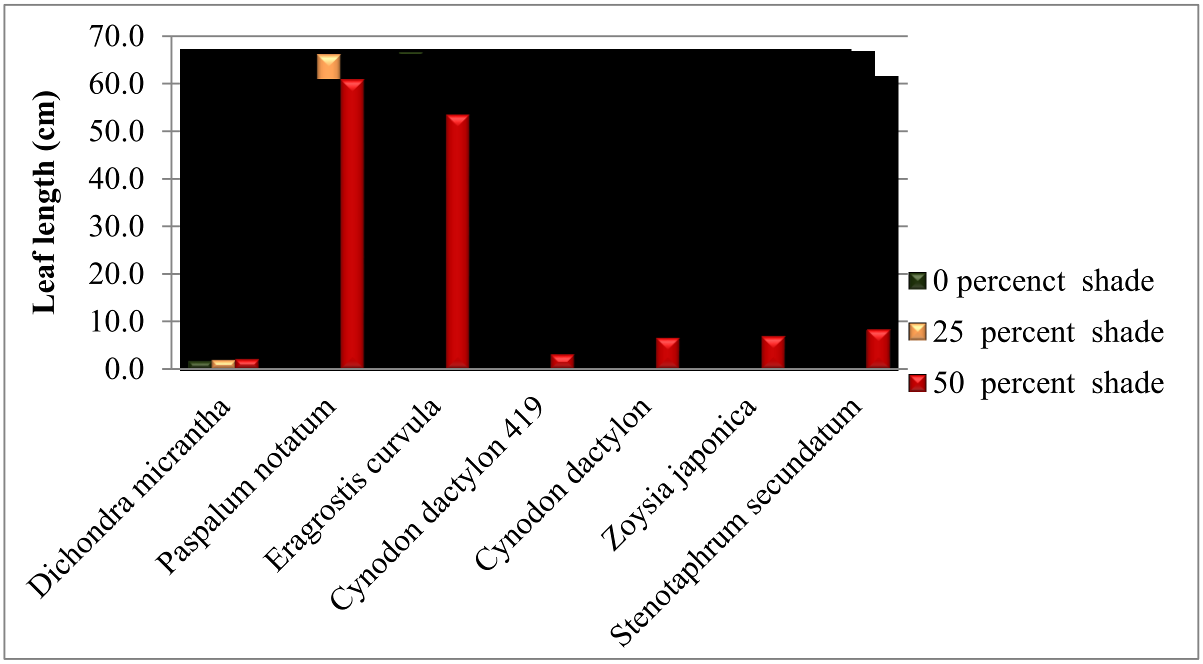


Fig. 13. Influence of various shade levels on leaf length (cm) in different turf grass species after six months of establishment

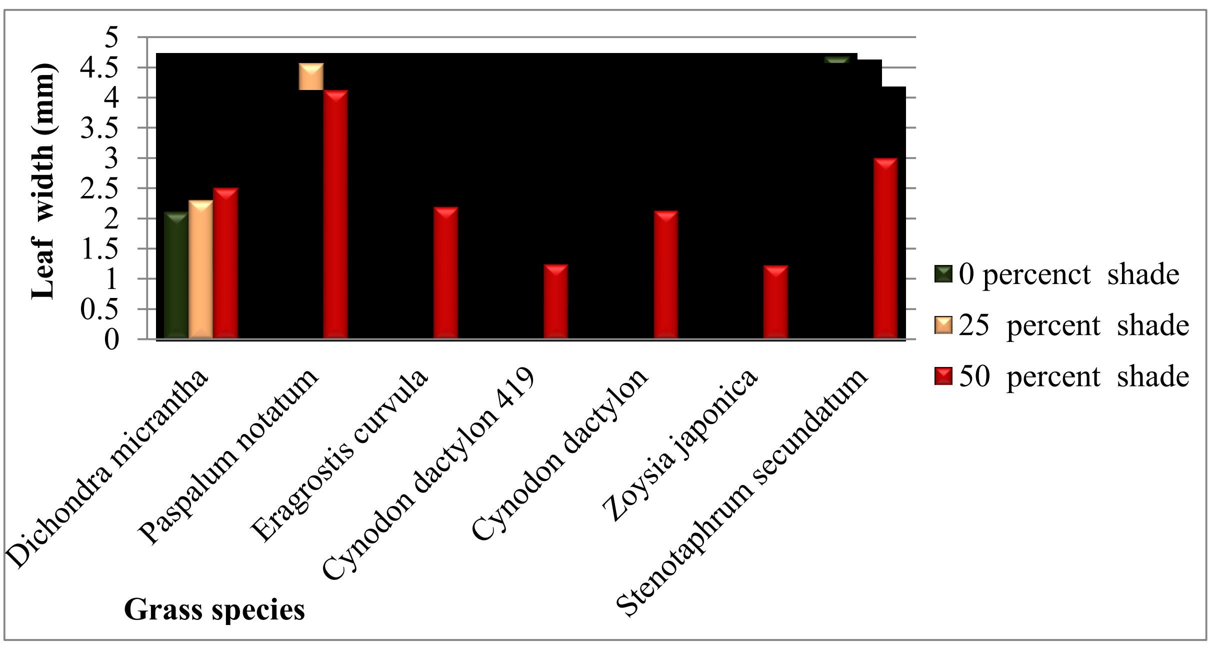


Fig. 14. Influence of various shade levels on leaf width (mm) in different turf grass species after six months of establishment

4.2.3.3 Leaf texture

All turf grass species were evaluated under various (0%, 25%, 50%) shade levels. Results shown that all the turf grass species differed significantly with respect to leaf texture with each other (Table. 15). Results shown that different (0%, 25%, 50%) shade levels were not having any effect on the leaf texture. Each species showed same texture under all shade levels.

4.2.3.4 Leaf colour

Turf grass species differed significantly with respect to leaf colour under various shade levels (Table. 16). *Dichondra micrantha* showed light green colour both under 0 per cent and 25 per cent shade levels and it was dark green under 50 per cent shade level.

Pasplaum notatum showed light green colour under 0 per cent shade and it was green under 25 and 50 per cent shade levels.

Eragrostis curvula showed light green colour under 50 per cent shade level and green under 25 and 50 per cent shade levels.

Cynodon dactylon and *Cynodon dactylon* 419 showed green colour both under 0 and 25 per cent shade levels and it was dark green under 50 per cent shade level. *Zoysia japonica* showed dark green colour under 0 per cent shade, green under 25 per cent shade and light green under 50 per cent shade levels. *Stenotaphrum secundaum* showed light green colour under 0 per cent shade and green colour under 25 per cent shade and dark green under 50 per cent shade levels.

4.2.3.5 Arrangement of unfurled leaves

Evaluation of different turf grass species under various shade levels showed that arrangement of unfurled leaves was not affected by different shade levels and all turf grass species shown same results for unfurled leaves, studied under open field condition. Arrangement of unfurled leaves in different turf grass species are given in Table 17.

Table 15. Turf grass species texture rating based on 1 to 9 rating scale, under different levels of shade

Sl.No.	**Grass species**	**Leaf texture**		
		T0	T1	T2
1	*Dichondra micrantha*	1	1	1
2	*Paspalum notatum*	1	1	1
3	*Eragrostis curvula*	7	7	7
4	*Cynodon dactylon 419*	9	9	9
5	*Cynodon dactylon*	7	7	7
6	*Zoysia japonica*	9	9	9
7	*Stenotaphrum secundatum*	1	1	1

T0 = 0 % Shade
T1 = 25 % Shade
T2 = 50 % Shade

1 = Coarse leaf texture
9 = Very fine leaf texture

Table 16. Turf grass colour rating, based on 1 to 9 rating scale under different levels of shade

Sl.No.	Grass species	Colour/Rating		
		T0	**T1**	**T2**
1	*Dichondra micrantha*	Light green (1)	Light green (1)	Dark green (9)
2	*Paspalum notatum*	Light green (1)	Green (7)	Green (7)
3	*Eragrostis curvula*	Light green (1)	Green (7)	Green (7)
4	*Cynodon dactylon* 419	Green (7)	Green (7)	Dark green (9)
5	*Cynodon dactylon*	Green (7)	Green (7)	Dark green (9)
6	*Zoysia japonica*	Dark green (9)	Green (7)	Light green (1)
7	*Stenotaphrum secundatum*	Light green (1)	Green (7)	Dark green (9)

T0 = 0 % Shade
T1 = 25 % Shade
T2 = 50 % Shade

1 = Light green
9 = Dark green

Table 17. Arrangement of unfurled leaves in turf grass species under different shade levels

Sl. No.	Grass Species	Arrangement of unfurled leaves		
		T0	**T1**	**T2**
1	*Dichondra micrantha*	Rolled	Rolled	Rolled
2	*Paspalum notatum*	Folded	Folded	Folded
3	*Eragrostis curvula*	Rolled	Rolled	Rolled
4	*Cynodon dactylon* 419	Folded	Folded	Folded
5	*Cynodon dactylon*	Rolled	Rolled	Rolled
6	*Zoysia japonica*	Rolled	Rolled	Rolled
7	*Stenotaphrum secundatum*	Folded	Folded	Folded

T0 = 0 % Shade
T1 = 25 % Shade
T2 = 50 % Shade

4.2.4 Roots characters

Turfgrass species were compared with respect to the number and length of roots length and root shoot ratio under various (0%, 25%, 50%) shade levels. The data are furnished in (Table. 18).

4.2.4.1 Number of roots

Significantly highest number of roots was observed in *Cynodon dactylon* 419 (181.0) and *Eragrostis curvula* (178.0) at zero per cent shade and the data was on par. The number was siginificantly the lowest in *Stenotaphrum secundatum* (27.0) at 50 per cent shade level.

4.2.4.2 Length of roots

Eragrostis curvula at 0 per cent shade and *Stenotaphrum secundatum* (at 50 per cent shade) recorded maximum root length (34.1, and 34.0 cm, respectively) which were on par. The minimum length was in *Dichondra micrantha* (10.7 cm) at 50 per cent shade level.

4.2.4.3 Root shoot ratio

Root shoot ratio was the highest in *Stenotaphrum secundatum* at 50 per cent shade (0.52) and at 0 per cent shade level (0.44), which were on par. Minimum root shoot ratio was observed in *Eragrostis curvula* and *Zoysia japonica* under all levels of shade.


Dichondra micrantha


Zoysia japonica


Stenotaphrum secundatum

Plate 7. Roots and shoots of turf grass species grown under shade condition - I


Eragrostis curvula


Cynodon dactylon

Plate 7. Roots and shoots of turf grass species grown under shade condition -I I

Cynodon dactylon 419

Plate 7. Roots and shoots of turf grass species grown under shade condition - III

Table 18. Root characters of turf grass species as influenced by shade levels (after six month of establishment)

Sl. No.	Grass species	Levels of shade (%)	No of roots	Root length (cm)	Root shoot ratio
1	*Dichondra micrantha*	0	29.3^{gh}	14.6^{h}	0.1890^{de}
		25	35.0^{gh}	11.5^{ij}	0.0963^{efg}
		50	51.3^{efgh}	10.7^{j}	0.0927^{efg}
2	*Paspalum notatum*	0	115.7^{b}	27.7^{bc}	0.0563^{g}
		25	44.0^{fgh}	27.0^{c}	0.0843^{fg}
		50	73.3^{cde}	21.7^{def}	0.1730^{ef}
3	*Eragrostis curvula*	0	178.0^{a}	34.1^{a}	0.0653^{g}
		25	116.0^{b}	27.6^{bc}	0.0327^{g}
		50	63.7^{ef}	30.9^{ab}	0.0633^{g}
4	*Cynodon dactylon* 419	0	181.0^{a}	18.5^{fgh}	0.1880^{de}
		25	87.0^{cd}	16.8^{gh}	0.0927^{efg}
		50	137.0^{b}	15.2^{h}	0.0350^{g}
5	*Cynodon dactylon*	0	48.7^{fgh}	21.7^{def}	0.3210^{c}
		25	53.7^{efg}	18.0^{fgh}	0.2760^{cd}
		50	38.7^{gh}	18.3^{fgh}	0.4237^{b}
6	*Zoysia japonica*	0	65.7^{def}	20.4^{efg}	0.0797^{fg}
		25	38.3^{gh}	19.5^{efg}	0.0660^{g}
		50	31.3^{gh}	14.9^{hi}	0.0683^{g}
7	*Stenotaphrum secundatum*	0	89.3^{c}	24.3^{cd}	0.4390^{ab}
		25	50.7^{efgh}	22.7^{de}	0.3033^{c}
		50	27.0^{h}	34.0^{a}	0.5223^{a}

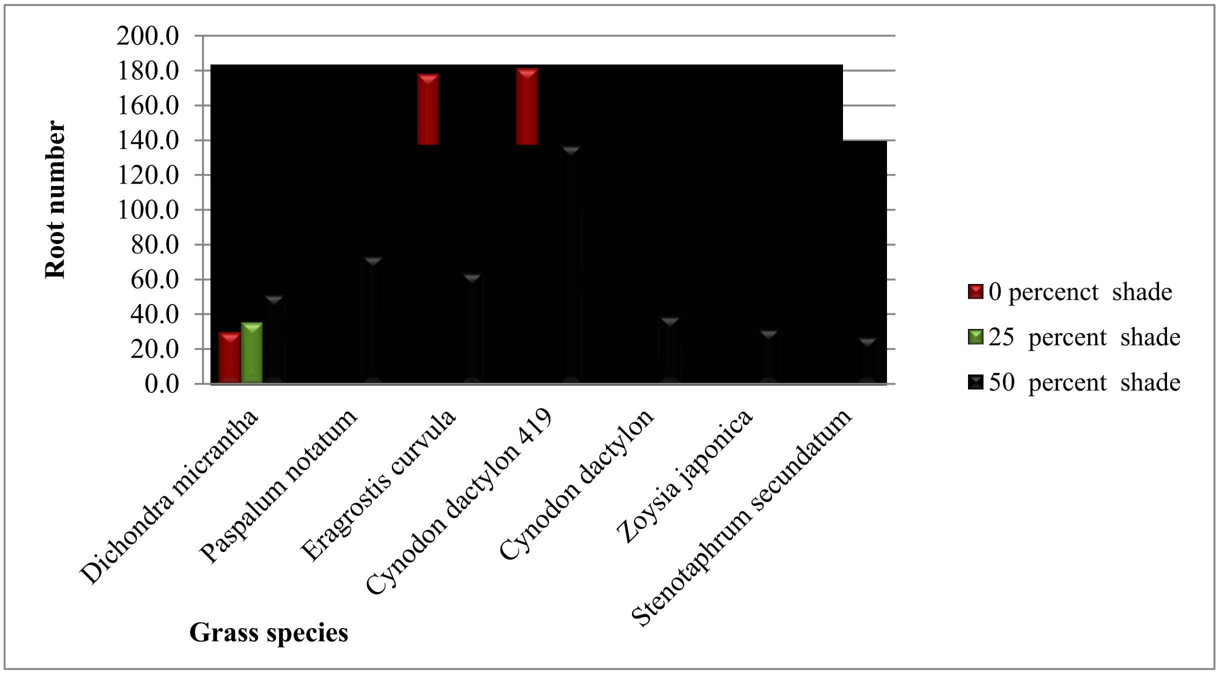


Fig. 15. Influence of various shade levels on number of roots in different turf grass species

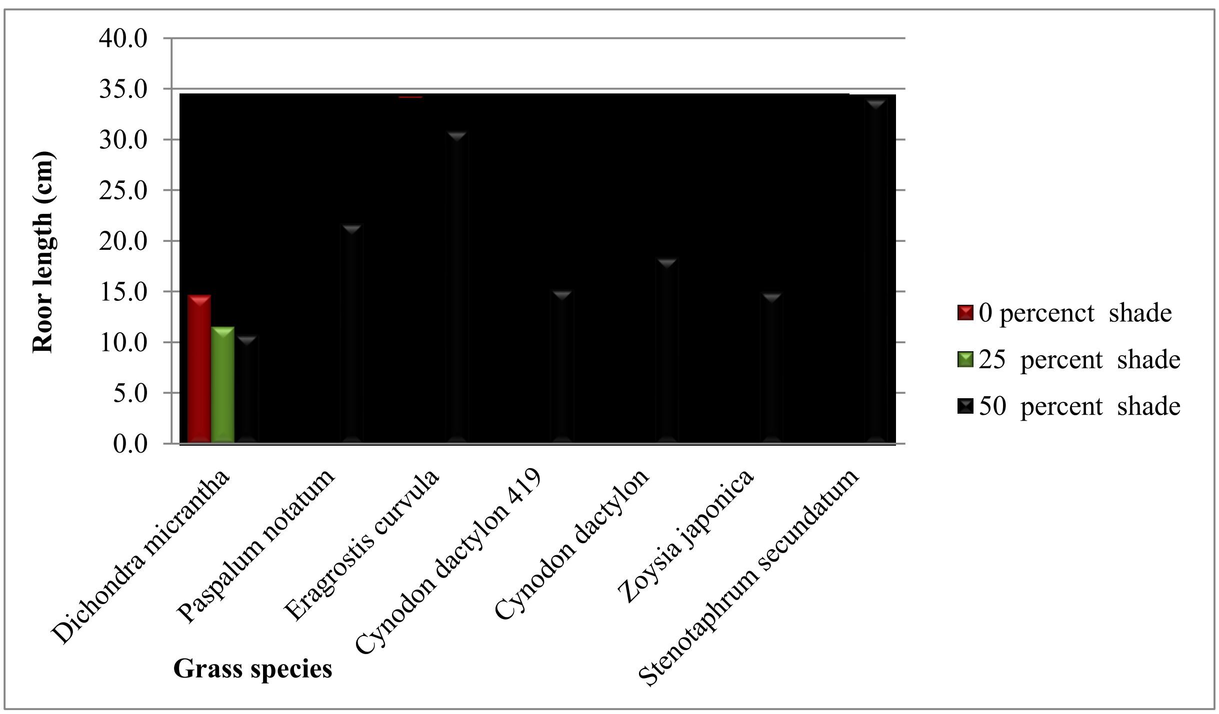


Fig. 16. Influence of various shade levels on root length in different turf grass Species

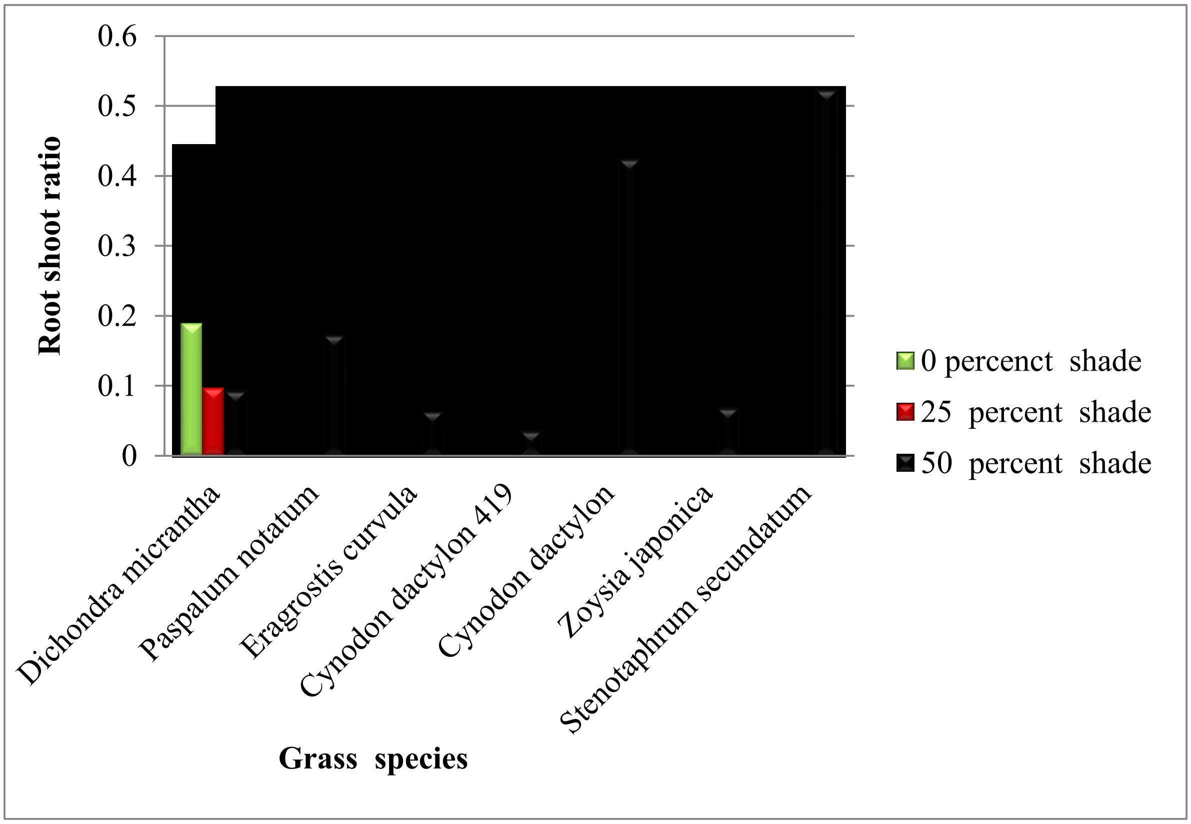


Fig. 17. Influence of various shade levels on root shoot ratio in different turf grass species

4.2.5 Mowing effectiveness of turf grass species under various shade conditioins

4.2.5 .1 Relative mowing height

Turf grass species under different shade levels were mowed equall to turf grass species in open field condition (Table. 19). The relative mowing height was high (5 cm) in coarse grasses (*Paspalum notatum, Eragrostis curvula* and *Stenotaphrum secundatum and* medium (3 cm) in *Dichondra micrantha, Cynodon dactylon.* It was close (2.5 cm) in *Cynodon dactylodon* 419 and *Zoysia japonica.*

4.2.5 .2 Recuperative ability

All the turf grass species differed significantly with respect to recuperative ability (Table. 20). *Dichondra micrantha* showed good density in 25 per cent shade and it was poor in 0 and 50 per cent shade levels. *Paspalum notatum* made an open turf under all shade levels where the density was poor and the species did not show any significant differences with density under various shade levels. *Eragrostis curvula* showed poor density under all shade condition, but it was comparatively low under more shade condition. *Cynodon dactylon* 419 *and Cynodon dactylon* showed good density under 0 per cent shade level and it was very low under 25 and 50 per cent shade condition. *Zoysia japonica* showed good density under 0 and 25 shades and it was comparatively low under 0 per cent shade. *Stenotaphrum secundatum* showed under 25 and 50 per cent shade and it was comparatively medium under 0 per cent shade level.

4.2.5 .3 Mowing frequency

Turf grass species differed significantly with respect to mowing frequency under various levels of shade (Table. 21).

. *Dichondra micrantha* plant showed maximum vigour under 50 per cent shade levels, but density was low and death ratio was high under 50 per cent shade level. *Paspalum notatum* showed maximum plant vigour under 0 % shade level, which was followed by 25 per cent shade level. *Paspalum notatum* was recommended for full sun and partial shade condition. The species also showed same result under 0 per cent and 25 per cent shade levels.

Eragrostis curvula showed maximum plant vigour compare to all other turf grass species under all (0%, 25%, 50%) shade levels. Maximum plant vigour was shown under 0 per cent shade, followed by 25 per cent shade level. Plant vigour was poor under 50 per cent shade level. *Eragrostis curvula* recommended for a partial shade and full sun condition. *Cynodon dactylon* 419 showed good plant height under 0 per cent shade level, but it was poor under 25 and 50 per cent shade levels. *Cynodon dactylon* had poor tolerance to shade condition. The same results (*Cynodon dactylon)* was seen in *Cynodon dactylon* 419 also.

Zoysia japonica had comparatively more vigour under 50 per cent shade and was recorded less both under 0 per cent and 25 per cent shade level. This is one of the common properties of *Zoysia japonica* that, it is having more plant height under partial shade condition compare sun condition. Density of the plant was poor and death ratio of was high under 50 per cent shade level.

Stenotaphrum secundatum showed comparatively more vigour under 50 per cent shade level. The species was highly tolerated to 25 per cent and 50 per cent shade levels. This was more suitable species for shade conditions compare to all other species.

4.2.5.4 Mowing tolerance/quality

Dichondra micrantha showed good uniformity and cleanness of cut after mowing under 25 % shade level and it was poor under 0 and 50 per cent shade level (Table. 22). The reason for its poor uniformity and cleanness of cut was poor density and more death ratio of plant under the mentioned condition.

Paspalum notatum and Eragrostis curvula showed poor mowing quality/tolerance under all (0%, 25%, 50%) shade conditions. *Paspalum notatum* is always making an open turf that was one of the reasons for the poor mowing quality and tolerance.

Eragrostis curvula was form only tillers and there was no habit of creeping like another turf grass species. More bare areas were seen in pot culture of *Eragrostis curvula,* because of its poor density. *Eragrostis curvula* had poor cleanness of cut and uniformity after mowing under all (0%, 25%, 50%) shade condition. the species was not recommended for as a turf grass for shade conditions. Mowing quality/ tolerance was high under 0 per cent and 25 per cent shade level, but it was poor under 50 per cent shade level, because of its poor density.

Stenotaphrum secundatum mowing tolerance/ quality was good under all shade condition. *Stenotaphrum secundatum* was highly tolerated to shade condition compare to all turf grass species in the study. Species showed good cleanness of cut and uniformity under 25 and 50 per cent shade level and it was medium under 0 per cent shade.

Table. 19 Relative mowing height of turf grass species under different shade levels

Sl. No.	Grass species	Relative mowing height (cm)		
		T0	T1	T2
1	*Dichondra micrantha*	3.0	3.0	3.0
2	*Paspalum notatum*	5.0	5.0	5.0
3	*Eragrostis curvula*	5.0	5.0	5.0
4	*Cynodon dactylon* 419	2.5	2.5	2.5
5	*Cynodon dactylon*	3.0	3.0	3.0
6	*Zoysia japonica*	2.5	2.5	2.5
7	*Stenotaphrum secundatum*	5.0	5.0	5.0

T0 = 0 % Shade
T1 = 25 % Shade
T2 = 50 % Shade

Table 20. Recuperative ability of turf grass species under different shade levels

Sl.No.	Grass species	Recuperative ability (1-9)		
		T0	**T1**	**T2**
1	*Dichondra micrantha*	1	3	2
2	*Paspalum notatum*	1	1	1
3	*Eragrostis curvula*	3	3	1
4	*Cynodon dactylon* 419	7	1	1
5	*Cynodon dactylon*	8	5	3
6	*Zoysia japonica*	9	8	6
7	*Stenotaphrum secundatum*	5	8	9

T0 = 0 % Shade
T1 = 25 % Shade
T2 = 50 % Shade

1= Poor density
9= High density

Table 21. Mowing frequency rating in different turf grass species based on 1 to 9 rating scale, under various shade levels

Sl.No.	Grass species	Mowing frequency		
		T0	**T1**	**T2**
1	*Dichondra micrantha*	1	2	3
2	*Paspalum notatum*	8	7	6
3	*Eragrostis curvula*	9	8	6
4	*Cynodon dactylon* 419	1	1	1
5	*Cynodon dactylon*	3	2	1
6	*Zoysia japonica*	3	2	1
7	*Stenotaphrum secundatum*	3	4	5

T0 = 0 % Shade
T1 = 25 % Shade
T2 = 50 % Shade

1= Minimum vigour
9= Maximum vigour

Table 22. Mowing quality/ tolerance rating in different turf grass species based on 1 to 9 rating scale, under various shade levels

Sl.No.	Grass species	Mowing tolerance/Mowing quality		
		T0	**T1**	**T2**
1	*Dichondra micrantha*	9	7	8
2	*Paspalum notatum*	8	8	9
3	*Eragrostis curvula*	8	8	9
4	*Cynodon dactylon* 419	1	9	9
5	*Cynodon dactylon*	1	7	9
6	*Zoysia japonica*	1	1	3
7	*Stenotaphrum secundatum*	3	3	3

T0 = 0 % Shade
T1 = 25 % Shade
T2 = 50 % Shade

1 = High mowing quality
9 = Poorest mowing quality

4.2.6 Evaluation of turf grass species under various shade levels at two months after mowing

4.2.6 .1 Plant characters at two months after mowing under different shade levels

Turf grass speceis were compared with respect to their plant height and shoot length, under different (0%, 25%, 50%) shade levels (Table. 23). Species showed significant differences for plant height and shoot length.

4.2.6 .1.1 Plant height

Eragrostis curvula showed significantly maximum plant height in all (0%, 25%, 50%) shade levels, which were statistically on par. This was followed by *Paspalum notatum* in different (0%, 25%, 50%) shade levels, which were also on par. The minimum plant height was in *Cynodon dactylon* in various (0%, 25%, 50%) shade levels. *Dichondra micrantha* and *Stenotaphrum secundatum* showed on par values for plant height in all (0%, 25%, 50%) shade condition.

4.2.6 .1.2 Shoot length

The maximum shoot length was in *cynodon dactylon* under all (0%, 25%, 50%) shade conditions, followed by *Eragrostis curvula* in various (0%, 25%, 50%) shade levels. The minimum shoot length was in *Zoysia japonica* in all shade condition, all the values being on par. *Paspalum notatum* and *stenotaphrum secundatum* showed on par values for shoot length in I all shade conditions.

4.2.7 Leaf characters

The quantitative characters of the leaves of turf grass species studied are given in Table 11. There were significant differences for leaf length and leaf width, under different shade levels.

Plate 8. General view of shade condition after mowing

4.2.7.1 Leaf length

Eragrostis curvula recorded significant maximum leaf length under all (0%, 25%, 50%). shade conditions, which were on par statistically. This was followed by *paspalum notatum*. The minimum leaf length was in *Dichondra micrantha* under all shade levels, which were on par.

4.2.7.2 Leaf width

Maximum leaf width was in *Dichondra micrantha* in 25 per cent (20 mm), 0 per cent (18.0 mm) and 50 per cent shade (17 mm). The minimum leaf width was in *Cynodon dactylon* 419 and *Zoysia Japonica* in various (0%, 25%, 50%) shade levels, all the values were statistically on par.

Table.23. Influence of shade levels on the plant characters of different turf grass species (two months after mowing)

Sl. No.	Grass species	Levels of shade (%)	Plant height (cm)	Shoot length(cm)	Leaf length (cm)	Leaf width (mm)
1	*Dichondra micrantha*	0	6.5[de]	5.7[cd]	1.4[e]	18.0[a]
		25	7.2[de]	5.3[cd]	1.4[e]	20.0[a]
		50	8.1[d]	6.4[cd]	1.6[e]	17.0[a]
2	*Paspalum notatum*	0	54.6[b]	5.4[d]	38.2[bc]	4.8[b]
		25	52.9[b]	5.3[d]	48.4[ab]	4.5[b]
		50	48.0[b]	5.2[d]	43.9[b]	3.9[c]
3	*Eragrostis curvula*	0	74.4[a]	14.6[b]	60.5[a]	2.6[d]
		25	74.0[a]	14.3[b]	57.7[a]	1.9[ef]
		50	71.9[a]	13.9[b]	54.7[a]	1.9[f]
4	*Cynodon dactylon* 419	0	5.0[e]	4.5[de]	1.5[c]	1.1[g]
		25	5.4[e]	4.3[de]	1.4[e]	1.0[g]
		50	5.6[e]	4.6[de]	1.5[e]	1.3[g]
5	*Cynodon dactylon*	0	26.4[c]	23.2[a]	5.1[d]	2.4[de]
		25	25.1[c]	22.4[a]	5.4[d]	2.3[def]
		50	21.9[c]	19.3[a]	6.1[d]	2.0[ef]
6	*Zoysia japonica*	0	8.5[d]	6.4[e]	4.8[d]	1.1[g]
		25	9.4[d]	7.1[e]	5.5[d]	1.1[g]
		50	10.2[d]	7.3[e]	5.5[d]	1.1[g]
7	*Stenotaphrum secundatum*	0	6.5[de]	5.8[d]	4.0[de]	4.9[b]
		25	7.9[de]	5.5[d]	4.9[d]	4.7[b]
		50	8.8[d]	5.9[d]	5.7[d]	4.5[b]

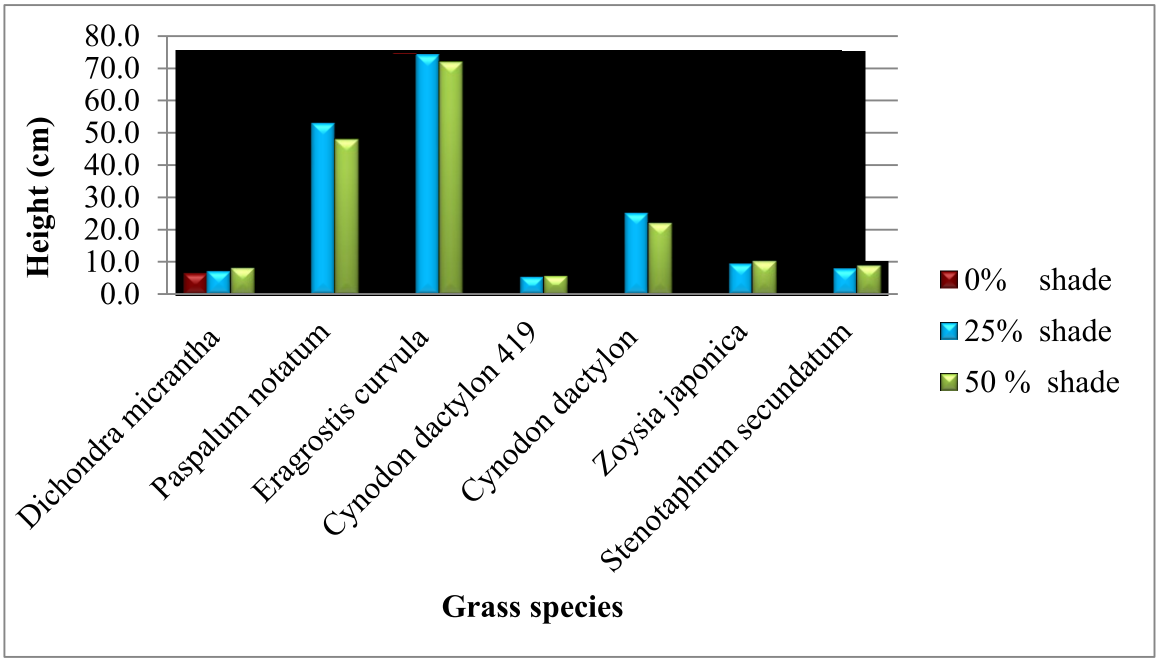


Fig. 18. Influence of various shade levels on plant height (cm) in different turf grass species after two months of establishment

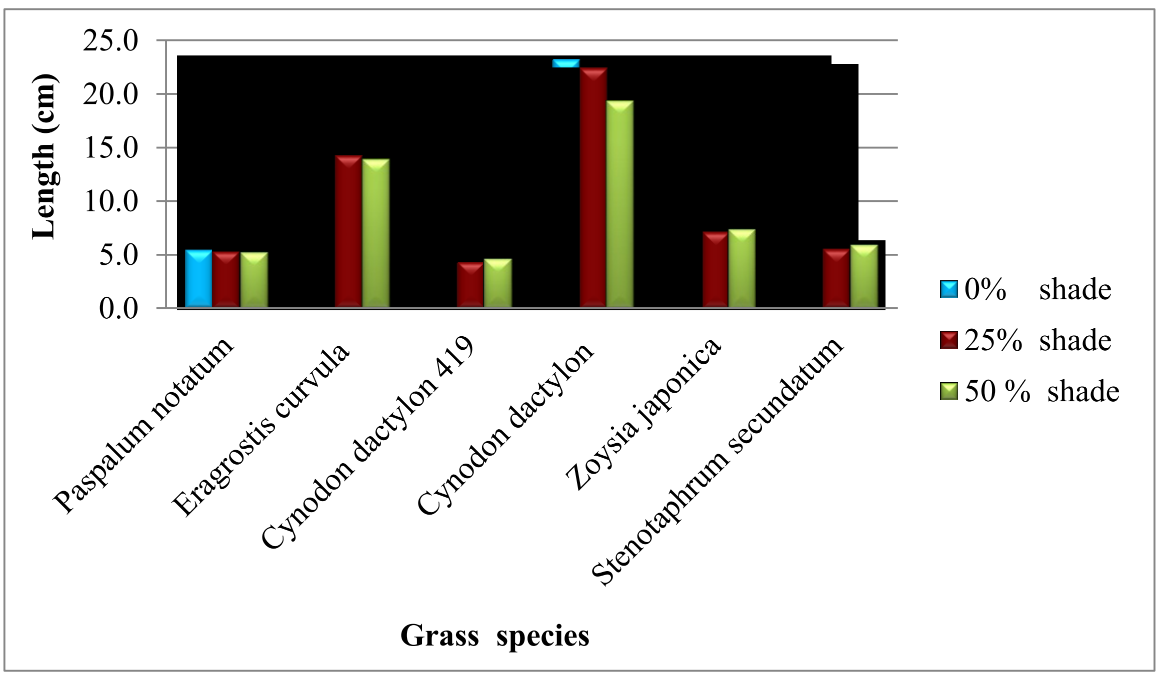


Fig. 19. Influence of various shade levels on shoot length (cm) in different turf grass species after two months of establishment

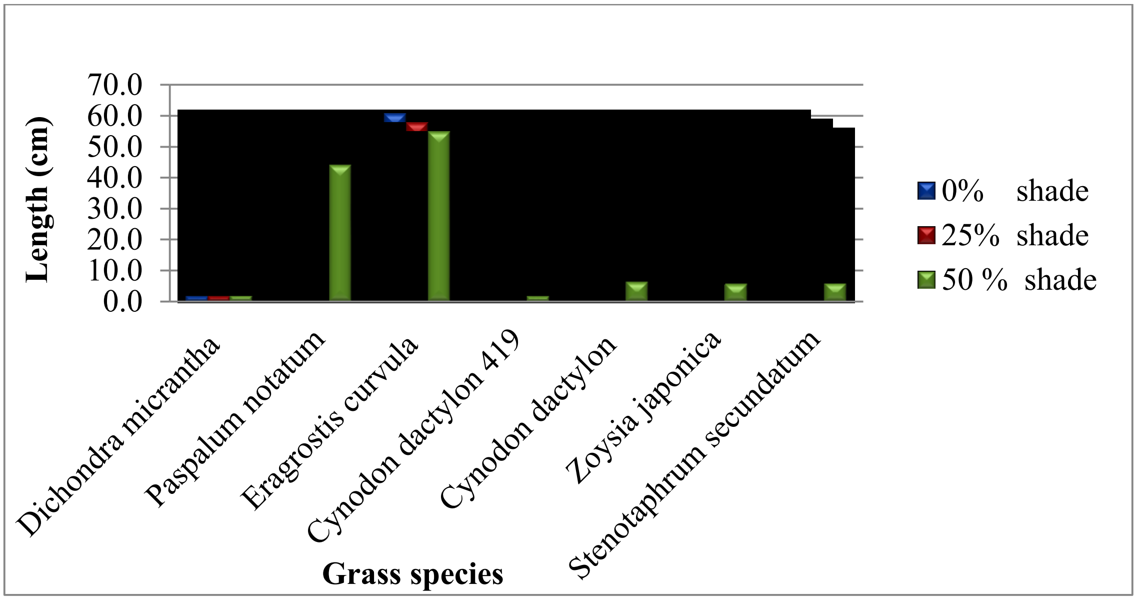


Fig. 20. Influence of various shade levels on leaf length (cm) in different turf grass species after two months of establishment

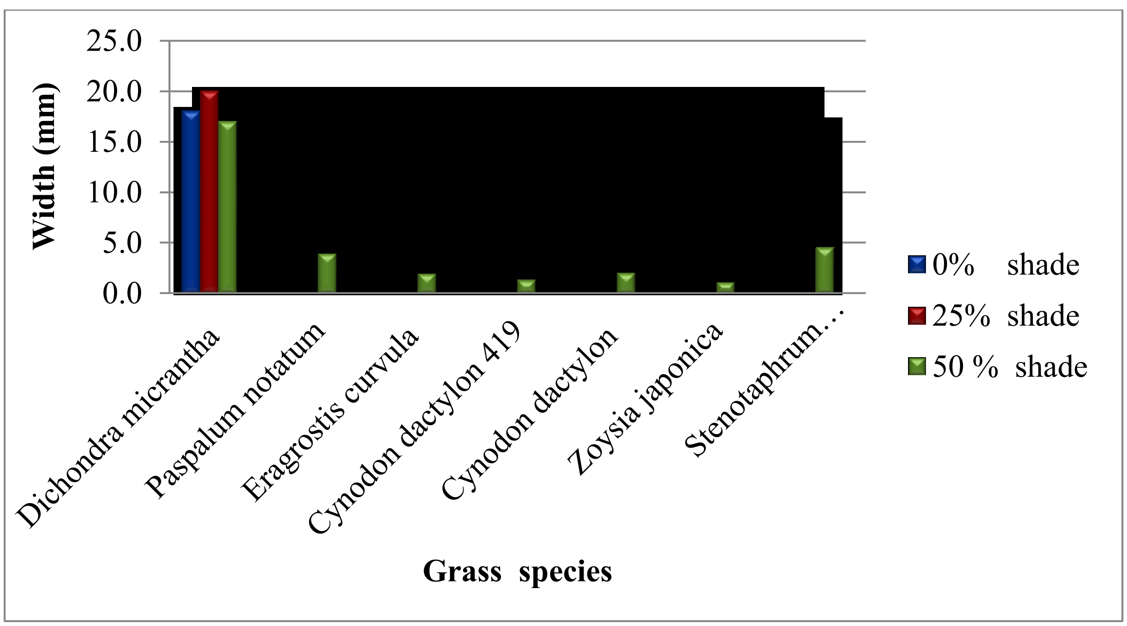


Fig. 21. Influence of various shade levels on leaf width (mm) in different turf grass species after two months of establishment

4.2.8 Air Pollution Tolerance Index (APTI) of turf grass species

All the turf grass species were compared for their air pollution tolerance index, under field condition and under various (0%, 25%, 50%) shade levels (Table. 24). The grass species showed significant differences with respect to ascorbic acid content, leaf extract pH, total chlorophyll content and relative water content.

4.2.8 .1 Ascorbic acid content (mg/g)

All the turf grass species showed significant difference with respect to their ascorbic acid content.

Ascorbic acid content was the maximum in *Dichondra micrantha* under open field condition (28.19) . It was the minimum in *Pasphalum notatum* (0.50) at 25 per cent shade level.

4.2.8.2 Total chlorophyll content (mg/g)

Cholorophyll content was the maximum in *Zoysia japonica* (0.51) and *Stenotaphrum secundatum* (0.51) at 50 per cent shade level. This was on par with the cholorophyll content at 25 per cent shade level. The minimum chlorophyll content was in *Paspalum notatum* (0.15) in open field condition, followed by *stenotaphrum secundatum* (0.19) under similar condition.

4.2.8.3 4.12.4 Relative water content

Dichondra micrantha recorded significantly maximum relative water content under 50 per cent shade, followed by *Stenotaphrum secundatum* (95.07) under 50 per cent shade and *Dichondra micrantha* (93.12) under 25 percent shade. The minimum relative water content was recorded in *Cynodon dactylon* (78.77) in 25 per cent shade, *Paspalum notatum* (78.68) in open field condition and *Eragrostis curvula* (79.28) under similar conditions, all the values being statistically on par. *Dichondra micrantha*

(81.56) and *Zoysia japonica* (82.24) under 0 per cent shade showed on par values for relative water content.

4.2.8.4 Leaf extract pH

Paspalum notatum (6.1) showed significantly maximum pH in 25 per cent shade, followed by *Cynodon dactylon* (5.8) under 25 per cent shade condition. The minimum pH was in *Stenotaphrum secundatum* (5.1) under open field condition followed by the same (5.2) under 50 per cent shade.

4.2.8.5 Air Pollution Tolerance Index (APTI)

The Air Pollution Tolerance Index was computed from the above parameters. The susceptibility level of plants to air pollution was assessed and the results are presented in Table 12.

All grass species differed significantly with respect to their Air Pollution Tolerance Index (APTI) values.

Dichondra micrantha (24.28) showed significant differences maximum Air Pollution Tolerance Index (APTI) in open field condition, followed by the values at 0, 25 and 50 percent shade levels of *Stenotaphrum secundatum* which were on par with that of *Dichondra micrantha* at 25 per cent shade level. Minimum air pollution tolerance index (APTI) was in *Cynodon dactylon* (8.35) followed by *Paspalum notatum* (8.62) in 25 per cent shade, *Cynodon dactylon* (8.63) in open field condition and *paspalum notatum* (8.62) in 0 per cent shade, which were on par statistically.

Table 24. APTI values in different turf grass species grown under different condition

Sl. No.	Grass species	Levels of shade (%)	Ascorbic acid (mg/g)	Chlorophyll (mg/g)	Relative water content (%)	pH	APTI
1	*Dichondra micrantha*	0	19.11^{b}	0.3187^{ghi}	88.61^{def}	5.4^{cdefgh}	19.81^{b}
		25	6.09^{d}	0.3370^{fgh}	93.88^{abc}	5.5^{bcdefg}	12.94^{d}
		50	10.13^{c}	0.4140^{bcde}	97.20^{a}	5.5^{bcdefg}	15.70^{c}
		Open field	28.19^{a}	0.2413^{klmn}	81.56^{ijkl}	5.5^{bcdefg}	24.28^{a}
2	*Paspalum notatum*	0	1.18^{ijk}	0.2290^{lmn}	80.71^{jkl}	5.6^{bcde}	8.75^{ij}
		25	0.50^{k}	0.2577^{jklm}	82.98^{hijk}	6.1^{a}	8.62^{ij}
		50	3.25^{efgh}	0.2880^{hijkl}	84.58^{fghij}	5.6^{bcde}	10.37^{ef}
		Open field	1.75^{ghijk}	0.1457^{o}	78.68^{kl}	5.6^{bcde}	8.88^{hij}
3	*Eragrostis curvula*	0	1.13^{ijk}	0.2543^{jklm}	84.18^{ghij}	$5.5^{bcdefgh}$	9.06^{fghij}
		25	0.83^{jk}	0.3687^{efg}	87.11^{efgh}	5.2^{fgh}	9.17^{fghij}
		50	3.70^{efg}	0.4213^{bcde}	90.49^{cde}	5.4^{cdefgh}	11.21^{e}
		Open field	2.93^{efghi}	0.2157^{mn}	79.28^{kl}	5.5^{bcdefg}	9.59^{fghij}
4	*Cynodon dactylon* 419	0	4.40^{e}	0.4303^{bcd}	71.60^{m}	5.3^{defgh}	9.70^{fghi}
		25	1.94^{fghijk}	0.3887^{def}	78.77^{kl}	5.7^{bcd}	9.05^{fghij}
		50	3.34^{efgh}	0.3803^{def}	82.98^{hijk}	5.5^{bcdef}	10.27^{efg}
		Open field	3.92^{ef}	0.4547^{abc}	65.82^{o}	5.6^{bcde}	8.95^{ghij}
5	*Cynodon dactylon*	0	3.62^{efg}	0.3113^{ghij}	70.37^{mn}	5.6^{bcde}	9.17^{fghij}
		25	1.60^{hijk}	0.2733^{ijklm}	73.83^{m}	5.8^{b}	8.35^{j}
		50	2.75^{efghij}	0.2617^{ijklm}	78.08^{l}	5.7^{bc}	9.44^{fghij}
		Open field	3.22^{efgh}	0.3197^{ghi}	66.95^{no}	5.7^{bc}	8.63^{ij}
6	*Zoysia japonica*	0	1.73^{ghijk}	0.4037^{cde}	82.24^{ijkl}	5.5^{bcdefg}	9.24^{fghij}
		25	1.03^{ijk}	0.4693^{ab}	85.28^{fghi}	5.6^{bcde}	9.15^{fghij}
		50	2.15^{fghijk}	0.5067^{a}	88.36^{defg}	5.5^{bcdef}	10.14^{efg}
		Open field	2.32^{fghijk}	0.2510^{klm}	77.93^{l}	$5.4^{bcdefgh}$	9.10^{fghij}
7	*Stenotaphrum secundatum*	0	1.77^{ghijk}	0.2967^{hijkl}	88.26^{defg}	5.4^{defgh}	9.82^{fghi}
		25	1.77^{ghijk}	0.4640^{ab}	92.12^{bcd}	5.3^{efgh}	10.24^{efg}
		50	6.51^{d}	0.5083^{a}	95.07^{ab}	5.2^{gh}	13.21^{d}
		Open field	2.32^{fghijk}	0.1927^{no}	82.66^{ijk}	5.1^{h}	9.50^{fghij}

Table 25. Classification of turf grass species based on air pollution tolerance index

APTI category	Turf grass species			
	0 % shade	**25 % shade**	**50 % shade**	**Open filed**
Sensitive (<14)	*Paspalum notatum* *Eragrostis curvula* *Cynodon dactylon* 419 *Cynodon dactylon* *Zoysia japonica* *Stenotaphrum secundatum*	*Dichondra micrantha* *Paspalum notatum* *Eragrostis curvula* *Cynodon dactylon* 419 *Cynodon dactylon* *Zoysia japonica* *Stenotaphrum secundatum*	*Paspalum notatum* *Eragrostis curvula* *Cynodon dactylon* 419 *Cynodon dactylon* *Zoysia japonica* *Stenotaphrum secundatum*	*Paspalum notatum* *Eragrostis curvula* *Cynodon dactylon* 419 *Cynodon dactylon* *Zoysia japonica* *Stenotaphrum secundatum*
Intermediate (15-19)	-	-	*Dichondra micrantha*	-
Moderately tolerant (20-24)	*Dichondra micrantha*	-	-	-
Tolerant (>24)	-	-	-	*Dichondra micrantha*

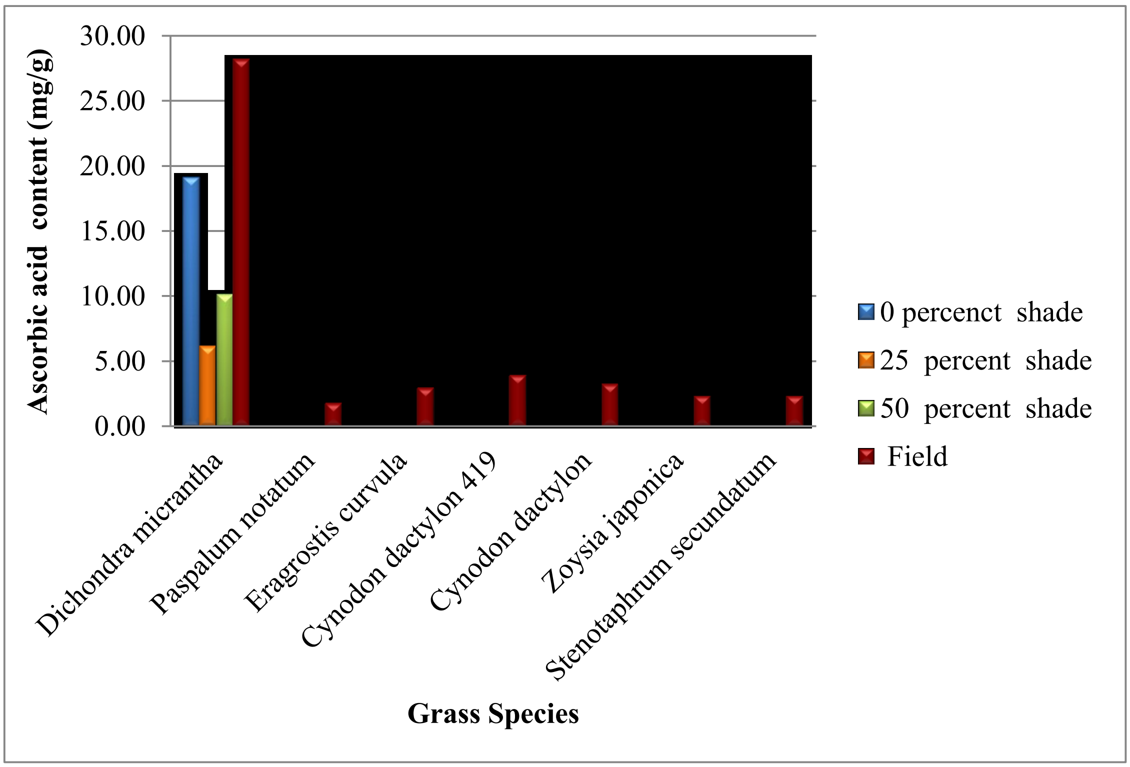


Fig. 22. Influence of various shade levels on ascorbic acid content in different turf grass species

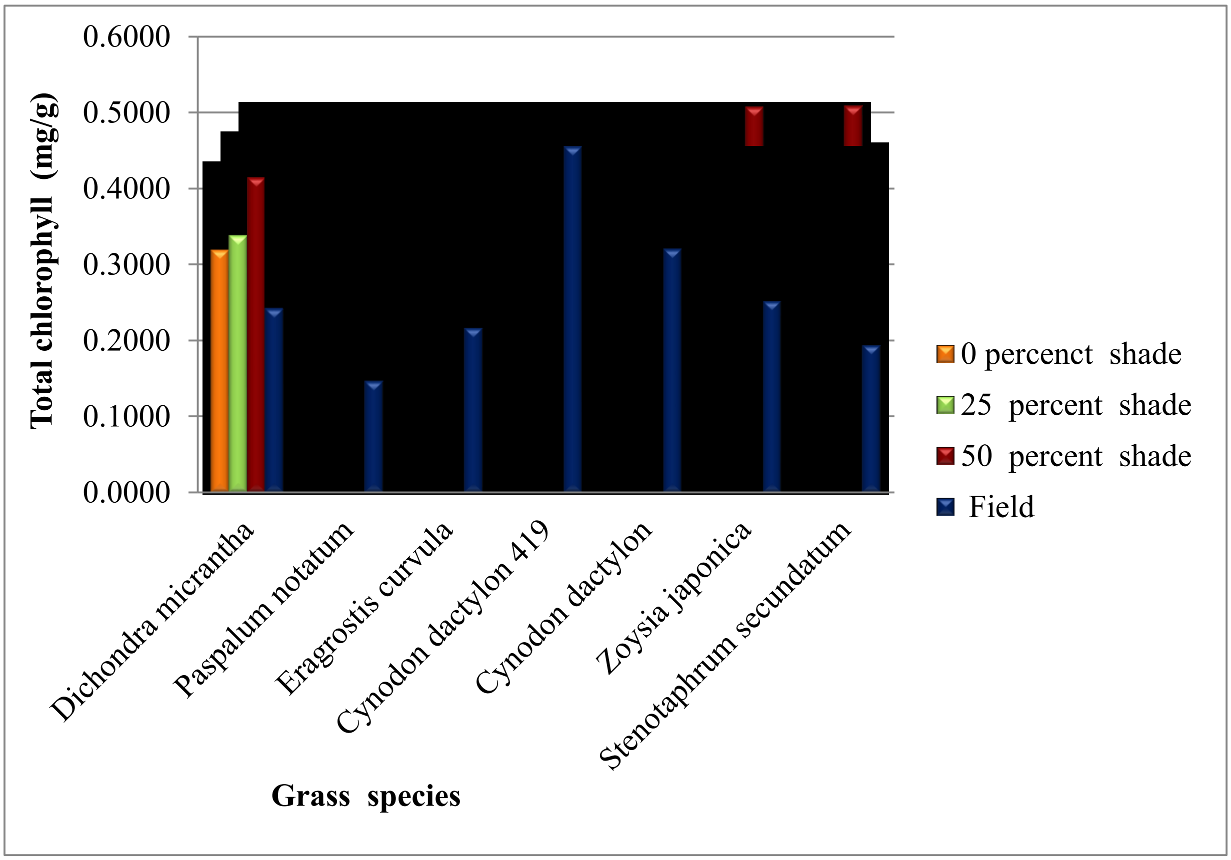


Fig. 23. Influence of various shade levels on total chlorophyll content in different turf grass species

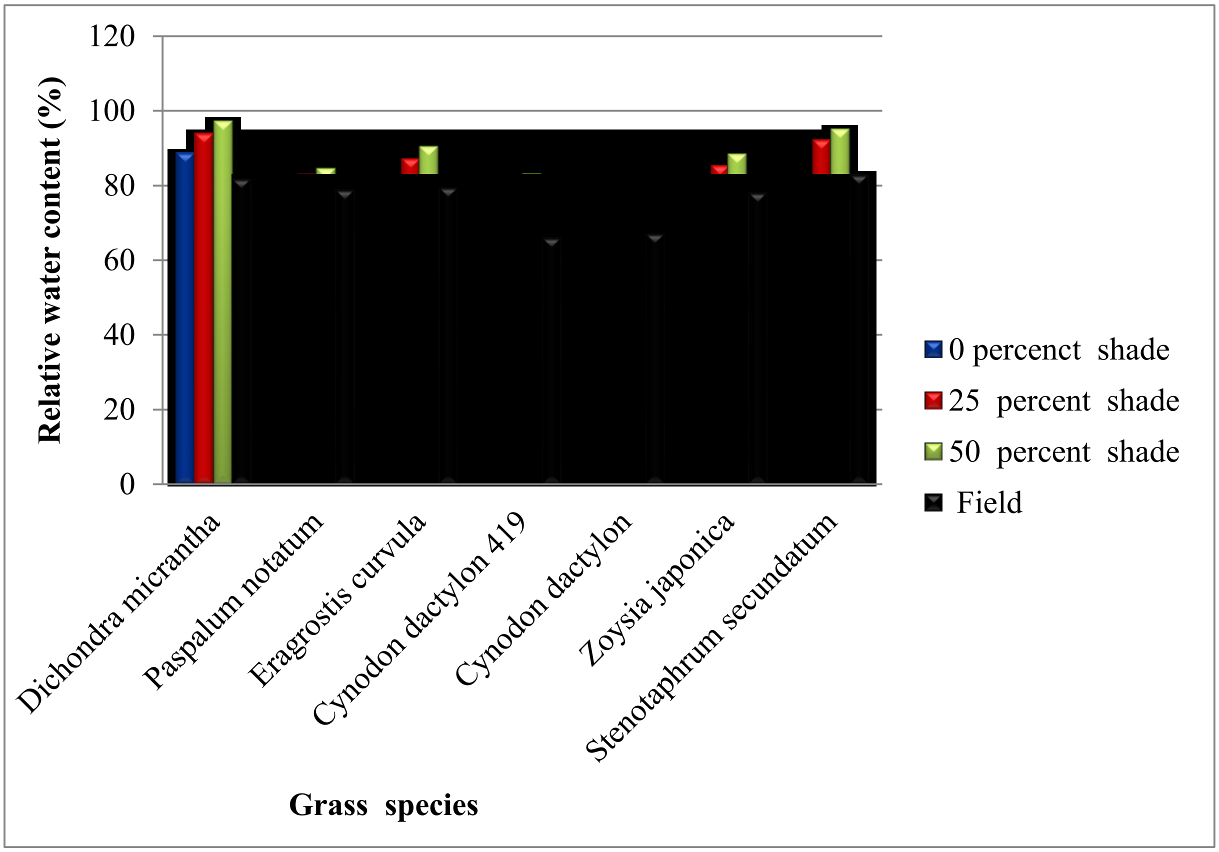


Fig. 24. Influence of various shade levels on relative water content in different turf grass species

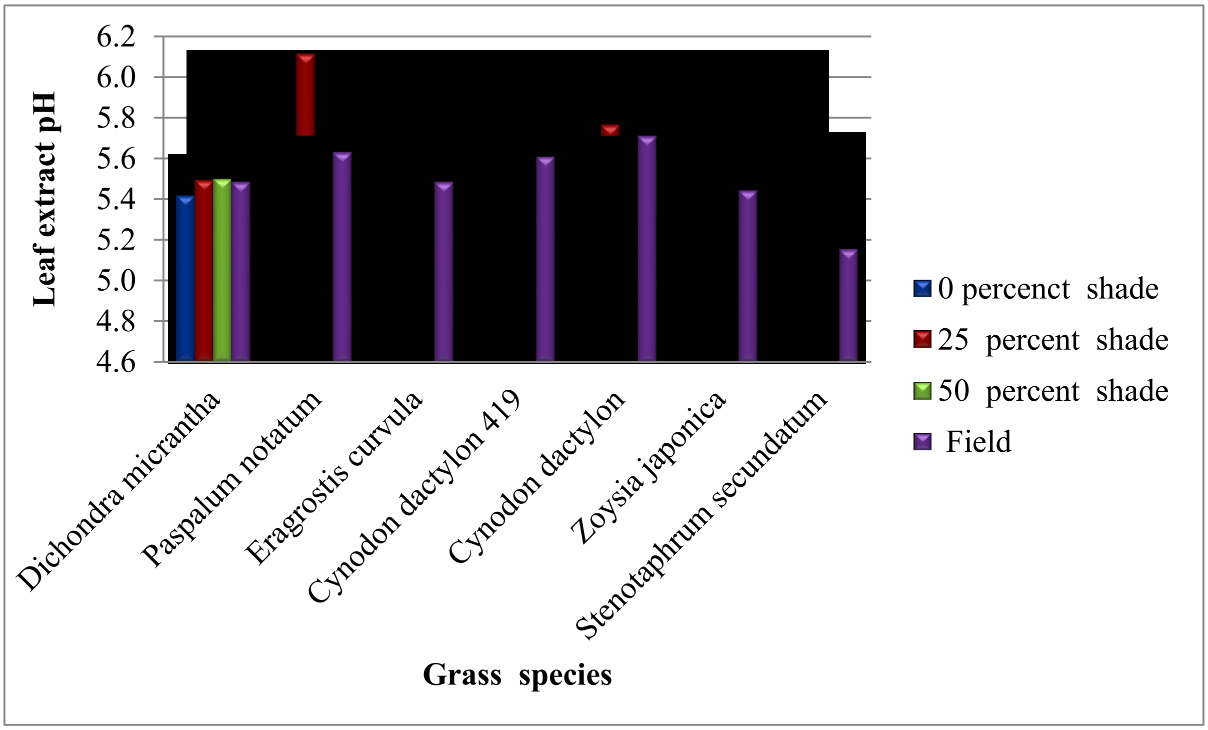


Fig. 25. Influence of various shade levels on leaf extract pH in different turf grass species

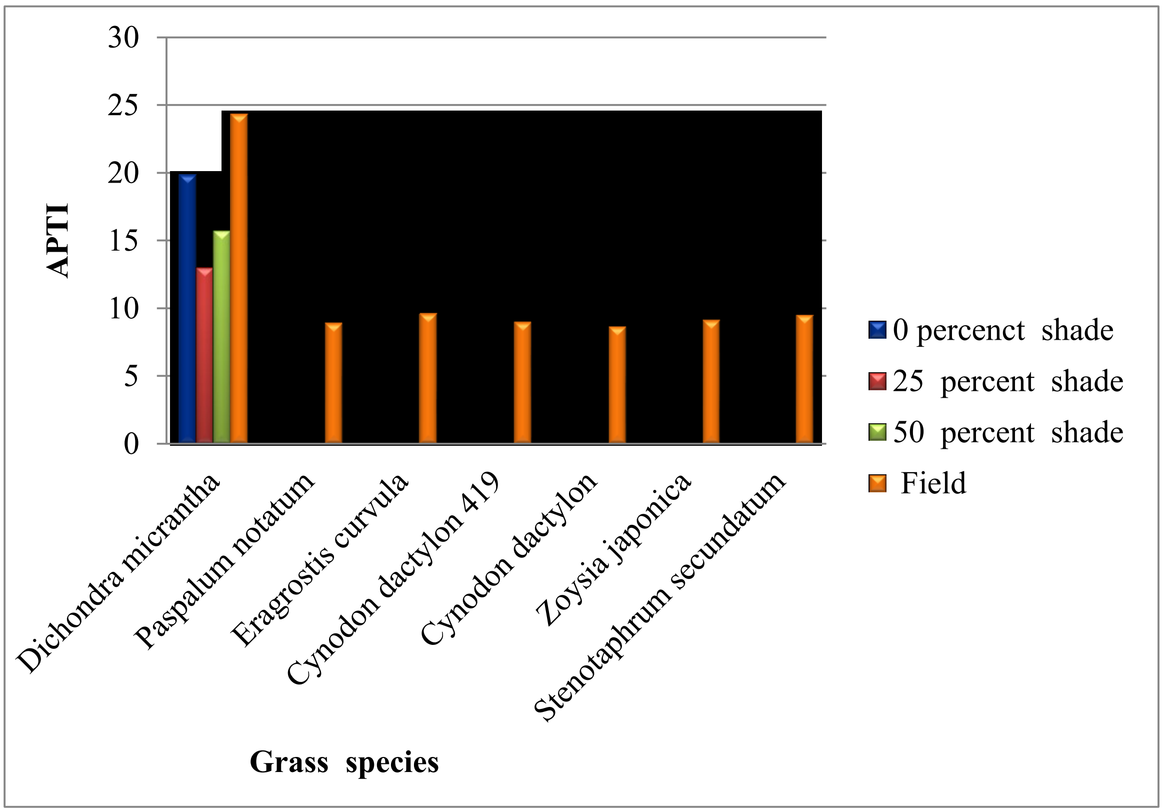


Fig. 26. Influence of various shade levels on APTI in different turf grass species

4.2.9 Incidece of pest and diseases

The pest and disease incidences in all the grass species during the period under study was recorded.

4.2.9.1 Pests

Turf grass species were observed for insect problems under various shade (0%, 25%, 50%) levels and in open field condition. Army worms, termites, fire ants and worker ants were found. Army worms were found in catter pillar stage uner all shade levels in *Paspalum notatum* and *Eragrostis curvula*. But they were not found in other turf grass species. Young army worms skeletonized the turf grass species by chewing the leaf blades. This was not a serious problem.

Termites were one of the most damaging pests in turf during the study.They demaged the turf by loosening the soil, constructing big mounds in the nesting area and eating their roots. Termite attack was the most serious problem in *Dichondra micrantha*, *Zoysia japonica* , *Cynodon dactylon* 419, *Eragrostis curvula*, *Paspalum notatum*. *Stenotaphrum secundatum* and *Cynodon dactylon* were not affected by termites.

Termites were found under 0 per cent shade level and in open field condtion, the problem being very serious during the study in open field condition, Under 25 per cent and 50 per cent shade levels, termites infestation was not observed.

Ants were also a problem during the study. They demaged specially the ornamental view of the lawn. Fire ants (*Solenopsis* sp), ants from worker group like little black ants (*Monomorium minimum*), caused minor demage to the turf, by loosing the soil and constructing small mounds in the nesting area.

Rats were another problem in turf area. They demaged the turf by loosening the soil, making holes, and bringing out soil to the turf, which affected the ornamental view of turf.

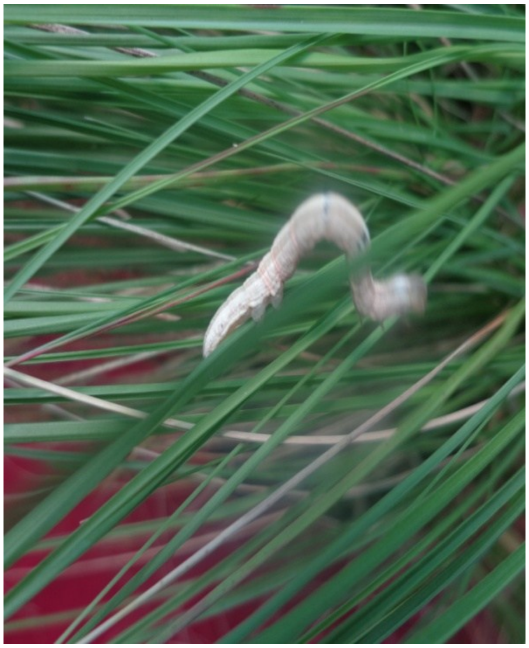


Plate 9. Incidence of pest in turf grass species under shade condition

4.2.9.2 Diseases

All the turf grass species were observed for diseases problems. No serious disease was observed except the gray leaf disease, found in the *Stenotaphrum secundatum*. This was more serious under 50 per cent and 25 per cent shade levels compared to 0 per cent and in open field condition. This disease was was observed under all shade conditions and also in open field condition.

Gray leaf spot disease is a fungal disease caused by *Pyriculari grisea*. Initial syptoms were brownish gray leaf spots with darker margins on the leaves. Numerous spots develop, resulting in the death of infected leaves. The disease was most severe on newly established grass. Most favourable condition for gray leaf spot was recorded as hot, humid and rainy season. Poor ventilation was also noticed favourable for the development of spots.

Plate 10. Incidence of disease in turf grass species under shade condition

4.2.10 Weeds

During the study, weed growth was much more in turf grass species. They affected the turf growth seriously, both under shade and in open field conditions.Weeds were controled by hands. The weed growth in general was more in open field condition compared to 0, 25, 50 per cent shade levels. A list of weeds observed in turf grass species during the study is given in Table 26.

Table.26. List of weeds associated with the turf grass species, both in shade and open field conditions

Sl. No	Scientific Name	Common Name	Family
1	*Adiantum spp*	Maidenhair Fern	Adiantaceae
2	*Ageratum conyzoides*	Goat weed, Billy goat weed, Tropical whiteweed	Asteraceae
3	*Alloteropsis cimicina* (L.)	Summer Grass, Bug-seed grass, Cockatoo grass	Poaceae
4	*Alysicarpus vaginalis*	Alyce clover, buffalo clover, one-leaf clover, and white moneywort	Fabaceae
5	*Boerhavia diffusa*	Hog weed, Horse Purslane, Snathikari (Hindi)	Nyctaginaceae
6	*Centrosem pubescens*	Butterfly peas	Fabaceae
7	*Cyanotis cristata*	Nabhali	Commelinaceae
8	*Cynodon dactylon*	Bermuda grass	Poaceae
9	*Cyperus iria*	Rice flatsedge ,Umbrella sedge	Cyperaceae
10	*Cyperus rotandus*	Nut Grass, purple nut sedge,Motha	Cyperaceae
11	*Desmodium triflorum*	Creeping tick trefoil, three-flower beggar weed, kuddalia	Fabaceae
12	*Digitaria bicornis*	Asian crabgrass	Poaceae
13	*Digitaria ciliaris*	Crabgrass, Tropical crab grass	Poaceae
14	*Eleusine indica*	Indian goosegrass, wiregrass, crowfootgrass	Poaceae
15	*Lindernia crustacea*	Malaysian false pimpernel	Linderniaceae
16	*Mimosa pudica*	Sensitive plant, sleepy plant	Fabaceae
17	*Mitracarpus verticillatus*		Rubiaceae
18	*Mollugo verticillata*	Carpet weed, Indian chickweed	Molluginaceae

19	*Oxalis Corniculata*	Creeping woodsorrel	Oxalidaceae
20	*Peperomia pellucida*	Shiny bush, Pepper elder, silver bush	Piperaceae
21	*Phyllanthus niruri*	Stone breaker, Gulf Leaf flower (Keezhar Nelli) in Malayalam	Phyllanthaceae
22	*Pilea microphylla*	Artillery Plant, Gunpowder Plant	Urticaceae
23	*Scoparia dulcis*	Sweet-broom	Scrophulariaceae
24	*Synedrella nodiflora*	Cinderella Weed, Nodeweed, Mudiyendra Pacha	Asteraceae
25	*Tridax procumbens* (L.)	Coat buttons	Asteraceae

Ageratum conyzoides

Centrosem pubescens

Lindernia crustacea

Cyanotis cristata

Pilea microphylla

Tridax procumbens

Plate 11. Weeds associated with turf grass species - I

Cyperus iria

Phyllanthus niruri

Cyperus rotandus

Synedrella nodiflora

Boerhavia diffusa

Alloteropsis cimicina

Plate 11. Weeds associated with turf grass species - II

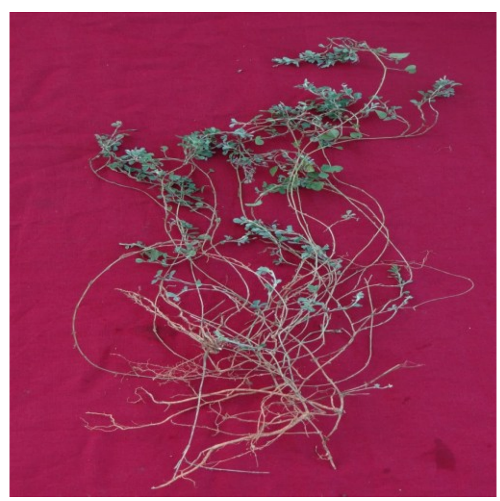
Digitaria ciliaris

Eleusine indica

Alysicarpus vaginalis

Scoparia dulcis

Cynodon dactylon



Desmodium triflorum

Plate 11. Weeds associated with turf grass species - III

Mimosa pudica

Mitracarpus villosus

Plate 11. Weeds associated with turf grass species - IV

Discussion

5. DISCUSSION

The results of the “Evaluation of turf grass species in the humid tropics” conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period 2011-2013 are discussed in this chapter.

The main objective of the study were to evaluate the performance of tropical turf grass species with respect to growth, establishment rate, tolerance to biotic and abiotic stresses and to evaluate the Air pollution tolerance index of turf grass species in order to introduce new grass species for the tropical lawns.

Ten turf grass species were grown under 0, 25 and 50 per cent shade levels (pot culture) and in open field condition. As the six turf grass species imported from the United State of America, three of them completely failed under humid tropical condition of Vellanikkara, Thrissur.

5.1 Evaluation of turf grass species under open field condition

5.1.1Time taken for the total coverage of the area

All the turf grass species differed significantly with respect to duration for total coverage of area. Present studies have shown the maximum time (days) for total coverage of area in *Paspalum notatum* (189) days. The main reason was that *Paspalum notatum* form relatively open turf and taking more time to cover the area. Christian (2004) reported the same reason.

The minimum time taken for total coverage of area was by *Eragrostis curvula* because of its fast establishment compare to all other turf grass species evaluated in the study.

5.1.2 Plant characters after six month of establishment

The study has shown significant differences in with respect to plant height and shoot length in different turf grass species.

5.1.2.1 Plant height

Present study has shown maximum plant height in *Eragrostis curvula* (108.7 cm) compared to all other species. Department of Agriculture, fisheries and forestry (DAFF) of Queensland in 2013 reported the same height for *Eragrostis curvula.*

Favorable environmental condition of the region was also one of the reasons for maximum plant height of *Eragrostis curvula.* Nohnston and Cregan (1979), Parsons and Curthbers (2001) had also reported the same height. Shoop and Mcllvain (1970) also reported the same maximum height in the description of *Eragrostis curvula.*

The minimum plant height was shown in *Dichondra micrantha* (4.6 cm). The reasons for low plant height was the unfavorable condition in open field. Favorable condition for the growth of *Dichondra micrantha* is under partial shade. Direct sun light limits growth in *Dichondra micrantha.*

Dichondra micrantha showed more plant height in 25 percent shade (13.7 cm) and 50 per cent shade (14.0 cm), when evaluated under various (0%, 25%, 50%) shade levels in the study.

5.1.2.2 Shoot length

In the present study, turf grass species showed significant differences with respect to shoot length. The result has shown that maximum shoot length was recorded in *Cynodon dactylon* (44.4 cm). All the remaining species were statistically on par for shoot length.

The reason for maximum shoot length in *Cynodon dactylon* (44.4 cm) was the best adaption of the species to the region viz, adaptation to the wide range of soil and tolerance to biotic and abiotic stresses, compared to other species.

Hansen *et al*. (2011) also reported the same reason for good growth of *Cynodon dactylon. Zoysia japonica* showed the minimum shoot length compared to all other grass species. The reason for the minimum shoot length in *Zoysia japonica* was the slow establishment rate of the species. *Zoysia japonica* need two or more years for complete establishment. Samples and Sorochan (2007) also reported the same reason

.

5.1.3 Leaf characters

All the turf grass species recorded significant differences with respect to leaf length, leaf width, leaf texture and leaf colour.

5.1.3.1 Leaf length

Present study has shown significant differences with respect to leaf length. The result indicates the maximum leaf length in *Eragrostis curvula* (71.6 cm). The result for the maximum leaf length was the favorable humid tropical condition of the region. Shoop and Mcllvain, 1970 also reported the same leaf length for *Eragrostis curvula.*

The minimum leaf length was found in *Dichondra micrantha (1.6 cm). Dichondra micrantha* is broad leaved species and it has a leaf length of 1.5 cm to 2 cm. *Dichondra micrantha* showed minimum leaf length in open field condition. So it is not recommended for open conditions. The species showed good leaf length under 25 per cent shade (1.75 cm) and 50 per cent shade (1.92 cm).

5.1.3.2 Leaf width

In the present study of turf grass species leaf width was observed, which varied from 20 mm to 1.6 mm. The maximum leaf width (20 mm) found in *Dichondra micrantha. Dichondra micrantha* is a broad leaved species having more leaf width in common, compared to all other turf grass species.

Cynodon dactylon 419 (1.6 mm) and *Zoysia japonica* (1.7 cm) recorded the minimum leaf length. *Zoysia japonica* and *Cynodon dactylon* are famous for their fine leaf textures and less leaf width is one of their common properties.

5.1.3.3 Leaf texture

Results have shown that all the turf grass species differed significantly with respect to their leaf texture in open field condition. Leaf texture of turf grass species were evaluated according to National Turf Evaluation Programme, USA visual rating scale (1-9). One was coarse, and 9 was very fine textured in different turf grass species evaluated in the study.

Cynodon dactylon 419 and *Zoysia Japonica* were recorded as fine, *Eragrostis curvula and Cynodon dactylon* as medium coarse and *Dichondra micrantha, Paspalum notatum* and S*tenotaphrum secundatum* were recorded as coarse textured turf grass species.

Beard (1973) reported the same leaf textures for *Cynodon dactylon, Cynodon dactylon, Paspalum notatum and* Stenotaphrum *secundatum*. Beard (1973) reported the same leaf texture for *Dichondra micrantha.* Emmons, 1995 also reported *Zoysia japonica* and *Cynodon dactylon*, *Cynodon dactylon* 419 as fine, *Stenotaphrum secundatum* and *Paspalum notatum* as coarse leaved turf grass species.

5.1.3.4 Leaf colour

Turf grass species were compared with respect to their leaf colour in open field condition. They were evaluated according to National Turf Evaluation Programme, USA visual rating scale (1-9). One was the light green, and 9 was the dark green colour in different turf grass species evaluated in the study.

The researches realized by Bunderson *et al.* (2009) have shown that the visual turf grass quality ratings proved effective in measuring a diverse set of criteria in turf grass plantings while the digitally based methods of evaluation were less useful by themselves. According to Bierman *et al.* (2004), maintaining dark green leaves is a key aspect of turf grass management. A rich green colour is aesthetically important, as well as an indicator of turf health and quality.

Variations in turf appearance or quality can occur frequently but can seldom be related to specific irrigation treatments (Younger *et al.*, 1981). The most common way of assessing turf grass quality is a visual rating system that is based on the turf grass evaluator's judgment (Morris, 2008).

Dichondra micrantha, Zoysia japonica and *Stenotaphrum secundatum* were categorized as dark green, *Paspalum notatum* and *Eragrostis curvula* as light green and *Cynodon dactylon* 419 and *Cynodon dactylon* as medium green turf grass species.
Beard (1973) and Emmons (1995) reported the same results for the leaf colour of the above turf grass species.

5.1.3.5 Arrangement of unfurled leaves

Results have shown that turf grass species had different arrangement of unfurled leaves. *Dichondra micrantha*, *Eragrostis curvula*, *Cynodon dactylon* and *Zoysia japonica* recorded rolled arrangement of unfurled leaves.

Paspalum notatum, *Cynodon dactylon* 419 and *Stenotaphrum secundatum* recorded folded arrangement of unfurled leaves. Christian (2004) and Emmons (1995) also reported the same arrangement of unfurled leaves for above turf grass species.

5.1.4 Root characters

5.1.4 .1 Number of roots

Present study has shown that turf grass species varied significantly with respect to their roots length. *Eragrostis curvula* recorded the maximum root length compared to all other turf grass species. The reason for maximum roots length of the *Eragrostis curvula* was the favorable climate condition of the region for it.

5.1.4 .2 Root length

Length of roots varied significantly in different turf grass species. The maximum root length recorded was in *Eragrostis curvula* (34.8). Dahl and cotter (1984) and Wan and Sosebee (2000) reported the same result for *Eragrostis curvula.*

Minimum root length was recorded in *Dichondra micrantha*. The reason of minimum root length in *Dichondra micrantha* was the shallow root system of the species in open field condition.

5.1.5 Root shoot ratio

The root shoot ratio is usually given as the ratio of the weight of the roots to the weight of the top of a plant (Harris, 1992). Measures such as the quantity of roots and shoots give additional information about the quality and vigor of a turf grass. Root shoot ratio in turf grass species is showing the quality of turf of grass species used for different purposes. In the present study all turf grass species were compared with respect to their root shoot ratio, in which they differed significantly.

Root shoot ratio varied from 0.2647 in *Cynodon dactylon* to 0.0097 in *Eragrostis curvula,* followed by *Dichondra micrantha* (0.1580). *Cynodon dactylon* is a drought tolerant turf grass species and it is forming more number of roots which grow deep into soil. This was one of the reasons for the more shoot ratio in the species. Increase in root shoot ratio of *Dichondra micrantha* was indication of less favorable condition. The reason for less root shoot ratio in *Eragrostis curvula* was the most favorable growing condition.

Harris (1992) also reported that reduction in the root shoot ratio is almost always in response to more favorable growing conditions. An increase in the root-shoot ratio, on the other hand, indicates that a plant is probably growing under less favourable conditions.

5.1.6 Weight of biomass removed at first mowing

Biomass production is an important decisive factor. In the present study weight of biomass varied from 3330.7(g) in *Eragrostis curvula* to 30.0 g in *Zoysia japonica. Eragrostis curvula* (3330.7 g) was followed by *Stenotaphrum secundatum* (2733.3 g) and *Paspalum notatum* (1815.0 g). *Eragrostis curvula* recorded maximum plant height, shoot and leaf length. The same result was the same in *Pasplaum notatum*, in which the growth was good. *Stenotaphrum secundatum* also showed more weight (2733.3 g) for biomass removed at first mowing, because of its dense shoot growth and wide leaf blade in the open field condition.

Beard (1973) reported that, turf grass biomass yield measures the growth rate of shoots, providing some indication of the potential ability to recover from injury and ability to resist weed invasion. Verdure production correlates with the shoot density components of turf grass quality.

5.1.7 Mowing effectiveness of turf grass species

5.1.7.1 Time taken for first mowing

New lawns need time for their roots to become established before they can be mowed for the first time. Among the turf grass species evaluated in open field condition, *Dichondra michrantha* showed maximum (174.7 days) time duration for first mowing and minimum by *Eragrostis curvula* (57.7 days*).*

Dichondra micrantha was not recommended for open field condition, but it was recommended for partial shade condition. *Dichondra micrantha* had very slow growth rate in open field condition and this was one of the reasons for taking long time for first mowing. Humid tropical condition is favourable for *Eragrostis curvula,* that is why the species had fast growth compared to all other grass species. *Eragrostis curvula* was not recommended as a turf grass for humid tropical condition for it was not having the properties of a turf grass.

5.1.7.2 Relative mowing height

How much to cut at each mowing depends upon the growth habit of the grass and the leaf texture, or width of the leaves. Grass survival depends on having adequate leaf surface for food production through photosynthesis. Mowing too low removes too much of the food producing area. As the grass literally starves, the lawn thins and looks poor. Mowing too high can hurt the appearance or usefulness of the turf (University of California, 2014). All the turf grass species were mowed on different height. Coarse turf grass species were mowed at 5 cm and fine turf grass species at 2.5 to 3cm.

The relative mowing height was high (5cm) in coarse grasses (*Paspalum notatum, Eragrostis curvula* and *Stenotaphrum secundatum and* medium (3cm) in *Dichondra micrantha and Cynodon dactylon.* It was close (2.5cm) in *Cynodon dactylodon* 419 and *Zoysia japonica.* Relative mowing height depends upon on the use of the species.

5.1.7.3 Recuperative ability

Recuperative ability was recorded as poor or high density of species after mowing. Density is one of the more important components of turf grass quality. Visual quality ratings are positively correlated with density. A high turf grass shoot density or plant population is desired because of the increased competition to invading weeds (Beard, 1973, Turgeon 1996).

According to visual rating scale (1-9) of National Turf grass Evaluation Programme, USA, which is a leader in evaluation of turf grass species. Grade 1 was the poorest or lowest density and 9 was the best or highest.

The turf grass species evaluation showed significant differences with respect to recuperative ability. *Dichondra micrantha*, *Paspalum notatum*, and *Eragrostis curvula* showed poor recuperative ability. *Cynodon dactylon* 419 and *Cynodon dactylon* showed high recuperative ability. *Zoysia japonica* and *Stenotaphrum secundatum* recorded as species having good recuperative ability.

Dichondra micrantha is not recommended for open field condition because of its slow establishment, and this was one of the reasons for poor density of *Dichondra micrantha* under open field condition. *Paspalum notatum* made open turf, which was one of its common properties. This was a big reason for poor density of *Pasplaum notatum.*

Eragrostis curvula is growing upright and making tillers, it is not having spreading habit like other turf grass species and that's why the density was poor in the species. *Eragrostis curvula* was not having turf grass properties and it was not recommended as turf grass species.

Cynodon dactylon and *Cynodon dactylon* 419 had thick sod formation and after cutting the plant species showed good uniformity and density in turf. *Zoysia japonica* had good recuperative ability but it was not high like *Cynodon dactylon* and *Cynodon dactylon* 419, because of its slow establishment. *Zoysia japonica* is famous for slow establishment and it is taking long time to cover the area. *Stenotaphrum secundatum* is a coarse leaved turf grass species and its shoot density was not good as other fine textured turf grass species but its density was good compared to *Dichondra micrantha*, *Pasplaum notatum and Eragrostis curvula.*

5.1.7.4 Mowing frequency

The frequency of mowing is based on the growth of the grass. As a general rule, mow as often as needed so that no more than one-third of the total leaf area is removed in a single mowing (Jones *et al*., 2009).

The primary purpose of mowing a lawn is to improve its appearance. Proper mowing technique, equipment, frequency and height will improve the quality of a lawn which also increases the health of the turf grass plants and decreases weed growth (Patton and Boyd, 2007).

Mowing frequency of turf grass species was evaluated based on plant vigor after mowing. According to NTEP visual rating scale (1-9), one was the minimum vigor and nine was the maximum vigour of plant. Results have shown that turf grass species differed significantly with respect to mowing frequency.

Dichondra micrantha, Cynodon dactylon 419, Stenotaphrum secundatum and Zoysia japonica were recorded as having less mowing frequency. *Paspalum notatum and Eragrostis curvula* were recorded as having more mowing frequency and *Cynodon dactylon* as medium.

Eragrostis curvula and *Paspalum notatum* had fast establishment compared to all other turf grass species. They showed maximum plant vigour. *Dichondra micrantha, Cynodon dactylon* 419, *Zoysia Japonica* and *Stenotaphrum secundatum* had minimum plant vigor, which is one of their common properties. *Cynodon dactylon* had medium plant vigor compared to all other turf grass species.

5.1.7.5 Mowing quality/ tolerance

Results have shown that all the turf grass species differed significantly with respect to mowing quality/tolerance. All species were evaluated based on uniformity and cleanness of cut after mowing.

Evaluation was done according to NTEP visual rating (1-9). One was the poorest mowing quality/tolerance and 9 was the high mowing quality.

Dichondra micrantha, Paspalum notatum, Eragrostis curvula were recorded as species having low mowing quality/tolerance. *Cynodon dactylon 419, Cynodon dactylon and Zoysia Japonica* had high and *Stenotaphrum secundatum* medium mowing quality/ tolerance.

The same was the reason in *Dichondra micrantha*, *Paspalum notatum, Eragrostis curvula as* they were not having good density and after mowing, uniformity and cleanness of cut was poor in them. The reason for their poor density mentioned under “recuperative ability" of turf grass species. *Cynodon dactylon* 419, *Cynodon dactylon* and *Zoysia japonica* were recorded as high mowing quality/tolerance turf grass species. The reason for their high mowing quality/ tolerance was their good density.

Only *Stenotaphrum secundatum* had medium uniformity and cleanness of cut compare to fine textured grasses (*Cynodon dactylon, Cynodon dactylon 419, Zoysia japonica)* because the density was medium in these species compared to fine textured grasses.

5.1.8 Plant character after two months of mowing, under open field condition

Present studies have shown that all the turf grass species in open field condition were significantly different with respect to plant characters after two months of mowing.

Plant height varied from 78.1 cm in *Eragrostis curvula* to 3.4 cm in *Dichondra micrantha* (3.4 cm). Shoot length was significantly maximum in *Cynodon dactylon* and minimum in *Zoysia japonica, which* was on par with all the remaining species.

The result indicated that leaf length was significantly maximum (61.3 cm) in *Eragrositis curvula* and was minimum (1.0 cm) in *Dichondra micrantha*.

In the present study, turf grass species were compared with respect to their Leaf width. With respect to leaf width, turf grass species differed significantly. Leaf width varied form (15mm) in *Dichondra micrantha* to 1.2mm in *Zoysia japonica which was on par with Cynodon dactylon* 419 (1.4 mm).

All the results for plant character at two months after mowing were same with results of, after six months of establishment. The results for their maximum and minimum plant characters were already described under “plant characters after six months of establishment”.

5.1.9 Evaluation of turf grass species under various shade levels, after six months of establishment (pot culture).

Shade is a common detrimental factor in landscapes with turf grasses. Home and school lawns, golf courses, cemeteries, parks and many other landscapes with turf grasses are either partially or fully shaded by trees or buildings.

Shade is one of the most common reasons for the deterioration of turf. Grass and trees are highly desirable in the landscape, and it is inevitable that both are grown together. Unfortunately, they are somewhat incompatible. It is often difficult to maintain turf under trees.

All turf grass species were also evaluated under various (0%, 25%, 50%) shade levels, to find out their tolerance to shade and biotic and abiotic stresses, in order to introduce new species/varieties for lawn under shade.

5.1.9.1 Plant characters

5.1.9.1.1Plant height

Present study have shown that all the turf grass species under different (0%, 25%, 50%) shade levels, shown significant differences with respect to plant height. Height varied from 102.2 cm in *Eragrostis curvula to* 7.0 cm in *Cynodon dactylon* 419 under 0 per cent shade level. *Eragrostis curvula* and *Cynodon dactylon* have shown statistically on par values for plant height under all shade levels (0%, 25%, 50%).

Two other turf grass species *Stenotaphrum secundatum* and *Zoysia japonica* did not record any significant variation in plant height under different (0%, 25%, 50%) shade levels.

5.1.9.1.2 Shoot length

In the present study, turf grass species were compared with respect to their shoot length. With respect to shoot length, turf grass species differed significantly.

Shoot length varied from 35.1 cm in *Cynodon dactylon* under 0 per cent shade level to 5.4 cm in *Paspalum notatum* under 50 per cent shade level, *Paspalum notatum, Cynodon dactylon* 419 and *Stenotaphrum secundatum* showed *statistically* on par values for shoot length under various (0%, 25%, 50%) shade levels.

5.1.10 Leaf characters

5.1.10.1 Leaf length

The result indicates that leaf length was significantly varied from 66.04 cm in *Eragrositis curvula* under 0 per cent shade levels, to 1.75 cm in *Dichondra micrantha* under 0 per cent shade level. *Eragrostis curvula* average leaf length is always long compare to all other turf grass species. This was one of the reason for its maximum leaf length. The reason for its maximum leaf length under 0 per cent shade was its good adaptation. *Eragrostis curvula* always showed good growth under direct sunlight. *Eragrostis curvula* was not recommended as turf grass species, in which one of the reason was its leaf length.

The reason for minimum leaf length in *Dichondra micrantha* under all shade condition was its leaf texture. *Dichondra micrantha* is a broad leaved ground cover, which is commonly having less leaf length. Christian (2004) also reported the same leaf texture for *Dichondra micrantha*. The reason for its less leaf length under 0 per cent shade level was its poor tolerance to direct sun light.

Dichondra micrantha, Zoysia japonica, and *Stentaphrum secundatum* showed statistically on par values for leaf length under all (0%, 25%, 50%) shade levels, which shows good tolerance of the species under the mentioned shade levels. Barrios et al. (1986) and Beard (1973) classified the *Zoysia japonica* as a shade tolerant turf grass species. Christian (2004) reported partial shade tolerance for *Dichohndra micrantha.* According to Brosnan and Deputy (2008), St. *Augustine* grass having better shade tolerance than most other warm season turf grasses. *Cynodon dactylon* and *Cynodon dactylon* 419 also showed statistically on par values with respect to leaf length under different (0%, 25%, 50%) shade levels.

5.1.10.2 Leaf width

Results have shown that all the turf grass species differed significantly with respect to leaf width. Leaf width varied from 25 mm in *Dichodra micrantha* under 50 per cent shade level to 1.22 mm in *Zoysia japonica* under 50 per cent shade level. The reason for *Dichondra micrantha* maximum leaf length was its texture. *Dichondra micrantha* is warm season, perennial, broad leaf species (Christian, 2004).

Zoysia japonica and *Cynodon dactylon* 419 showed statistically on par values for leaf width, under all (0%, 25%, 50%) shades levels. *Stenotaphrum secundatum* and *Paspalum notatum* also showed statistically on par values for leaf width under various (0%, 25%, 50%) shade levels. *Zoysia japonica, Stenotaphrum secundatum* and *Paspalum notatum* had good shade tolerance, and their leaf width was not affected by different shade levels. The shade adaptation of *St. Augustine* grass is excellent in warm climates, while the *zoysia* species show good adaptation. *Zoysia* grass has good shade and drought tolerance and shade tolerance was fair in bahia grass (Emmons, 1995). St. Augustine grass has the best tolerance of any of the warm season grass species and also grows well I full sun light (Trenholm, 2012).

5.1.10.3 Leaf texture

All turf grass species were evaluated under various (0%, 25%, 50%) shade levels. Results shown that all the turf grass species differed significantly with respect to leaf texture with each other. Results shown that different (0%, 25%, 50%) shade levels were not having any effect on the leaf texture. Each species showed same texture under all shade levels.

5.1.10.4 Leaf colour

Results have shown that turf grass species differed significantly with respect to leaf colour under various shade levels. With increasing shade level, leaf color increased in *Dichondra micrantha*, *Paspalum notatum, Eragrostis curvula*, *Cynodon dactylon,* *Cynodon dactylon 419* and *Stenotaphrum secundatum*. Changing of colour under different shade levels in all turf grass species showed the influence of shade. Trenholm (2013) reported the same reason for changing of colour in turf grass species. *Boradman,* (1977) also summarized the response of plants under shade that are commonly found in turf grasses as higher chlorophyll content. Only in *Zoysia japonica* leaf colour was decreased with increasing level of shade (Christian, 2004).

5.1.10.5 Arrangement of unfurled leaves

Results have shown, that arrangement of unfurled leaves was not affected by different shade levels. All turf grass species showed same results for unfurled leaves, studied under open field condition.

5.1.11 Root characters

5.1.11.1 Number of roots

Results have shown that number of roots was significantly high in *Cynodon dactylon 419* (181.0) and *Eragrostis curvula (*178.0) under 0 per cent shade and the data was on par. The number was significantly the lowest in *Stenotaphrum secundatum* (27.0) at 50 per cent shade level. Extensive growth system of *Eragrostis curvula and Cynodon dactylon* 419 was one of the reason for its maximum number of roots under 0 per cent shade. Compare to all other turf grass species weeping love grass is a vigorous-growing perennial with an extensive root system (Shoop and McIlvain, 1970).

Both of the species have good performance under direct sun light. The reason for *Stenotaphrum secundatum* for having lowest number of roots was low light stress. In the low light stress, turf grass has various morphological changes, such as decline in root numbers, shorter rhizome, tilling decline, higher and thinner stem, longer internodal length, lighter color and thinner leaf, flatter leaf angles and slower growth (Beard, 1997; Bell and Danneberger, 1999).

5.1.11.2 Length of roots

Results showed that all the turf grass species differed significantly with respect to length of roots. *Eragrostis curvula* at zero per cent shade and *Stenotaphrum secundatum* at 50 per cent shade recorded maximum root length (34.1, and 34.0 cm, respectively) which were on par. The minimum length was in *Dichondra micrantha* (10.7 cm) at 50 per cent shade level. Love grass is having long roots compared to other turf grass species in the study. Love grass commonly has roots growing upto 10 to 15 feet. Horizontal roots can reach out at least 3 feet and fill all of the soil surface between plants. This makes love grass very effective in using light rain showers and in preventing other plants from establishing (Scott and Rabie, 1956). *Stenotaphrum secundatum* having maximum root length under 50 per cent shade was due to its good adaptation to shade. St. Augustine grass has excellent shade tolerance and can produce a relatively high quality turf (Christian and Engelke, 2004). *Dichondra micrantha* had shallow root system and that may be one of the reasons for its minimum root length. Compared to other turf grass species *Dichondra micratha* has shallow root system (Harrington *et al*., 1999).

5.1.12 Root shoot ratio

A high root shoot ratio (ratio of the root weight to shoot weight) is preferred for a well managed turf grass. In general environmental condition such as temperatures above the optimum for root growth and development. Close mowing, excessive nitrogen and irrigation and low light intensities favour top growth of cool and warm season grasses and therefore the root shoot ratio will be low.

In the present study, turf grass species were compared with respect to their root shoot ratio. With respect to root shoot ratio, all turf grass species differed significantly.

Root shoot ratio was the highest in *Stenotaphrum secundatum* at 50 per cent shade (0.52) and at zero per cent shade level (0.44), which was on par. *Stenotaphrum secundatum* had good shade tolerance and was able to grow both under different shade levels and open field condition, This may be one of the reasons for its good root shoot ratio. St. Augustine grass has the best tolerance for shade of any of the warm-season grass species and also grows well in full sunlight (Trenholm, 2012). Minimum root shoot ratio was observed in *Eragrostis curvula* and *Zoysia japonica* under all levels of shade. *Eragrostis curvula* had maximum growth under all shade conditions compared to other turf grass species. This species had maximum plant height and leaf length, which is not remaining to a turf grass and that was one of the reasons for its poor root shoot ratio. Compared to all other turf grass species weeping love grass is a vigorous growing perennial grass species (Shoop and McIlvain, 1970).

5.1.13 Mowing effectiveness of turf grass species

5.1.13.1 Relative mowing height

All the turf grass species were mowed on different height. The mowing height was equal to the turf grass species mowed in open field condition. Coarse turf grass species were mowed on 5 cm and fine turf grass species at 2.5 to 3cm.

The relative mowing height was high (5cm) in coarse grasses (*Paspalum notatum, Eragrostis curvula* and *Stenotaphrum secundatum and* medium (3cm) in *Dichondra micrantha and Cynodon dactylon.* It was close (2.5cm) in *Cynodon dactylodon* 419 and *Zoysia japonica.* Beard (1973) also reported the same mowing height for the above turf grass species.

5.1.13.2 Recuperative ability

In the present study all turf grass species were compared with respect to recuperative ability, under different shade levels. Results indicate that all the turf grass species differed significantly. The reason for having good recuperative ability in *Dichondra micrantha* under 25 per cent shade level was its good tolerance to partial shade condition. *Dichondra micratha* is not recommended for full sun light condition. Under 50 per cent shade level the plant death ratio was very high especially in rainy season, which affected the density of turf and showed poor recuperative ability under 50 per cent shade level.

It is one of the common properties of *Paspalum notatum,* that it is always making open turf. This was one of the main reasons for its poor density. The species was evaluated under different shade levels and result showed that the species had poor recuperative ability under all shade condition. *St. Augustine* grass had strong, thick stolons and produces a turf of medium density (Emmons, 1995).

Eragrostis curvula is always growing upright and it is not having spreading habit like another turf grass species, So density was always poor under all (0%, 25%, 50%) shade levels. This was the main reason for which the species did not recommend as turf grass species.

Cynodon dactylon and *Cynodon dactylon* 419 showed poor shade tolerance which was the reason for its poor recuperative ability. The species had good recuperative ability only under 0 per cent shade. Barrios et al. (1986) and Beard (1973) classified berumda grass as one of the poor shade tolerant turf grass species.

Zoysia japonica had good recuperative ability under zero and 25 per cent shade levels, which showed good tolerance of the species to the above shade levels. *Zoysia japonica* is a slow growing, sod-forming species forms a dense, uniform turf under full sun condition (Samples and Sorochan, 2000). Only its density was medium under 50 per cent shade level. Under more shade condition the species become very thin which may be one of the reason for its poor recuperative ability. *Zoysia japonica* has good shade tolerance, although it may become thin badly in shade (Christian, 2004). The species was recommended for all shade condition, but for quality turf the species was recommended for zero and 25 per cent shade levels.

The reason for *Stenotaphrum secundatum having* good recuperative ability was its excellent shade tolerance. (Christian, 2004).

5.1.13.3 Mowing frequency

Results shown that all the turf grass species differed significantly with respect to mowing frequency under different shade levels.

Because of the partial shade tolerance, of *Dichondra micrantha* the species showed good mowing frequency under 25 per cent shade level. Emmons (1995) also reported the same. Under 50 per cent shade level its mowing frequency was medium which may be due to wet and compacted soil. *Dichondra micrantha* does not grow well on wet, compacted soils (Emmons, 1995). *Dichondra micrnatha* had very poor mowing frequency under zero per cent shade level. The species was not recommended for direct sun light under Vellanikkara climate condition.

Paspalum notatum had second maximum growth under all shade condition. Species with good vigor shows tolerance to shade. But compared to 25 and 50 per cent shade levels, its vigor was medium under zero per cent shade level. Barrios et al. (1986) and Beard (1973) classified *Paspalum notatum* as one of the fair shade tolerant turf grass species.

Eragrostis curvula had maximum plant vigor compared to all other turf grass species in the study under different levels of shade. Plant vigour was maximum under zero per cent shade followed by 25 per cent shade. Compare to other shade levels its vigour was less under 50 per cent shade. The main reason for maximum mowing frequency was its good vigour. Weeping love grass is a large bunchgrass that is generally a long-lived perennial. Weeping love grass may reach 75 inches (190 cm) tall, and the basal crown diameter of isolated plants may reach 15 inches (Gucker, 2009).

Cynodon dactylon showed good mowing frequency under zero per cent shade level, but *Cynodon dactylon 419* had poor mowing tolerance under all shade condition, showing their poor tolerance to shade. Bermuda grass had poor shade tolerance (Christian and Engelke, 1994).

In *Zoysia japonica* mowing frequency was less under all shade condition but compared to different shade condition it was more in 50 per cent shade, which may be due to the influence of shade level. The rhizomes and stolons of shaded turf grasses tend to grow upright (Gray, 1967). *Zoysia japonica* had maximum plant height and maximum leaf length under 50 per cent shade condition.

Stenotaphrum secundatum had good plant vigour under all shade condition showing the excellent shade tolerance of the species. Mowing frequency of this species was good under all shade condition, being comparatively high under 50 per cent shade. St. Augustine grass is a fast growing turf grass species that requires frequent mowing during the growing period (Patton and Boyd, 2013).

5.1.13.4 Mowing quality/Mowing tolerance

Mowing is a defoliation process in which a portion of turf grass leaf is removed. Mowing is the most fundamental and universal practice utilized in turf grass culture. It provides a uniform surface for ornamental beautification and for many outdoor sport and recreational activities. Several variables in the mowing programme influence turf grass quality. These include the height, frequency, and pattern of mowing. Each type of turf grass has a mowing tolerance range that is expressed as the lowest and highest mowing heights. In addition, turf grass quality and cultural requirements can be affected by the removal or return of clippings during mowing.

Evaluation was done based on their uniformity and cleanness of cut after mowing. Results have shown that all the turf grass species, differed significantly under various (0%, 25%, 50%) shade levels.

Dichondra micrantha showed good uniformity and cleanness of cut after mowing under 25 % shade level and it was poor under zero and 50 per cent shade levels. The reason for its poor uniformity and cleanness of cut was poor density and more death ratio of plants under the mentioned condition. The reason for its good mowing tolerance/ cleanliness of cut was its good density under 25 per cent shade level, which showing partial shade tolerance of the species. *Dichondra micrantha* has partial shade tolerance (Cal West, 2012).

Paspalum notatum and Eragrostis curvula showed poor mowing quality under all (0%, 25%, 50%) shade conditions. *Paspalum notatum* is always making an open turf that was one of the reasons for the poor mowing quality. The species showed good mowing tolerance under all shade conditions.

Eragrostis curvula is not creeping like other turf grass species. More bare areas were seen in pot culture of *Eragrostis curvula, because of its poor density. Eragrostis curvula* had poor cleanness of cut and uniformity after mowing under all (0%, 25%, 50%) shade condition. The species was not recommended as a turf grass. Mowing tolerance was high under zero per cent and 25 per cent shade levels, but poor under 50 per cent shade level, because of its poor density.

Cynodon dactylon and *Cynodon dactylon* 419 had good mowing tolerance and good mowing quality under zero per cent shade condition, but it was poor under 25 and

50 per cent shade levels, which shows poor tolerance of the species. Bunnell et al. (2005) found that *Cynodon dactylon* 419 and *Cynodon dactylon* had poor shade tolerance.

Zoysia japonica showed excellent mowing tolerance/quality under all shade condition but it was slow. Mowing quality of the species was also excellent but it was medium under 50 per cent shade condition. Beard (1973) also reported the same mowing tolerance/ quality for *Zoysia Japonica.*

In *Stenotaphrum secundatum* mowing tolerance was good under all shade conditions. Compared to all turf grass species in the study *Stenotaphrum secundatum* was highly tolerated to shade condition. Since it is a coarse texture turf grass it is mowing quality was medium under all shade condition. Patton and Boyd (2013) also reported the species, as good mowing tolerant turf grass species.

5.1.14 Evaluation of turf grass species under various shade levels, at two months after mowing (pot culture)

All the species were evaluated once again under various (0%, 25%, 50%) shade condition at two months after mowing. The main objective of the study was to find out their tolerance to different shade levels also, after mowing. The species showed same significant differences with each other for plant height, shoot length, leaf length and leaf width as they showed after six months of establishment. But the same species showed statistically on par values for all above plant characters under different shade levels.

5.1.15 Air Pollution Tolerance Index

Polluted atmosphere is one of the major challenges that man has to face today for his existence. In some circumstances, poor indoor air quality may pose serious health risks, particularly in susceptible individuals. Plants are our resource and weapon to fight against this. The air pollution tolerance index of plants can be used to maintain the quality of air. As suggested by Singh et al. (1991), APTI can be calculated by estimating four parameters viz., total chlorophyll content, leaf extract pH, relative water content and ascorbic acid content.

5.1.15.1 Total chlorophyll content

Among the different parameters that determine the tolerance level of plants to pollution, chlorophyll content plays an important role as it indicates the photosynthetic activity as well as the growth and development of biomass (Bell and Mudd, 1976; Jyothi and Jaya, 2010). Tolerance of plants to SO2 is reported to be linked with synthesis or degradation of chlorophyll (Bell and Mudd, 1976; Ninave et al., 2001). Thus, plants having high chlorophyll content are generally found tolerant to air pollutants (Singh et al., 1991). Further the total chlorophyll content is also related to ascorbic acid productivity (Aberg, 1958) which is having a strong reductant action against the pollutants and ascorbic acid is concentrated mainly in chloroplast (Franke and Heber, 1964). In the present study, plants showed variation for chlorophyll content. *Zoysia Japonica* and *Stenotaphrum secundatum* (under 50 % shade level) showed highest leaf chlorophyll content. Turf grass species like *Paspalum notatum and Stenotaphrum secundatum* (under open field condition) showed lowest APTI values. The total chlorophyll content of the foliage plants was evidently influenced by prevailing light conditions during the seasons and also variegation of leaves. Plants with dark green leaves have more chlorophyll content compared to plants with variegated leaves (Wood and Burchett, 1995).

5.1.15.2 Leaf extract pH

Leaf pH is the determining factor for most of the biochemical reactions in leaf. Moreover, photosynthetic efficiency strongly depends on this factor (Liu and Ding, 2008). Türk and Wirth (1975) reported that photosynthetic efficiency was found to be low in plants when the leaf pH was low. It has been reported that, in the presence of an acidic pollutant, the leaf pH is lowered and the decline is greater in plants which are sensitive to pollution compared to tolerant ones (Scholz and Reck, 1977). Thus, a higher level of leaf-extract pH in plants under polluted conditions may increase their tolerance level (Singh *et al*., 1991). Further, the presence of an acidic pollutant may turn the cell sap acidic and decrease the efficiency of conversion of hexose sugar to ascorbic acid. However, the reducing activity of ascorbic acid is pH dependent being more at higher and less at lower pH (Jyothi and Jaya, 2010). In the present study, turf grass species showed variation in their leaf pH value. *Paspalum notatum* (under 25% shade level) had higher leaf pH value and lower pH value was observed in *Stenotaphrum secundatum* under open field condition.

5.1.15.3 Relative Water Content (RWC)

Relative water content is associated with protoplasmic permeability (Oleinikova, 1969) and the air pollutants increase cell permeability (Keller, 1986) in the case of sensitive species (Farooq and Beg, 1980). Pollutants induced increased permeability in cells causes loss of water and dissolved nutrients, resulting in early senescence of leaves (Masuch *et al*., 1988). Therefore it is likely that plants with high RWC under polluted conditions may be tolerant to pollutants (Singh *et al*., 1991).

Further, high water content within a plant body will help to maintain its physiological balance under stress condition such as exposure to air pollution when the transpiration rates are usually high and high water content favours drought resistance in plants. If transpiration rate is reduced due to air pollution, plants cannot sustain due to loss of capacity to pull water up with roots for photosynthesis. Then, the plants neither bring minerals from the roots to leaves where biosynthesis occurs, nor reduce the leaf temperature (Liu and Ding, 2008). In the present study, *Dichondra micrantha* under 50 per cent showed highest value for relative leaf water content, which was followed by *Stenotaphrum secundatum* under 50 per shade level. Turf grass species like *Cynodon dactylon* (under open field) showed lowest leaf water content.

5.1.15.4 Ascorbic acid

Ascorbic acid content of plants is considered to be more important than any other parameter to determine the susceptibility level. Though a plant possesses relatively low pH, chlorophyll content, and RWC, there is a great chance for the plant to have a higher APTI as the low values can be counter-balanced by the ascorbic acid multiplier effect in the APTI formula (Wood and Burchett, 1995). Moreover, studies showed that ascorbic acid is a strong reductant and a higher content favours pollution tolerance in plants (Lee *et al*., 1984).

The level of this acid declines on exposure to pollutants. Thus, plants maintaining high ascorbic acid level even under polluted conditions are considered to be tolerant to air pollutants (Singh *et al*., 1991). Conklin (2001) reported that ascorbic acid plays a vital role in cell wall synthesis, defense and cell division. Chaudhary and Rao (1977) are of the opinion that higher ascorbic acid content in plants is a sign of its tolerance against sulphur dioxide pollution. Tripathi and Gautam (2007) also reported that the increase in the concentration of ascorbic acid in the leaves of *Mangifera indica* near roadsides is due to enhanced pollution from automobiles. In the present study, higher leaf ascorbic acid values were obtained for *Dichondra micrantha* under open field followed by the same species under zero, 25 and 50 per cent shade levels. The lower values for ascorbic acid was observed for grass species like *Paspalum notatum* under 25 per cent shade level, followed by *Eragrostis curvula* under 25 per cent shade level.

5.1.15.5 APTI and susceptibility levels

The APTI values were computed for each species using the above four parameters. *Dichondra micrantha* showed maximum value for APTI. *Cynodon dactylon* (under 25% and open field) followed by *Paspalum notatum* (under 0% and 25%), showed lower APTI value. It is evident that, no species had the maximum value for all the four parameters and each parameter plays a distinctive role in the determination of susceptibility of plants. Though different parameters were taken, wide variation was seen only in ascorbic acid and it increased its impact by its multiplier effect in the APTI formula.

Studies reveal that ascorbic acid through its reducing power protects chloroplasts against SO2-induced H2O2, O2- and OH accumulation, and thus protects the enzyme of the CO2 fixation cycle and chlorophyll from inactivation (Tanaka *et al.,* 1982).Together with leaf pH, APTI plays a significant role in determining the SO2-sensitivity of plants (Chaudhary and Rao, 1977). Its reducing power is more at higher and lower at low pH values. Thus, it may be possible that ascorbic acid protects chloroplasts and chlorophyll functions from pollutants through its pH-dependent reducing power. RWC, one of the parameters to compute APTI shows the capacity of the cell membrane to maintain its permeability under polluted condition. Thus, the combination of four parameters is suggested as representing the best index of the susceptibility levels of plants under any condition.

5.1.16 Pest and diseases

Establishment and maintenance of turf grasses is a multibillion dollar industry in the world for good reason. Millions of dollars are spent annually on fungicides to prevent or arrest turf grass disease development of golf courses, high maintenance lawns and other landscapes. Additional money is spent to repair and renovate severely damaged turf. Accurate diagnosis is the Key to managing turf grass disease in an economically and environmentally sound manner.

There are two types of pathogens that cause plant disease: (1) infectious or biotic and (2) noninfectious on abiotic. Most of the common infectious turf grass diseases are caused by plant pathogenic fungi. Cultural practices such as mowing, aerification and irrigation or the misuse of herbicides, growth regulators, fungicides and fertilizers can cause turf grass injury or decline. The abiotic plant disease are often the most difficult to diagnose.

There were only minor incidences of pest and diseases. The attack noticed include, leaf eating caterpillar (army warm) under all (0%, 25%, 50%) shade levels in *Paspalum notatum* and *Eragrostis curvula*. The incidence was not found in the same species grown in open field condition. Schread, (1964), Beard (1973), Emmons (1995) and Erin, 2007 reported army worm as pest in different turf grass species.

Termite attack was found in *Dichondra micrantha*, *Zoysia japonica* , *Cynodon dactylon 419*, *Eragrostis curvula and Paspalum notatum*. *Stenotaphrum secundatum* and *Cynodon dactylon* were not affected by termites.

Ants incidence was found in open field condition in all turf grass species. They made mound and tunnels in turf area and distrupt its uniformity. Schread (1964), Beard (1973), Koppenhofer (2003), Buss (2012) and Hoover (2013) reported ants as a pest in turf grass species.

Gray leaf spot disease observed in *Stenotaphrum secundatum under various (*(0%, 25%, 50%) shade levels and also in open field condition. Beard (1973), Emmons, (1995), Nick Christian (2004), (Ki jo *et al*., 2010) and Van (2013) also reported gray leaf spot disease in *Stenotaphrum secundatum.*

5.1.17 Weeds

Nothing is more distracting in an otherwise attractive lawnscape than the presence of weeds, both broadleaf and grassy types. More than being a visual nuisance, they can compete with the desired turf grass plants for space, light, water and nutrients. The presence of weeds in a home lawn mar the appearance of turf, but more importantly they compete with the desired turf grass for water, nutrients, light and space. Lack of control of these weeds often results in a deterioration of the turf grass stand as the number of weeds increase.

Results have shown that, weed growth in the turf was a serious problem during the study. Weeds affected the turf growth seriously, both under shade and in open field conditions. The important weeds were *Alloteropsis cimicina, Ageratum conyzoides*, *Lindernia crustacean*, *Cyperus iria*, *Cyperus rotandus*, *Digitaria bicornis, Synedrella nodiflora, Cynodon dactylon, Mimosa pudica and Desmodium triflorum.* Zuk *et al,.* 2011 reported the incidence of broad leaf, perennial grassy and annual grassy weed in turf grass species. Hoffmann and Moore, (2010) reported the presence of summer grass (*Digitaria ciliaris)* is an annual weed of lawns with spreading stems that grows close to the ground. Beard (1973) and Emmons (1995) reported *Agrostis palustris*, *Mullugo verticillata, Cynodon dactylon, Cyperus rotandus, Cyperus iria, Cyprus verticullatea* and *Digitaria* species as weeds, associated with turf grass species. *Christian (2004)* also reported *Digitaria cillaris, Digitaria bicornis, Cyprus spp, Mullugo verticillata* as turf grass weeds.

Summary

6. SUMMARY

The present study "Performance evaluation of turf grass species in the humid tropics" conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara from January 2012 to August 2013. The turf grass species were compared with respect to different characters under open field condition as well as under different shade levels, viz., 0, 25, and 50 per cent.

The study comprised of evaluation of 10 turf grass species or varieties for their establishment, plant characters, Growth parameters, Air Pollution Tolerance Index, Tolerance to shade, Incidence of pests and disease and weeds associated with turf grass species.

The salient findings of the study could be summarized as follows:

A. Evaluation of turf grass species in open field condition.

1. Only seven turf grass species, *Dichondra micrantha*, *Paspalum notatum*, *Eragrostis curvula*, *Cynodon dactylon*, *Cynodon dactylon* 419*, Zoysia japonica* and *Stenotaphrum secundatum were able to grow in open field, under humid tropical condition*. The remaining three species, *Poa pratensis, Lolium perenne* and *Agrostis palustris* were not able to grow under humid tropical condition.
2. With respect to establishment, plant characters and growth parameters the best varieties which could be used as turf, under humid tropical condition are *Cynodon dactylon* 419*, Zoysia Japonica, Cynodon dactylon and Stenotaphrum secundatum.* They were observed to have best qualities under open field condition
3. *Paspalum notatum* made an open turf for which the visual quality was poor. The species was recommended for use on road sides, air fields and similar extensive, low quality turf grass areas where minimum maintenance cost is more important than turf grass quality.

4. *Eragrostis curvula* was not recommended as turf grass. Plant characters of this species was not suitable for making a turf. The species can be used in the landscape for mass planting and also for temporary cover for erosion control of areas.
5. After two months of mowing the species showed similar performance as after six months of establishment, before mowing.

B. Evaluation of turf grass species under various shade levels

1. Only 7 turf grass species, *Dichondra micrantha*, *Paspalum notatum*, *Eragrostis curvula*, *Cynodon dactylon*, *Cynodon dactylon* 419*, Zoysia japonica* and *Stenotaphrum secundatum were able to come up well under various* (0%, 25%, 50%) *shade levels in humid tropical condition*. The remaining three species, *Poa pratensis, Lolium perenne* and *Agrostis palustris* were not suitable to be grown under the above shade levels.
2. With respect to plant characters and growth parameters the best varieties which could be used as turf, under various (0%, 25%, 50%) shade levels in humid tropical condition are given below. *Dichondra micrantha* was recommended for 25 per cent shade. *Cynodon dactylon* and *Cynodon* 419 are recommended only under open condition, the species had very poor shade. *Zoysia Japonica* had a quality turf under zero and 25 per cent shade levels, the species was recommended for zero and 25 per cent shade levels. *Stenotaphrum secundatum* was recommended for all shade conditions. Compared to all other turf grass species, *Stenotaphrum secundatum* showed good shade tolerance to different (0%, 25%, 50%) shade levels. They were observed to have best qualities under different shade levels.
3. *Paspalum notatum* showed good tolerance to zero and 25 per cent shade levels, but its visual quality was poor. This species is recommended for

open and 25 per cent shade condition to be used on road sides, air fields and similar extensive, low quality turf grass areas where minimum maintenance costs are the most important concern.

4. *Eragrostis curvula* showed good tolerance to zero and 25 per cent shade levels. This species was not recommended as a turf grass because its characters were not suitable for making a turf. The species can be used under open and 25 per cent shade condition in the landscape, for mass planting and also for temporary cover for erosion control.

D. Air Pollution Tolerance Indices of the turf grass species were calculated. *Dichondra micrantha* showed the highest value (24.28) for Air Pollution tolerance Index in open field condition, followed by 50 per cent and 25 per cent shade (pot culture) condition and the lowest (8.62) was by *pasplaum notatum* in 25 per cent shade followed (8.75) by 50 per cent shade and *Cynodon dactylon* in 0pen field condition.

Turf grass species were categorized into sensitive (value ≤ 14), intermediate (15-19), medium tolerant (20-24) and tolerant (> 24) groups based on their APTI values. *Paspalum notatum, Eragrostis curvula, Cynodon dactylon 419, Cynodon dactylon, Zoysia japonica and Stenotaphrum secundatum* came under the sensitive category. *Dichondra micrantha came under* intermediate category, under 50 per cent shade level.

E. Turf grass species were observed for insect incidence under various shade (0%, 25%, 50%) levels and in open field condition. army worms, termites, fire ants and worker ants were found. Army worms were found in catter pillar stage under all shade levels in *Paspalum notatum* and *Eragrostis curvula*. But they were not found in other turf grass species. Turf grass species were not severely affected by army worm.

F. All the turf grass species were also observed for diseases incidence. No serious disease was observed except the gray leaf disease, found the *Stenotaphrum secundatum*. Gray leaf spot disease is a fungal disease caused by *Pyriculari grisea*. This was more serious under 50 per cent and 25 per cent shade levels compared to open field condition. Disease was observed under all shade conditions and also in open field condition.

G. All the turf grass species were observed for weeds, associated with turf species under shade and open field condition. Weeds were identified and data was recorded.

References

REFERENCES

Aberg, B. 1958. Ascorbic acid, Hdb Pflz Physiol, 6:479-499.

Ainslie, G. G. 1930. The bluegrass webworm. The bluegrass webworm. USDA Tech. Bull. 173p.

Ainslie, G. G. 1930. The bluegrass webworm. USDA Tech. Bull. 173. 192p.

Aldous, D. 1999. *International Turf Management*. Routledge, New York, USA, 345p.

Alex, R. 2012. Evaluation of foliage plants for interior plantscaping. Phd (Horti.) Thesis, Kerala Agriculture University, Thrissur.

Allard, G., Nelson, C. J. and Pallardy, S. G. 1991a. Shade effects on growth of tall fescue: Leaf anatomy and dry matter partitioning. *Crop Sci.*, 31: 163-167.

Allard, G., Nelson, C. J. and Pallardy, S. G. 1991b. Shade effects on growth of tall fescue: II. Leaf gas exchange characteristics. *Crop Sci.,* 31: 167-172.

Anonymous. 1999. National Gardening Survey1998-1999. National Gardening Association [Online]. Available: http://www.landcarenetwork.org/legislative/EnvironmentslandSocialBenefitsofLawns.pdf [May 23, 2012].

App. B.A and Kerr, S.H. 1965. Harmful Insects. In: Hanson, A.A. and Juska, F.V. (eds.) *Turfgrass Science* (Reprint, 1971). American Society of Agronomy, Wisconsin, USA, pp. 336 – 356.

Bain, D. C. 1962. *Sclerotinia* blight of bahia and Costal bermuda grasses. *Plant Disease Reporter,* 46: 55- 56.

Barrios, E.P., Sundstrum, F. J., Babcock, D. and Leger, L. (1986). Quality and yield response of four warm-season lawn grasses to shade conditions. Agron. J. 78: 270-273.

Beard, J. B. 1973. Warm season turfgrasses. In: Englewood Cliffs, N. J. (ed.). Turfgrass: Science and Culture.Prentic-Hall, pp 132-165.

Beard, J. B. 1997. Shade stress and adaption mechanisms of turfgrasses. *Turfgrass*, 8: 1186–1195.

Beard, J.B. 1973. *Turfgrass Science and Culture*. Printce Hall, Inc., Englewood Cliffs, N.J.pp 197 – 199.

Bell, G.E. and Danneberger, T. K. 1999. Temporal shade on creeping bentgrass turf. *Crop Sci.,* 39: 1142–1146.

Bell, J.N.B. and Mudd, C.H. 1976. Sulphur dioxide resistance in plants: a case study of *Lolium perenne*. In: Mansfield, T.A (ed) Effects of air pollutants on plants. Cambridge, Cambridge Univ. Press. pp.87-103.

Bibby, F. F., and Tuttle D.M. 1959. Notes on phytophagous and predatory mites of Arizona. *J. Econ. Entomol.,* 52(2): 186 – 190.

Bibby, F. F. and Tuttle, D. M. 1959. Notes on phytophagous and predatory mites of Arizona. *J. Econ. Entomol*. 52(2):186-190.

Bierman, P., Rosen,C. and Horgan, B. 2004. Evaluating the Effects of Foliar Iron Formulations on Turf Quality, Hole Notes. pp. 34-35.

Bigelow, C. 2005. Turfgrass identification tool. Turfgrass science department of agronomy. Purdue University. [Online]. Available: http://www.agry.purdue.edu/ TURF/tool/index.html [July 12th, 2012].

Bjorkman. O. 1981. Responses to different quantum flux densities. In ‘Physiological Plant Ecology. I. Responses to the Phsyical Environment’. (Eds. O. L. Lange, P. S. Nobel, C. B. Osmond and H. Ziegler.) *Encycl. Plant Phsyiol. New Ser.,* 12A: 57-107.

Boardman, N. K. 1977. Comparitive photosynthesis of sun and shade plants. *Annu. Rev. Plant Physiol.,* 28: 355-377.

Bohart, R. M. 1947. Sod webworms and other lawn pests in California. Hilgardia, 17(9): 267-308.

Bohart, R.M. 1947. Sod webworms and other lawn pests in California. *Hilgardia,* 17(8): 267- 308.

Brosnan, J. T. and Deputy, J. 2008. St. Augustinegrass [online]. Available: www.ctahr.hawaii.edu/oc/freepubs/pdf/TM-3.pdf [7th September, 2012].

Brosnan, J.T. and Deputy. J. 2008. Bermuda grass. University of Hawaii, College of Agriculture and Human Resources, Cooperative Extension Service [Online]. Available:http://turfgrass.ctahr.hawaii.edu/downloads/Bermudagrass_NEW2.pdf [22 Feb, 2013].

Bunderson, L.D., Johnson, P.G., Kopp, K.L., and Vandyke, A. 2009. Tools for Evaluating Native Grasses as Low Maintenance Turf. *Hort. Technol*. 19 (3): 626-632.

Bunnell, B.T., L.B. McCarty, and W.C. Bridges.2005. Evaluation of three bermudagrass cultivars and Meyer Japanese zoysiagrass grown in shade. Int. Turfgrass Soc. Res. Journal 10:826-833.

Burton, G. W., Jackson, J. E. and Knox, F. E. 1959. Influence of light reduction upon the production, persistence, and chemical composition of costal bermuda grass (*Cynodon dactylon*). *Agron. J.,* 51: 537-542.

Busey, P. and B.J. Myers. 1979. Growth rates of turfgrasses propagated vegetatively. *Agron. J.* 71:817-821.

Busey, P. and Davis, E. H. 1991. Turfgrass in the shade environment. Florida State Hort. Soc. Proc. 104: 353-358.

Buss, E. A. 2012. Insect pest management on turfgrass. [online]. Available: http://solutionsforyourlife.ufl.edu/lawn_and_garden [13 May, 2012].

Buttler, G. D. and Tuttle, D. M. 1961. New mite is damaging to bermudagrass. *Prog. Agr. Ariz*. 13(1):11p.

Buttler, G. D. and Tuttle, D. M. 1961. New mite is damaging to bermuda grass. *Prog. Agr. Arziz.,* 13(1):11.

Cal/West Seeds. 2012. Dichondra [online]. Available: http://www.calwestseeds .com/ products/dichondra/ [10 July, 2011].

Chalmers, D. R. and McAfee, J. 2009. Tufrgrass establishment in Texa [Online]. Available: http://aggieturf.tamu.edu [25 May, 2012].

Chalmers, D.R. 2009. Turfgrass Establishment In Texas. Department of Soil and Crop Sciences, Texas A&M University, College Station, Texas. [Online]. Available: http://aggieturf.tamu.edu/answers4you/publications/Turf%20Establishment%20SCS-2009-06lr.pdf [January 18th, 2012].

Chaudhary, C.S. and Rao, D.N. 1977. Study of some factors in plants controlling their susceptibility to sulphur dioxide pollution. Proc. Ind. Natl. Sci. Acad. Part B. 46:236-241.

Chauhan, A. 2010. Trees as bio-indicator of automobile pollution in Dehradun city: A case study. *New York Sci. J.,* 3 (6): 88 – 95.

Christian, N. 2004, *Fundamental of Turfgrass Management* (2nd Ed.). John Wiley & Sons, Inc., Hoboken, New Jersey, 399p.

Christians, N. E. and M. C. Engelke. 1994. Choosing the right grass to fit the environment. In *Handbook of Integrated Pest Management for Turfgrass and Ornamentals*. Lewis Publishers, Boca Raton, Fl, pp. 99-1122.

Conklin, P.C. 2001. Recent advances in the role and biosynthesis of ascorbic acid in plants. Plant cell Environ., 24:383-394.

Corriher, V.A. and Redmon, L.A. 2001. Bermuda grass varieties, Hybrids and Blends for Texas, Agri Life Extension, Texas A&M System [Online]. Available: AgriLifeExtension.tamu.edu [15 Feb, 2012].

Couch, H.B. 1995. *Disease of Turf grasses*. Krieger Publishing Co., Malabar, FL, pp. 249-278.

Cough, H. B., and Bloom. J.R. 1960. Influence of soil moisture stresses on the development of the root knot nematode. *Phytopathology*, 50: 319 – 321.

Cough, H.B. and Moore. L. D. 1960. Broad spectrum fungicides tested for control of melting out of Kentucky bluegrass and *Sclerotina* dollar spot of Seaside bentgrass. *Plant Disease Reporter*, 44: 56-509.

Crawford, C. S. and Hardwood. 1964. Bionomics and control of insects affecting Washington grass seed fields. Washington Agri. Exp. Sta. Tech. Bull. 44. 53p.

Crawford, C. S. and Harwood, R. F. 1964. Bionomics and control of insects affecting Washington grass seed fields. Washington Agri. Exp. Sta. Tech. Bull. 44p.

Dahl, B.E. and Cotter. P. F. 1984. Management of weeping lovegrass in west Texas. Management Note 5. Texas Tech University, College of Agricultural Sciences, Department of Range and Wildlife Management, Lubbock, Texas. pp. 38-47.

Danneberger, T.K. McDonald, M.B. Geron, C.A. and Kumari P. 1992. Rate of germination and seedling growth of perennial ryegrass seed following osmoconditioning. *Hort Sci.* 27 (1):28-30.

Deputy, J. 2009. Turf Establishment. Department of Tropical Plant and Soil Sciences. [Online]. Available: http://www.ctahr.hawaii.edu/oc/freepubs/pdf/PP-07.pdf [May 13th, 2012].

Double, R.L. and Novosad, A. C. 1973. Home lawns. Texas Agricultural Extension Service, Rep. MP-1180, 19 p.

Duble, R. L. 1989. *Southern Turfgrasses*: *Their Management and Use*. Texscape, Inc., College station, TX, pp. 64-70.

Duble, R.L. 1996. Southern turfgrasses. In: Turfgrasses: Their Management and Use in the Southern Zone. 2nd Ed. Texas A&M Univ. Press. College Station, TX, pp. 38-99.

Dunn, J. and K. Diesburg 2004. Grass species. In: Hoboken, N.J. (ed.), Turf Management in the Transition Zone. John Wiley & Sons, Inc. pp. 11-39.

Emmons, R. 1995. *Turfgrass Science andManagement* (2nd Ed.). Delmar Publishers, United States of America. 512p.

Ericksen, F. I. and Whitney, A. S. 1981. Effects of light intensity on growth of some tropical forage species. I. Interaction of light intensity and nitrogen fertilization on siz forage grasses. *Agron. J.*,73: 427-433.

Erin, W. H. 2007. Armyworm and cutworms in turfgrass [Online]. Available: www.utahpests.usu.edu [13 January, 2012].

Fagerness, M.J., 2001.Turf grass identification. Professional Series Turfgrass Identification, Kansas State University. [Online]. Available: http://www.ksre.ksu. edu/bookstore/pubs/mf2031.pdf [January 10th, 2012].

Farooq, M. and Beg, M.U. 1980. Effect of aqueous sulphur dioxide on the membrane permeability of common Indian tree leaves. New Botanist. 7:213-217.

Forest, W. 2011. Planting Bermuda grass [online]. Available: http://www.wakeforestnc.gov/SearchResults.aspx?q=planting+of+bernuda+grass [8th June 2012].

Franke, W. and Heber, U.1964.Uber die quantitative verteilund der ascorbinsaure innerhalb der Pflanzenelle, Zeitschrift Naturf, 196: 1146 – 1149.

Freeman, T. E. 1967. Disease of southern turfgrasses. Florida Agr. Exp. Sta. Tech. Bul. 713. 31p.

Gaikwad, U. S., Ranade, C. D. and Gadgil, J. M. 2006. Plants as bio-indicators of automobile exhaust pollution-a case study of Sangli city. 86:26-28.

Gardner, D. 1997. Turfgrass Identification.The Ohio State University. [Online]. Available: http://buckeyeturf.osu.edu/pdf/01_turfgrass_identification.pdf [May 20th, 2012].

Gaskin, T. A. 1965. Varietal reaction of creeping bent grass to stripe smut. *Plant Disease Reporter*, 49(3): 268.

Givnish, T. J. 1988. Adaptation to sun and shade: a whole-plant perspective. *Aust. J. Plant Physiol.,* 15: 63–92.

Gouia, H., Ghorbal, M. H. and Meyer, C. 2000. Effects of cadmium on activity of nitrate reductase and on other enzymes of the nitrate assimilation pathway in bean. *Plant Physiol. Biochem.,* 38: 629–638.

Gould, C. J. 1963. Some practical aspects of disease control. Golf Course Reptr. 31:1-5.

Gould, F.W. and Shaw. R. B. 1969. *Grass Systematics* (2nd ed.). McGraw-Hill Book Co., New York, 397p.

Gray, J. E. 1967. The vegetative establishment of four major turfgrasses and the response of stolonized 'Mayer' zoysia grass (*Zoysia japonica* var. Meyer) to mowing height, nitrogen fertilization, and light intensity. M.S. Thesis. Mississippi State University. pp. 1-50.

Gray, J.E. 1967. The vegetative establishment of four major turfgrasses and the response of stolonized 'Mayer' zoysiagrass (Zoysia japonica var. Meyer) to mowing height, nitrogen fertilization, and light intensity. M.Sc. Thesis. Mississippi State University. pp. 1-50.

Gucker, Corey L. 2009. Eragrostis curvula. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. [Online].Available: http://www.fs.fed.us/database/feis/ [2013, November 29].

Gudauskas, R. T. and McGlohon. 1964. *Sclerotinia* blight of bahiagrass in Albama. *Plant Disease Reporter*, 48: 418.

Han and Huckabay. 2008. Bermudagrass lawn [online]. Available: http://www.aces.edu /search/ACESresults.php?q=Bermuda%20grass%20lawn [5th May, 2011].

Hansen, T., Mammen, R., Crawford, R., Massie, M., Hurley, G. B. and Kallenbach, R. 2011. Bermudagrass [online]. Available: http://extension.missouri.edu/publications /DisplayPrinterFriendlyPub.aspx?P=G4620 [6th June, 2011].

Hanson, A. A. Jusk, F. V. Burton, G. W. 1969. Species and varieties. In: Hanson and Juska, F.V. (Ed.), *Turfgrass Science: Agronomy,* Madison, WI, 14:370 – 409.

Hanson, A.A. and Juska. F.V. 1969. *Turfgrass Science* (Reprint, 1971), American Society of Agronomy, Wisconsin, USA, 701p.

Harper, J.C. 2000. Mowing Turfgrasses. Penn State College of Agricultural Sciences research, extension, and resident education programs. Pennsylvania State University.

[Online]. Available: http://plantscience.psu.edu/research/centers/turf/extension/fact sheets /pdfs/mowing.pdf [May 12th , 2012].

Harrington, K. Zhang, T. Obsome, M. and Rahman. A. Orchard weed control with *Dichondra micrantha* ground covers. In: Abstracts, Twelfth Australian Weeds Conference: 12-16, September, 1999, AgResearch, Ruakura Research Centre, PB 3123, Hamilton, New Zealand, pp. 250-254

Harris, R. W. 1992. Root-shoot ratio. *J. Arboriculture*, 18(1): 39-41.

Haydu, J. J., Satterthwaite, L. N. and Cisar, J. L. 1996. An Economic and Agronomic Profile of Florida's Sod Industry in 1996. Economic Information Report EIR 98-x.

Henn, A. 2012. Gray Leaf Spot of St. Augustine grass. Mississippi State University, Extension Service [Online]. Available: http://msucares.com/pubs/infosheets /is1683.pdf [13th August, 2012].

Higgins, J. 1998. Bermuda grass Lawns. Alabama Coop. Ext. Sys. ANR-29. Alabama A&M Univ. and Auburn Univ. pp. 723-729.

Hodges, A. W., Haydu, J. J., van Blokland, P. J., and Bell, A. P. 1994. Contribution of the turf grass industry to Florida's economy, 1991/92: A value added approach. Economics Report ER 94-1. Food and Resource Economics Department, Florida Agricultural Experiment Stations, Institute of Food and Agricultural Sciences, University of Florida, Gainsville.

Hoffman, H. and Moore, J. 2010. Control of common weeds in lawns [Online]. Available: www.agric.wa.gov.au [21 August, 2012].

Holt, E. C. and Payne. K. T. 1952 Variation in spreading rate and growth characteristics of creeping bentgrass seedlings. *Agron. J.* 44: 88-90.

Hoover, G.A. 1992. Ants in home lawns [Online]. Available: http://ento.psu.edu/ extension /factsheets/ants-lawns [20 July, 2012].

Huang, W. D., Wu, L. K. and Zhan, J. C. 2002. Effect of weak light on the peroxidation of membrane lipid of cherry leaves. *Acta Bot. Sin.,* 44 (8): 920–924.

Huxley, A. 1992. Lawns. In *New RHS Dictionary of Gardening* Macmillan publications, 3: 26-33.

Jiang Y. W., Duncan, R. R. and Carrow, R. N. 2004. Assessment of low light tolerance of seashore paspalum and bermudagrass. *Crop Sci.,* 44: 587–594.

Jizhou, Z.J.R. 1997. Vegetative Establishment Methods of Warm Season Turf. *Acta Prataculturai Sci.* 1997-01.

Jyouthi , S. J and Jaya, D. S. 2010. Evaluation of air pollution tolerance index of selected plant species along roadsides in Thiruvananthapuram, Kerala. *J. Envorion. Biol.,* 31:379-386.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service. 2001. Turfgrass identification [online]. Available: http://search.k-state. edu/?qt=Turfgrass+identification [26th August 2011].

Keeley, S. and M.J. Fagerness 2001.Bermudagrass Lawns. Horticulture Report. Kansas State Univ. Agric. Exp. Stn. and Coop. Ext. Ser. pp. 135-158.

Keller, T. 1986. The electrical conductivity of Norway spruce needle diffusate as affected by air pollutants. Tree Physiol. 1:85 – 94.

Kelsheimer, E. C. and Kerr, S. H. 1957. Insects and other pests of lawns and turf. Florida Agr. Exp. Sta. Cir. S-96p.

Ki jo, Y., Rimelspach, W and Boehm, M. J. 2010. Gray leaf spot on turfgrass [Online]. Available: http://ohioline.osu.edu/lines/hygs.html [25 january, 2012].

Koppenhofer, A. M. 2003. Ant management in turfgrass [Online]. Available: www.rce. rutgers.edu [16 July, 2012].

Kovács, M. 1992. Herbaceous (flowering) plants. In: Biological indicators in environmental protection, Kovács, M. (ed.), Ellis Horwood, New York.

Lakshmi, P. S., Sravanti, K. L. and Srinivas, N. 2008. Air Pollution tolerance index of various plant species growing in industrial areas. *The Ecoscan.* 2(2):203-206.

Ledeboer, F.B. and C.R. Skogley. 1967. Investigations into the nature of thatch and methods for its decomposition. *Agron. J*. 59:320-323.

Lee, E.H., Jersey, J.A., Gifford, C. and Bennett, J. 1998. Differential ozone tolerance in soybean and snapbeans; analysis of ascorbic acid in O_3- susceptible and O_3- resistant cultivars by high performance liquid chromatography. Environ. Exploratory Bot. 24:331-341.

Leslie, A. R. and Knoop, W. 1989. Societal benefits of conservation oriented management of turf grass in home lawns. In: Integrated Pest Management for Turfgrass and Ornamentals. U.S. Environmental Protection Agency, Washington, D. C. pp. 93-96.

Leuthold, L. Fry, J. and Pair, J. 1994. Bermuda grass lawn. Kansas State University, Manhattan, KS, pp. 1- 4.

Leuthold, L. 1988. Zoysia lawns. Kansas State Univ. Extension Pub. MF- 683, Kansas State University, Manhattan, KS, pp. 1- 4.

Leuthold, L. and Fry. J. 1994. Planting a home lawn. Kansas State University, Manhattan, KS, pp. 1- 4.

Liu, Y. and Ding, H. 2008. Variation in air pollution tolerance index of plants near a steel factory: Implications for landscape-plant species selection for industrial areas. WSEAS transactions on Environ and development. 4(1):24-32.

Lush, W.M. and Birkenhead, J.A. 1987. Establishment of turf using advanced ('pregerminated') seeds. *Aust. J. Exp. Agric.* 27(2) 323 – 327.

Malcolm, D. R. 1955. Biology and control of the timothy mite, *Paratetranychus pratensis* (Banks). Washington Agr. Exp. Sta. Tech. Bull. 17p.

Masuch, G., Kicinski, H.G., Kettrup, A. and Boss, K.S. 1988. Single and combined effects of continuous and discontinuous O_3 and SO_2 emission on Norway spruce needles. I. Histological and cytological changes. Int. J. Environ. Analytical chem. 32:213-241.

Mc Carty, L. B. 1994. Establishing Your Florida Lawn. In: *Florida Lawn Handbook*, University of Florida, Gansville, pp. 21-25.

McIlvain, E.H. and M.C. Shoop. 1970. Burning old growth of Weeping Lovegrass. *In*:Dalrymple, R.L. (ed.). Proceedings of the First Weeping Lovegrass Symposium, The Samuel Roberts Noble Foundation, Ardmore, Oklahoma.April 28-29, 1970. pp. 44-51.

Meinhold, V.H., Duble, R.L., Weaver, R.W. and E.C. Holt. 1973. Thatch accumulation in bermudagrass turf in relation to management. *Agron. J.* 65:833-835.

Meinhold, V.H., Duble, R.L., Weaver, R.W. and E.C. Holt. 1973. Thatch accumulation in bermudagrass turf in relation to management. *Agron. J.* 65:833-835.

Monteith, J. 1926. The brown patch disease of turf, its nature and control U.S.G.A. Greens Section Bul. 9:82-99.

Monteith, J. and Dahl, A.S. 1932. Turf disease and their control U.S.G.A Greens Section Bul. 12:85-186.

Monteith, J. and Dahl. A. S. 1928. A comparison of some strains of *Rhizoctonia solani* in culture. *J. Agric. Res.*, 36(10): 897- 903.

Monteith, J.1925. July experiments for control of brown patch on Arlington experimental turf garden. Bulletin of USGA Green Section. 5: 173 – 176.

Morris,K.N. 2008. A Guide to NTEP Turfgrass Ratings [on line]. Available: http://www.ntep.org/reports/ratings.htm[13.02.2011].

Morrow, R. 1967. Grass for player safety. *Turf Grass Times*, 3(1): 2-16.

Mueller, J. P., Green, J. T., Chamblee, D. S., Burns, J. C., Bailey, J. E. and Brandenburg, R. L. 2011. Bermudagrass management in North Carolina [online]. Available: www.ces.ncsu.edu/depts/hort/consumer/agpubs/ag-493.pdf [13th July, 2013].

Mueller, J.P., Green, J.T., Nelson, L.A. and J.V Hall. 1992. Establishment of two bermudagrasses in three soil environments. *Agron. J.* 84: 38-43.

Mulgrew, A. and Williams, P. 1998. Biomonitoring of Air Quality Using Plants – Impressum. [Online]. Available: http://www.umweltbundesamt.de/whocc/AHR10/III-GP-5.htm [13th September 2014].

Murphy, J. A., Indyk, H. W. and Engel, R. E. 2004. Zoysiagrass lawns in New Jersey [online]. Available: http://njaes.rutgers.edu [8th June 2012].

NCSU [NC State University]. 2005. Turf Files Centre. Turf grass environmental research and education. [Online]. Available: http://turfid.ncsu.edu [July 13th, 2012].

Ninave, S.Y., Chaudhri, P.R., Gajghate, D. G. and Tarar, J.L 2001. Foliar biochemical features of plants as indicators of air pollution. Bull. Environ. Contam. Toxicol. 67:133-140.

Oakley, R. A. 1924. Brown-patch investigations. U.S.G.A Green Section Bul. 4:87-92.

Oakley, R.A. 1924. Brown patch investigation. Bulletin of USGA Green Section. 4: 87-92.

Oleinikova, T.V. 1969. The effects of drought on protoplasm permeability in cells of springwheat leaves. Byull. Vses. Inst. Resteniev. 14:25 – 30.

Paramaguru. P. 2010. Diversity in turf grasses for landscape gardening [guest paper]. In: *Guest papers*, *National Conference on Plant Diversity for Aesthetic Values and Landscape Gardening*; 26-28 November, 2010. Tamil Nadu Agricultural University, Coimbatore, pp.75-80. Guest paper No. 10.

Parker, D.S. 2011. Influence of Sand Topdressing on Bermudagrass Thatch Decomposition. Master's Thesis. Louisiana State University and Agricultural and Mechanical College.[Online]. Available: http://etd.lsu.edu/docs/available/etd-01172011 120802/unrestricted/Parker_thesis.pdf [July 12th , 2012].

Patterson, D. T. 1980. Shading effects of growth and partitioning of plant biomass in cogongrass (*Imperata cylindrica*) from shaded and exposed habitats. *Weed Sci.,*28: 735-740.

Patton, A.J., Hardebecka, G.A., Williamsb, D.W. and Reichera, Z. J. 2004. Establishment of Bermudagrass and Zoysiagrass by Seed. *J. Crop Sci.* 10.2135/cropsci2004.2160.

Penn State University, Center for Turfgrass Science, 2013. Powedery Mildew [Online]. Available: http://plantscience.psu.edu [20th June, 2013].

Philip, A. and Knapp, A. K. 1998 .Response to short-term reductions in light in soybean leaves. *Int. J. Plant Sci.,* 159 (5): 805–810.

Piper, C. V. 1921. The brown-patch disease of turf. U.S.G.A Green Section Bul. 1:112-115.

Piper, C.V. and Oakley, R. A. 1921. The brown patch disease of turf. USGA Green Section Bulletin, 1: 112- 115.

Pohl, R. W. 1968. *How to know the Grasses*. Wm. C. Brown Company, Dubuque, IA, pp. 1-10.

Qian, Y. L. and Engelke, M. C. 1999. Diamond zoysiagrass as affected by light intensity. *Turfgrass Manage.,* 3(2): 1–15.

Randawa. G.S. and Adhya, M. 1986 *Floriculture in India* (Reprint, 2012). Allied Publishers, New Delhi, 656p.

Reynolds, C. A. and Flint, M.L. 2004. The UC Guide to Healthy Lawns. UC Statewide IPM Program. Agriculture and Natural Resources, University of California. [Online]. Available: http://www.ipm.ucdavis.edu/TOOLS/TURF/contents.html [July 12th , 2012].

Reynolds, W.C. 2002. Establishment rates and growth characteristics of six bermudagrass cultivars for use on athletic fields and golf course fairways. M. Sc. Thesis, Crop Science, Raleigh, North Carolina.

Richardson, M.D., Karcher, D.E. and L.C. Purcell. 2001. Quantifying turfgrass cover using digital image analysis. *Crop. Sci*. 41: 1884-1888.

Riordan, T. P., Meir, V. D., Long, J. A. and Gruis, J. T. 1980. Registration of Seville St. Augustinegrass. *Crop Sci*. 20:824-825.

Roacaas, G. and Scarano, F. R. 2001. Leaf anatomical variation in *Alchornea triplinervia*（Spreng）,Mull.Arg.（*Euphorbiaceae*） under distinct light and soil water regimes. *Bot. J. Linn. Soc.,* 136: 231–238.

Robert, D. E. 1995. *Turfgrass Science and Management* (2^{nd} Ed.). Delmar Publishers, USA 512p.

Roberts, E.C. 1965. A new measurement of turf grass response and vigor. *The Golf Course Reporter*, 33(8): 10 – 22.

Roosevelt, M. 2010. Turf grass not always a 'green' thing, study shows. *Los Angeles Times,* 23 February, 2010, p.15.

Samples, T. and Sorochan. J. 2007. Zoysia. University of Tennessee Cooperative Extension Bulletin W159-H.[online]. Available: http://utextension.tennessee.Edu /publications/wfiles/W159-H.pdf [May 12th, 2012].

Sauer, J. D. 1972. Revision of *Stenotaphrum* (*Graminae:Paniceace*) with attention to its historical geography. *Brittonia* 24: 202-222.

Scholz, F. and Reck, S. 1977. Effects of acids on forest trees as measured by titration *in vitro*, inheritance of buffering capacity in *Picea abies*. Water, Air and Soil Pollut. 8:41-45.

Schread, J. C. 1964. Insect pests of Connecticut lawns. Connecticut Agr. Exp. Sta. Circ. 212. pp 3-12

Scott, J. D. and J. W. Rabie. 1956. Preliminary studies on growth and development of *Eragrostis curvula* and *Themeda triandra*. S. Afr. J. Sci. 55:207-210

Shainberg, O., Rubin, B., Rabinowitch, H. D., Libalweksler, Y. and Telor, E. 1999. Adjustment to low light intensity enhances susceptibility of bean leaves to oxidative stress. *J. Plant Physiol.,* 155: 393–398.

Singh, S. K. 1993. Phytomonitoring of urban industrial pollutants: A new approach. *Environmental Monitoring and Assessment.* 24: 27-34.

Singh, S. K. and Rao, D. N., 1983. Evaluation of plants for their tolerance to air pollution. *In: Proceeding of the symposium on Air Pollution Control,* November, pp. 218-224.

Singh. S. K., Rao, D. N., Agarwal, M., Pandey, J. and Narayan, D. 1991. Air pollution tolerance index of plants. *J. Eniviron. Manag.*, 32 (1): 45-55.

Soper, D.Z., J.H. Dunn, D.D. Minner and D.A. Sleper. 1988. Effects of clipping disposal, nitrogen, and growth retardants on thatch and tiller density in zoysiagrass. *Crop Sci.* 28:325-328.

Sulistijorini, Masud, Z. A., Nasrullah, N., Bey, and Tjorosemito, S. 2008. Tolerance levels of roadside trees to air pollutants based on relative growth rate and air pollution tolerance index, HAYATI. J. *Biosci.,* 15(3):123-129.

Taliaferro, C.M. 2003. Bermudagrass (Cynodon (L.) Rich). In: Casler, M.D. and R. Duncan (eds.) Turfgrass Biology, Genetics, and Cytotaxonomy. Sleeping Bear Press, pp. 235-256.

Tannaka, K., Otsubo, T. and Kondo, N. 1982. Participation of hydrogen peroxide in the inactivation of calvin-cycle SH enzymes in SO_2- fumigated spinach leaves. Plant cell physiol. 28:1009-1018.

Taylor, H.J., Ashmore, M.R. and Bell, J.N.B. 1990. Air pollution injury to vegetation. IEHO, London.

The Pennsylvania State University. 2009. Turf grass species for Pennsylvania. [Online] Avilable: http://pubs.cas.psu.edu/FreePubs/pdfs/ec395.pdf [15-09-2011].

Toler, J.E., Higingbottom, J. K. and McCarty, L. B. 2007. Influence of fertility and mowing height on performance of established centipedegrass. *Hort Sci.* 42(3):678-681.

Trenholm, L. E. 2001. Bermudagrass for Florida Lawns. Environmental Horticulture Department, Florida Cooperative Extension Service, Institute of Food and Agricultural

Sciences, University of Florida [Online]. Available: http://edis.ifas.ufl.edu [June 16th , 2012].

Trenholm, L. E., Cisar, J. L. and Unruh J. B. 1997. St. Augustinegrass for Florida Lawns. [Online]. Avialable: http://edis.ifas.ufl.edu/lh010 [September 19, 2012].

Trenholm, L.E. 2012. Growing Turfgrass in the Shade, University of Florida, IFAS Extension [Online]. Available: http://edis.ifas.ufl.edu [25 June, 2012].

Trenholm, L.E. Cisar, J.L. and Unruh, J. B. 2012. Bermuda grass for Florida Lawns, University of Florida, Institute of Food and Agricultural Sciences [Online]. Available: https://www.espositogardencenter.com/Portals/0/LH00700.pdf [27 April, 2012].

Trenholm, L.E. 2011. Growing Turfgrass in the Shade. Environmental Horticulture Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. [Online]. Available: http://edis.ifas.ufl.edu [May 13th , 2012].

Tripathe, A.K. and Gautam, M. 2007. Biochemical parameters of plants as indicators of air pollution. J. Environ. Biol., 28:127-132.

Tripathi, A., Tiwari, P. B., Mahima and Singh, D.2009. Assesment of air pollution tolerance index of some trees in Moradabad city, India. *J. Environ. Biol*., 30(4): 545-550.

Turgeon, A. J. 2005. Turfgrass species. In: Turf grass Management. 7th Ed. Pearson Education, Inc., Upper Saddle River, NJ, pp. 59-119.

Turgoen, A.J,. 1996. *Turfgrass Management*. Prentice - Hall, Inc. Upper Saddle River, NJ.

Turk, R. and Wirth, V. 1975. The pH dependence of SO_2 damage to lichens, Oecologia. 19:285-291.

U.S. Department of Agriculture. 1965. Losses in agriculture. Agriculture Handbook, 291p.

University of California, 2014. The UC Guide to Healthy Lawns [Online]. Available: http://www.ipm.ucdavis.edu/TOOLS/TURF/TURFSPECIES [11 Feb, 2014].

University of California. 2009. Bermudagrass (seeded and hybrid species)- Cynodon spp. [online]. Available: http://ipm.ucdavis.edu/TOOLS/TURF/TURFSPECIES/index.html [20th May, 2011].

University of California. 2014. Agriculture and natural resources, University of California [Online]. Available: http://www.ipm.ucdavis.edu/ [20 August, 2014].

University of Elliniois, College of Agricultural, Consumer and Environmental Sciences, 1995. Powdery Mildew of Turf grasses [Online]. Available: http://ipm.illinois.edu [27th May, 2013].

University of Massachusetts, Center for Agriculture, Food and the Environment. 2012. Lawn Mowing [online]. Available https://extension.umass.edu [22 January, 2012].

Unruh, Band L.E. Trenholm. 2000. Improved zoysiagrasses may gain popularity in Florida turfgrass Market. *Florida Turf Digest* 17 (3):30, 32-34.

Van, S. 2013. Gray leaf spot of St. Ausustinegrass [Online]. Available: http://www. uaex.edu [27 July, 2012].

Volterrani, M., Magni, S., Gaetani, M. and Lulli, F. 2012. Trinexapac-ethyl effects on stolon activity and node vitality of 'Tifway' hybrid Bermudagrass. *HortTrchnology*, 22:479-483.

Wan, C. G. and Sosebee, R. E. 2000. Central dieback of the dryland bunchgrass *Eragrostis curvula* (weeping lovegrass) re-examined: The experimental clearance of tussock centers. *J. Arid Environ.* 46(1): 69–78.

Wang Wen-en, Zhang Jun-wei, Fu Qiang, Bao Man-zhu. 2003. The effect of different establishment methods of Bermuda grass in summer and overseeding with perennial ryegrass in autumn on turf stands. College of Horticulture and Forestry Sciences, Huazhong Agricultural University, Hubei, Wuhan430070, China). [Online]. Available: http://en.cnki.com.cn/Article_en/CJFDTOTAL-CYKX20050300X.htm [January 10th, 2012].

Ward, G. M. 1969. Evaluating turf grasses for shade tolerance. *Agron. J.* 61:347-353.

Wheeler, D. J. B., Jacobs, S. M. L. and Whalley, R. D. B. 2001. Grasses of New South Wales. The University Of New England Armidale Australia. [Online]. Available at: http://www.fog.org.au/grasses_of_nsw/grasses_of_nsw.htm [May 12th , 2012].

Wheeler, D. J. B., Jacobs, S. M. L. and Whalley, R. D. B. 2001. Grasses of New South Wales. The University of New England Armidale Australia [Online]. Available: http://www.fog.org.au/grasses_of_nsw/grasses_of_nsw.htm [June 28, 2012].

Wiecko, G. 2006, Turfgrass species. Fundamentals of Tropical Turf Management. CAB International, Wallingford, UK, pp. 18-38.

Wolfenbarger, D. O. 1953. Insects and mite control problems on lawn and golf. grasses. *Florida Entomol.* 36(1):9-12.

Wood, R.A. and Burchet, M.D. 1995. Developing interior foliage plants for the improvement of air quality. Acta Hort. 391:119-125.

Xu, Y. F., Chen, H., Zhou, H., Jin, J. W. and Hu, T. 2011. Acclimation of morphology and physiology in turf grass to low light environment: A review. *Afr. J. Biotechnol*. 10(48): 9737-9742.

Xu, Y. F., Sun, X. L., Jin, J. W. and Zhou, H. 2010a. Protective effect of nitric oxide on light-induced oxidative damage in leaves of tall fescue. *J. Plant Physiol.,* 167: 512–518.

Yeam, D. Y., Portz, H. L.and and J.J. Murray . 1980. Establishing Zoysiagrass from seed. 21st Illinois Turfgrass Assoc., Champange, IL, pp. 72-80.

Youngner, V. B., Marsh, A. W., Strohman, R. A., Gibeault, V. A.and Spaulding, S. 1981. Water Use and Turf Quality of Warm-season and Cool-season Turfgrasses, California Turfgrass Culture. 31 (3-4): 1-4.

Yu, T. Y. and D. Y. Yeam. 1968. the effect of seeding date, age of seed and kind of soil covering on germination of *Zoysia japonica* seed *Kor. Soc. Hort. Sci*. 4:73-78.

Zanthorea. 2012. Dichondra Lawn. [online]. Available: http://docsfiles.com/pdf_dichondra.html [8 August, 2012].

Zuk, A., Knodel, J. and Smith, R. 2011. Home lawn problems and solutions for North Dakota [Online]. Available: www.ag.ndsu.edu [20 May, 2012].

Zummo, Natale, and Plakidas, A. G. 1958. Brown patch of St. Augustine grass. Plant Dis. Reptr. 42:1141-1147.

Appendix

Appendix 1. Weather data at Vellanikkara during the period of study

Months	Temperature (°C)		Relative Humidity (%)	Sun shine (hrs)	Rainfall (mm)	Number of rainy days
	Max.	Min.				
Jan- 12	32.8	21.3	58	9.5	0.0	0
Feb- 12	35.1	22.1	54	9.2	0.0	0
Mar-12	35.2	24.2	67	7.6	3.5	1
Apr-12	34.7	24.8	73	6.6	101.9	8
May-12	32.6	25.3	76	6.0	117.3	5
Jun-12	30.1	23.9	85	2.6	551.5	23
Jul- 12	30.0	23.7	85	3.2	375.8	19
Aug-12	29.2	23.0	86	2.9	616.5	18
Sep-12	30.4	23.3	83	4.6	191.8	14
Oct-12	32.1	23.5	77	6.1	145.6	10
Nov-12	32.5	22.7	69	7.5	46.7	3
Dec-12	33.0	23.2	58	8.1	19.8	2

PERFORMANCE EVALUATION OF TURF GRASS SPECIES IN THE HUMID TROPICS

By

ABDUL RAZIQ
(2010-12-120)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Pomology and Floriculture
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

2014

ABSTRACT

The present study entitled "Performance evaluation of turf grass species in the humid tropics" was carried out at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara from January 2012 to August 2013. The objective was to evaluate the performance of turf grass species with respect to growth, establishment rate and tolerance to biotic and abiotic stresses in order to introduce new grass species for the tropical lawns.

Ten turf grass species, viz., *Cynodon dactylon, Stenotaphrum secundatum, Zoysia japonica, Paspalum notatum, Eragrostis curvula, Cynodon dactylon 419, Poa pratensis, Lolium perenne, Agrostis palustris, Dichondra micrantha* were selected for the study. The first four species were local and the remaining six were imported from the USA. Three species, viz., *Poa pratensis, Lolium perenne and Agrostis palustris* did not establish and hence further studies were carried out on the remaining seven.

Besides the studies in the open field condition, their tolerance to shade and air pollution were also evaluated. The experiment was laid out in CRD for shade tolerance studies and RBD for open field condition with three replications. Various vegetative and qualitative characters were recorded and data were statistically analysed.

The maximum duration for total coverage of the area was recorded by *Paspalum notatum* (189 days) and the minimum by *Eragrostis curvula* (100 days). There were significant differences for plant height and shoot length in shade and open field conditions. Leaf length, leaf width, leaf texture, leaf colour and arrangement of unfurled leaves were recorded and were used for categorizing the species. Based on leaf width, plants were categorized into fine, coarse and medium coarse textured. Leaf colour was categorized as light, medium and dark green. According to arrangement of unfurled leaves, they were classified as rolled and folded.

Root characters were recorded in terms of number, length and root shoot ratio. Growth habit was recorded as spreading and upright. Response of different turf grass species to mowing was recorded in terms of time taken for first mowing, relative mowing height, weight of biomass removed at first mowing, recuperative ability, frequency of mowing and mowing tolerance. The maximum duration for first mowing was recorded by *Dichondra micrantha* (174.7 days) and the minimum by *Eragrostis curvula* (57.7 days). The later showed the highest value (3330.7g) for biomass and the minimum (30.0 g) was by *Zoysia japonica*.

Relative mowing height in open field condition was recorded as low in *Cynodon dactylon 419* and *Zoysia Japonica,* medium for *Dichondra micrantha* and *Cynodon dactylon* and high in *Paspalum notatum, Eragrostis curvula* and *Stenotaphrum.* Recuperative ability was poor in *Dichondra micrantha, Paspalum notatum* and *Eragrostis curvula* and high in *Cynodon dactylon 419* and *Cynodon dactylon.*

Mowing frequency was less in *Dichondra micrantha, Cynodon dactylon 419, Zoysia japonica and Stenotaphum secundatum.* It was more in *Paspalum notatum, Eragrostis curvula.* Mowing tolerance was low in *Dichondra micrantha, Paspalum notatum* and *Eragrostis curvula* whereas it was high in *Cynodon dactylon 419, Cynodon dactylon, Zoysia japonica.* Response to mowing followed the same pattern under various shade levels also.

Air Pollution Tolerance Index of *Dichondra micrantha* was the highest (24.8) and the lowest value (8.35) was observed for *Cynodon dactylon.* Turf grass species were categorized into sensitive (value ≤ 14), intermediate (15-19), medium tolerant (20-24) and tolerant (>24). All the species, except *Dichondra micrantha,* was sensitive to air pollution.

Major pests observed were, leaf eating caterpillars (army worm) in *Paspalum notatum* and *Eragrostis curvula* and termites in *Dichondra micrantha*, *Zoysia japonica, Cynodon dactylon 419*, *Eragrostis curvula*, and *Paspalum notatum*. Rats were another problem in turf area. No serious disease was observed except the gray leaf disease, caused by *Pyriculari grisea* which was found in *Stenotaphrum secundatum.*Weeds affected the turf growth seriously, both under shade and in open field conditions. The important weeds were *Alloteropsis cimicina, Ageratum conyzoides*, *Lindernia crustacean*, *Cyperus iria*, *Cyperus rotandus* , *Digitaria bicornis, Synedrella nodiflora, Mimosa pudica and Desmodium triflorum.*

Among the turf grass species evaluated under open field condition *Cynodon dactylon 419, Cyndon dactylon, Zoysia japonica, Stenotaphrum secundatum* and *Paspalum notatum* were suitable for lawn under humid tropical condition. *Eragrostis curvula,* though not suitable as a turf grass, can be grown in pots and also as an edge plant. Among the turf grass species evaluated under various shade levels (0%, 25% and 50%) Dichondra *micrantha*, *Zoysia Japonica* and *Paspalum notatum* performed better under 25 per cent and zero per cent shade levels and *Stenotaphrum secundatum* at the shade levels tried.