Environmental Management of Golf Courses Turfgrass:

Water, Fertilisers and Chemicals

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WATER

Introduction

Water is an increasingly scarce resource in a wide part of the earth. It is not a local problem but a global issue that affects any human activity.

At the same time there is no universal answer to all landscape water – management issues. Any solution must be realised according the specific considerations on the site.

Climate is changing in Mediterranean Regions.

WATER

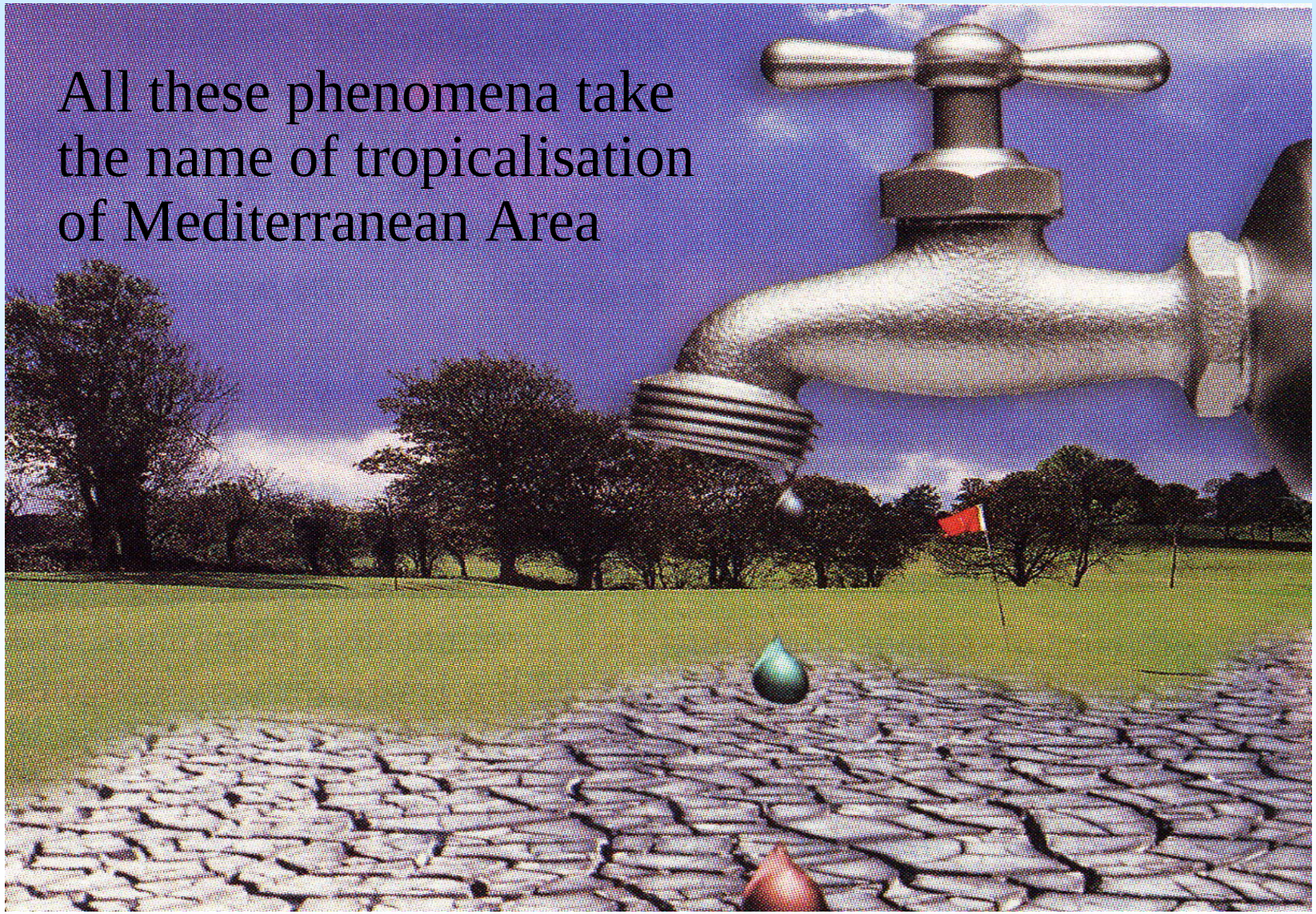
Changes in Mediterranean climate

It has been predicted that from April to September in North Africa and Middle East, from now to 2050, climate will be characterised by a reduction in rainfall by 20 / 25 % The winter season too is believed to be characterised by a drop in rainfalls, althought to a lesser extent (10 / 15 %). The temperature will increase by 2 / 2,75 °C inland and by about 1,5 °C along the coasts. (Ragab R, Prudhomme, 2002).

WATER

Changes in Mediterranean climate

In many regions of the Mediterranean areas, the low rainfall and limited water availability are, since now, the major developing concerns. The desertification process is increasing in many coastal areas in Spain, Italy, Greece and north of Africa. This makes these lands very sensitive to water supplying.



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WATER

Prospect for the future

Because in Mediterranean regions water is and will be the most important problem to control in achieving an environment friendly design and maintenance of golf courses, Local Authorities, Environmental Organisations, Golf Designers, Superintendents and Greenkeepers have to work together in order to develop guidelines able to reduce water consumption.

WATER

Water on turf

To plants water is:

- Vital constituent of the protoplasm
- Required for photosynthetic activities
- The end production of respiration
- The transport medium for nutrients
- Organic compounds and gases
- Moderator of temperature change of the protoplasm

(James Beard, 1973)

WATER

Water on turf

Water on turf is:

- Absorbed by the roots (the major quantity).
- Absorbed through the leaves (limited amount) and coming from dew (condensation and guttation).
- Transpired from the leaves (it is cooling process for plants).

WATER

Water on turf

Water use rate is defined as the total amount of water required for turfgrass growth in addition to the quantity transpired from grass plant and evaporated from the soil surface.

(Karl Danneberger, 1999)

WATER

Water on turf

Plants contain a variable % of water (between 75 and 90 %) by weight. A decrease of 10 % is enough for turf death. No more than 3 % of total absorbed water by plants is used in metabolic processes. It is estimated that about 600 kg of water are required to produce 1 kg of dry matter (Karl Danneberger, 1999)

WATER

Annual Water rate on turf is depending from

- Climatic condition (temp. humidity, wind, rainfall, exposure)
- Soil morphology and structure
- Type of Turfgrasses
- Type of turf management
- Pressure of traffic
- Amount of surface covered by irrigation

WATER

Annual Water rate on a golf Course

- 18 holes – fws in Creeping bentgrass (*Agrostis stolonifera*) 200 / 225.000 m^3)
- 18 holes – fws in Mix *(Lolium perenne, Poa pratensis, Festuca rubra)* 60 / 170.000 m^3)
- 18 holes – fws in warmseason grasses (i.e. Bermudagrass) 100 / 170.000 m^3)

Golf Courses vs crops?

Water

Annual water consumption (m^3) among crops in Mediterranean Regions

(based on 100 ha surface , mean data – Croce P., Mocioni M. - 2005).

Crops	Av. Prod. in ton.	Av. Water consum.
Corn *(Zea mays)*	**1.200**	**500 / 600.000**
Rice (*Oryza sativa*)	**650**	**1.300 / 3.250.000**
Soybean (*Glycine max)*	**350**	**150 / 500.000**
Tomato (*Solanum Lycopersicum)*	**5.000**	**500 / 700.000**
Potato (*Solanum tuberosum*)	**2.300**	**375 / 525.000**
Citrus fruits	**1.600 / 4.200**	**500 / 800.000**
Grapes (*Vitis vinifera)*	**1.800 / 2.500**	**250 / 400.000**
Olive tree (*Olea europea)*	**150/500**	**150 / 250.000**
Carrot (*Daucus carota)*	**2.500**	**300 / 400.000**
Golf course (*Agrostis stolonifera fws*)		**200 / 225.000**
Golf course (mix fws)		**60 / 170.000**
Golf Course (Bermuda fws)		**100 / 170.000**

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WATER

Prospect for the future

Guidelines should be referred to:

- How to build a golf course to save water
- How to manage a golf course to save water

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WATER RESOURCES IN TURFGRASS

Golf Course Construction

In order to reduce water consumption in general, but also to arrive at a more rational and even supply, the following requirements have to be met:

- Designing the course to save water
- Using of effluent water or other alternative water sources
- Improving soil
- Selecting the proper species (turfgrass, but also trees and bushes)
- Designing and realising a good irrigation system

WATER

Design the course to save water

It is necessary to avoid competition with other consumers (as farmers, urban centres, industries) to water supply. The aim in golf construction is to differentiate supply and whenever possible, to use rainwater. This means the golf course has to be designed so that rainwater can be collected into specific reservoirs.

WATER

Design the course to save water

Artificial basins have to be realised with great care in order to avoid a negative impact on water tables and to get a good introduction on landscape. Water reserves have to be sufficient to irrigate the golf course throughout the growing season, even in periods of prolonged drought.

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WATER

Design the course to save water

Collect all the water on the soil surface and subsurface (drainage) to constantly feed the reservoirs and recycle excess irrigation water. It is not a simple thing to do. Golf designers must be very qualified and the land has to be in a favourable position.

WATER

Design the course to save water

- Turfed areas and water demanding landscape areas are held to a minimum, resulting in water savings of 50 % or more (James T. Snow, National Director of U.S.G.A. Green Section).

WATER

Design the course to save water

Water requirements on a 18 holes Par 72 golf course (Croce et al., 1996)

Water requirements	Surface	% of maintained area	% of total area
Very high	Greens / Collars	5	3
High	Tees	4	2
Medium / high	Fairways	38	23
Medium / low	Semi rough/ Driving range	28	17
Low	Rough	25	15
None	Natural or renaturalised area	0	40

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WATER

Design the course to save water

Water consumption on a 18 holes Par 72 golf course, surface by surface, based on 160.000 m^3 of annual water and cool season grasses as turf. (Croce et al., 1996)

N° days of irrigation	Surface	Annual water consumption in m^3	% of total volume
150	Greens / Collars	10.500	6,5
150	Tees	7.500	4,5
130	Fairways	97.500	61
130	Semi rough and Driving range	27.000	17
60	Rough	17.500	11
None	Natural or renaturalised area	0	0

WATER

Using of effluent water or other alternative water sources

Whenever possible, use waste water from urban depurators. At the moment researches show there are no negative effects on turf. (A possible problem could be represented by the high bacterial presence in this water).

If necessary (when the water was submit to a partial treatment) create a specific phitopurification area before feeding the pump station. Natural factors as: solar radiation, filtering, absorption and bio concentration can help plants in reducing pollution from nitrogen, phosphorus, metals, virus and bacteria.

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WATER

Using of effluent water or other alternative water sources

Recycled water provide moisture and nutrients to turf while helping the municipality avoid discharging the effluent water into nearby rivers. The turf does an excellent job of filtering the water nutrients and breaking down various chemicals and biological contaminants in the water (James T. Snow).

WATER

Using of effluent water or other alternative water sources

Use of brackish water, or even ocean water, could be introduced as supplement of other water sources. *Seashore paspalum* shows an excellent tolerance of high salt content water, but also Bermudagrass is quite tolerant too. The Old Collier Golf Club in Naples (Florida) where two new cultivars of *Seashore paspalum* are planted on greens, tees, fairways and rough, will be using ocean water to irrigate the turf.

WATER

Using of effluent water or other alternative water sources

A further possible approach for using ocean or brackish water could be to build reverse osmosis (RO) desalinisation plants. It is a very expensive choice, but it represents a resource in all the sites where other water supplies are not available. Also, the Reverse Osmosis process is able to provide drinkable water to community.

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WATER

Improving soil

When the golf course has to be constructed on sites with poor or inconsistent soils, a good (but expensive) solution is to cap these soils with about 15 cm layer of sand, to allow uniform water infiltration and significant reduction in water use by reducing run off and avoiding over application of irrigation water (James T. Snow).


HANOMAG
HANOMAG

WATER

Selecting the proper species

A proper choice among turfgrass species and cultivars is a must in order to reduce water consumption. For this aim warm season grasses are by far the best option. *Cynodon spp*, *Zoysia spp*, *Paspalum vaginatum* and *Buchloe dactyloides* are the turf species with the lowest water use. A general tolerance of salinity of these species is also a very important character.

Warmseason grasses areal

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WATER

Selecting the proper species

Relative drought resistance among turfgrass species (Croce et al., 2005)

Cynodon spp	10
Paspalum vaginatum	10
Zoysia spp	9
Festuca rubra	8
Stenotaphrum secundatum	7
Poa pratensis	6
Lolium perenne	4
Agrostis stolonifera	3
Poa annua	2
Poa trivialis	1

WATER

Selecting the proper species

Relative water need values among turfgrass species (Panella et al., 2000)

Poa annua	10
Agrostis stolonifera	9
Poa trivialis	9
Lolium perenne	8
Poa pratensis	8
Stenotaphrum secundatum	7
Zoysia spp	7
Festuca rubra	6
Cynodon spp	6
Paspalum vaginatum	6

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WATER

Selecting the proper species

- Use *Agrostis stolonifera* conservatively on fairways. This turfgrass can be employed in these areas, only for golf courses with a high maintenance budget and without problems for water supply.


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WATER

Selecting the proper species

Among the warm season turfgrasses the *Cynodon* species and *Paspalum vaginatum* are characterised by superior drought resistance, salt tolerance and dehydration avoidance, which are related to extensive deep root systems (Beard, 1999; Beard and Sifers, 1997).

WATER

Designing and realising a good irrigation system

In the last years turfgrass industry was involved in a great improvement of irrigation system efficiency through the massive use of technology. In particular:

Proper irrigation system design

Weather stations

Irrigation uniformity

Computerised control system

WATER

Proper irrigation system design

An adequate design of the irrigation system especially in terms of range (at least double or triple), coverage (100 % or maybe more), number of sprinklers and capillary distribution of water (i.e. on collars) are strongly recommended in any situation where to save water is a must.

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WATER

Weather stations

The tendency toward over irrigation can be reduced using on site weather station (or maybe reporting services) to determine accurate daily water replacement needs. Other instruments including tensiometers, porous blocks, heat dissipation blocks, neutron probes and infrared thermometries can be very useful to evaluate turf soil moisture replacement.

WATER

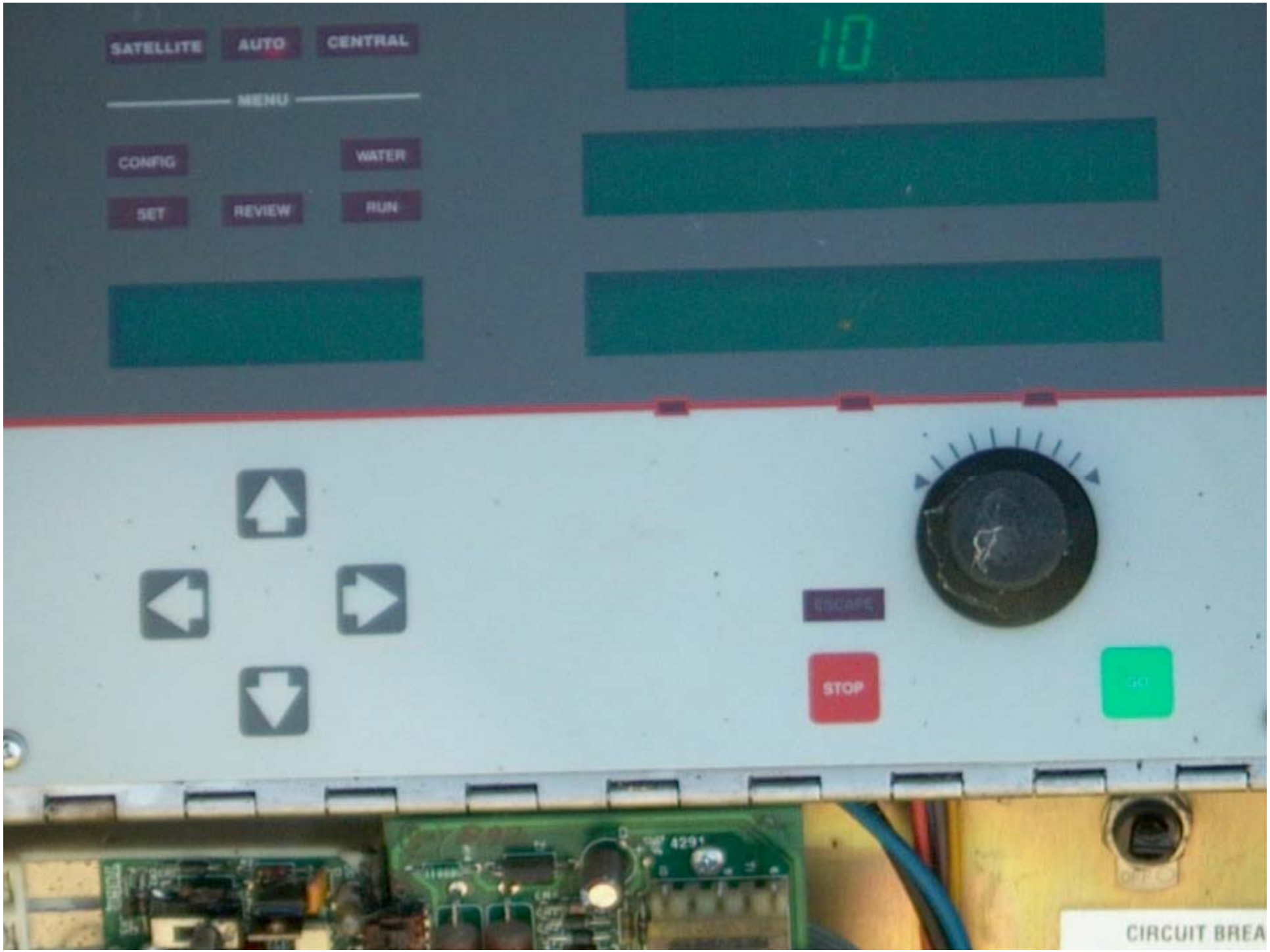
Irrigation uniformity

Irrigation uniformity can be improved through careful evaluation of sprinkler head design, nozzle selection, head spacing, pipe size and pressure selection. In this way it is also possible to combine sprinkler uniformity with relative turfgrass quality needs.

WATER

Computerised control system

New computerised control system, together with portable hand held controllers and variable frequency drive (inverter) pumping systems can really provide more efficiency in applying water and reducing water and energy consumption.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WATER

Computerised control system

All these technologies can achieve considerable savings of water and energy resources. For example, the Southern California Golf Association Members Club in Murrieta recently installed a new irrigation system that has reduced water use by about 35 %. And because the club is able to complete its irrigation schedule in a short time frame during night time hours, it has reduced its considerable energy cost by about 50 %. (James T. Snow).

WATER

Golf Course Maintenance

It is possible to save water through a combination of several factors as:

- Timing of irrigation
- Rate of irrigation
- Influence of other cultural practices

WATER

Timing of irrigation

- Best solution is to irrigate when the turf starts to wilt, before this phenomenon becomes permanent, in order to avoid too much stress and to optimise water consumption.
- A constant control of soil moisture (walking on turf or observing the soil profile) is necessary for this strategy.

WATER

Timing of irrigation

It is preferable to irrigate not so frequently, but abundantly so as to obtain a deeper root system and to prevent water drops from remaining on leaves for a long time, which can cause diseases.

WATER

Timing of irrigation

Irrigation during the night reduces water losses due to evaporation and transpiration, but it can severely damage turf by making it more susceptible to diseases. Therefore it is better to irrigate early in the morning, so that dew and leaf exudates rapidly disappear. Turf should not be irrigated when traffic is expected, otherwise soil compaction increases.

WATER

Timing of irrigation

- The perfect timing should maintain the water level in the soil at above 50 % of the total. Oversupply reduces the growth of shoots and roots. As a result turf will need more water and will be less resistant to traffic, heat, cold, drought and diseases.
- Daily irrigation is appropriate only for all the newly seeded or sodded areas or for putting greens in the peak of the summer.

WATER

Rate of irrigation

An efficient use of irrigation system is without question an important water conservation activity.

People waste water; plants don’t.

Overwatering not only wastes water, but it also weakens or kills turf more than underwatering.

WATER

Rate of irrigation

The amount of water to be supplied depends not only on the turf grass species, but also on the duration of irrigation that should be sufficient to wet the turf root system (15 / 20 cm of soil). In addition, it should be closely related to the infiltration velocity, in that excess water might be lost through run off.

WATER

Rate of irrigation

Compacts soils have a very low infiltration rate, between 1,2 and 2,5 mm / hour. In this case it is preferable to irrigate lightly and more frequently.

WATER

Influence of other cultural practices

Best management practices for water conservation include:

1. Adjusting mowing heights to ideal levels depending on species and seasonal water use characteristic.


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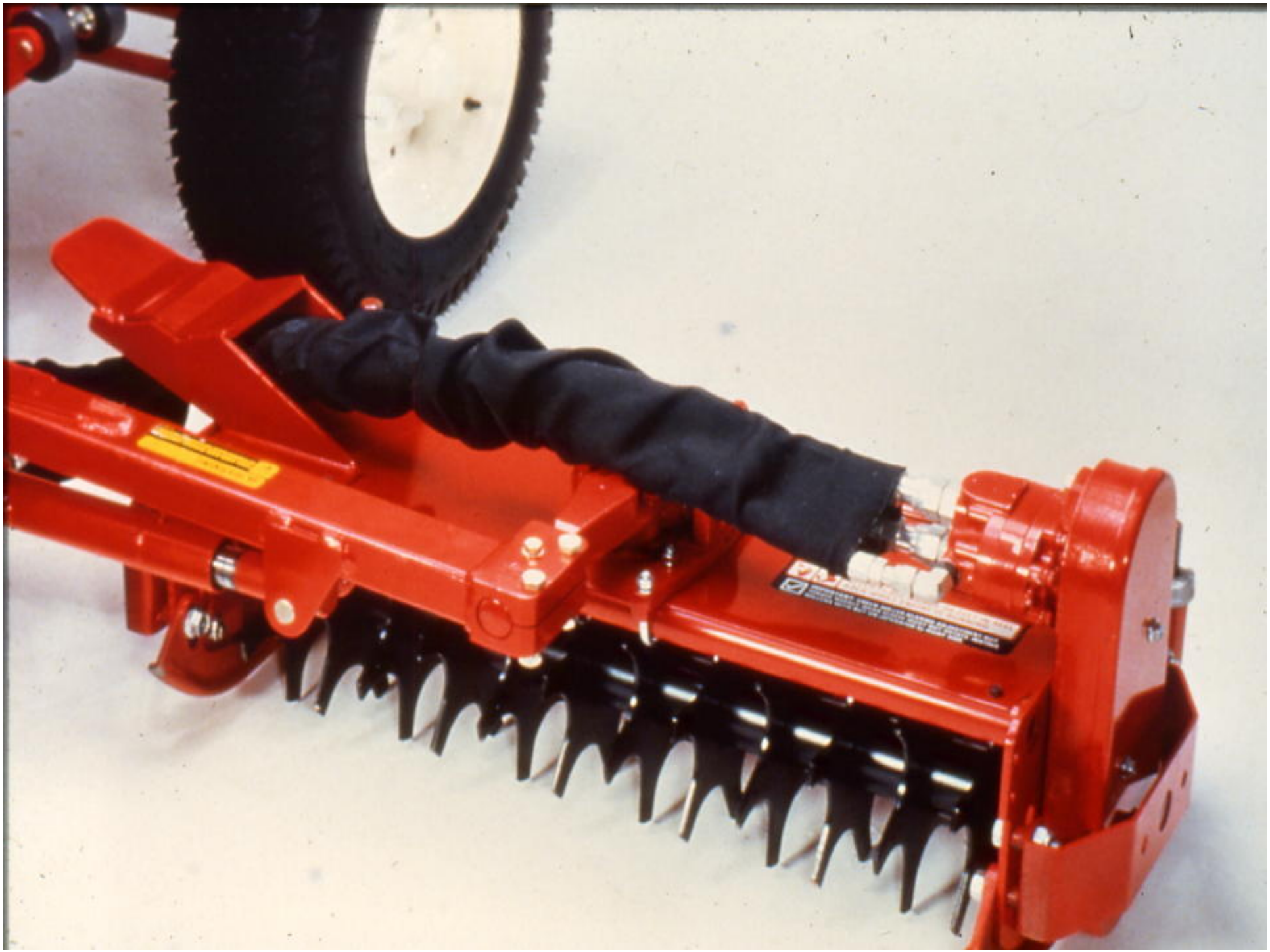
WATER

Influence of other cultural practices

2. Using soil cultivation techniques such as spiking, slicing and core aerification to improve water infiltration and minimise run off irrigation or rainfall.

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WATER

Influence of other cultural practices

3. Improving drainage where needed to produce a healthier turf with better root systems that can draw moisture from larger volume of soil compaction.
4. Cycling irrigation sessions to ensure good infiltration and minimise run off.
   Influence of other cultural practices
5. Pruning roots of trees near critical turf areas to prevent tree roots from competing with turf for moisture and nutrients.

FERTILISERS

Introduction

For environment friendly turf maintenance, fertilisation applications must be conducted accurately.

In fact in addition to making turf extremely sensitive to fungal diseases, fertilisers can be washed out and leach into the ground water

This is particularly true for nitrogen that is a very soluble and mobile nutrient.

FERTILISERS

Introduction

On turfgrass fertilisation the ultimate goal is to arrive at a negligible loss of fertilisers through leaching, especially on well drained soils.

On the contrary on crops fertilisation, the amount of nutrients lost for run off and leaching is usually very severe.

This because the shoot density of turf is much bigger of any crop's density

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FERTILISERS

Introduction

Nutrients requirements for a golf course turf, can vary with:

- Soil type
- Soil nutrient holding capacity (CEC)
- Amount of water applied
- Climate
- Turfgrass species and cultivars
- Pressure of players

FERTILISERS

Introduction

It does not exist a general fertilisation program able to solve any situation.

Any turf and any soil condition can involve different type of:

- Carrier
- Application rate
- Time of application

FERTILISERS

Introduction

A specific fertilisation program is a decision of the Golf Course Superintendent based on the specific conditions on the particular golf course.

Fertilisation on turf is quite different from crops. The target is the maintenance instead of the production. So the strategy of this cultural practice provides several operations with usually slow rate of material.

FERTILISERS

Introduction

Six are the elements essential for plant growth: Carbon, Oxygen and Hydrogen are present in high quantity (from 90 to 96 % of plant's dry weight).

But the most important macronutrients for plants growth are: Nitrogen (N), Phosporous (P) and Potassium (K).

FERTILISERS

When to apply fertilisers

Fertilisers should be applied in the peak growing period. From an environmental point of view (using coolseason turfgrasses):

- Avoid to apply N in late fall, late winter or in the summer, because this makes turf very sensitive to fungal diseases and abiotic stresses with greater pollution hazard for ground water.
- Do not apply too much fertiliser at irregular intervals so as to avoid growth peaks and the risk of nutrients loss due to leaching

FERTILISERS

How much fertiliser to apply

It depends on:

- Turfgrass species and cultivars (specific needs)
- Type of soil
- Type of fertilisers used (i.e. N carriers can be slow release or fast action)
- Turf growth rate
- Method of application (i.e. liquid or solid)
- Nutrients already present into the soil
- The removal of clipping

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FERTILISERS
N consumption on the main turfgrasses (Beard J. 2002)

Turfgrass species	Kg/ of N/100 m^2/month of growth
Agrostis stolonifera	0,25 / 0,65
Festuca arundinacea	0,20 / 0,50
Festuca rubra	0,05 / 0,25
Lolium perenne	0,20 / 0,50
Poa annua	0,15 / 0,35
Poa pratensis	0,15 / 0,40
Poa trivialis	0,15 / 0,30
Cynodon spp (Bermuda)	0,15 / 0,75
Zoysia spp	0,20 / 0,50
Paspalum vaginatum	0,20 / 0,50

FERTILISERS

Fertilisers on golf course

Avg. annual nutrients needs in a golf course with: Bermuda fws, 100 ha surface. (Croce, 2004)

Type	Surface (ha)	N (kg)	P_2O_5 (kg)	K_2O
GREENS	1,10	385	11	352
COLLARS	0,32	90	3	90
TEES	1,21	363	0	363
FAIRWAYS	14,22	3.413	0	3.143
SEMIROUGH	17,03	2.044	0	2.044
Tot in mainten.	**33,88**	**6.295**	**14**	**6.262**
ROUGH	12,42	0	0	0
T. playing sur.	**46,30**	**6.295**	**14**	**6.262**
Natural areas	53,70	0	0	0
TOTAL	**100,00**	**6.295**	**14**	**6.262**

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FERTILISERS

Fertilisers on golf course

Avg. annual nutrients needs in a golf course with: Mix fws, 100 ha surface. (Croce, 2004)

Type	Surface (ha)	N (kg)	P_2O_5 (kg)	K_2O
GREENS	1,10	440	11	352
COLLARS	0,32	128	3	102
TEES	1,21	290	0	242
FAIRWAYS	14,22	3.413	0	2.844
SEMIROUGH	17,03	1.703	0	1.703
Tot in mainten.	**33,88**	**5.974**	**14**	**5.243**
ROUGH	12,42	0	0	0
T. playing sur.	**46,30**	**5.974**	**14**	**5.243**
Natural areas	53,70	0	0	0
TOTAL	**100,00**	**5.974**	**14**	**5.243**

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FERTILISERS

Fertilisers on golf course

Avg. annual nutrients needs in a golf course with: Creeping bent fws, 100 ha surface. (Croce, 2004)

Type	Surface (ha)	N (kg)	P_2O_5 (kg)	K_2O
GREENS	1,10	440	11	352
COLLARS	0,32	128	3	102
TEES	1,21	387	0	290
FAIRWAYS	14,22	4.550	0	3.413
SEMIROUGH	17,03	2.044	0	2.044
Tot in mainten.	**33,88**	**7.549**	**14**	**6.201**
ROUGH	12,42	0	0	0
T. playing sur.	**46,30**	**7.549**	**14**	**6.201**
Natural areas	53,70	0	0	0
TOTAL	**100,00**	**7.549**	**14**	**6.201**

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Fertilisers

Annual fertilisers consumption (kg) among crops in Mediterranean Regions

(based on 100 ha surface , mean data – Croce P., Mocioni M. - 2005).

Crops consumption	Production (t)	N	P_2O_5	K
Wheat (*Triticum aestivum*)	600	17.500	7.200	15.500
Corn *(Zea mays)*	1.200	36.000	12.000	24.000
Rice (*Oryza sativa*)	650	10/13.000	10/11.000	10/13.000
Soybean (*Glycine max)*	350	0	5.000	7.000
Tomato (*Lycopersicum esculentum*)	5.000	13.500	5.000	23.000
Potato (*Solanum tuberosum*)	2.300	20.000	18.000	18.000
Grapes (*Vitis vinifera*)	1.800/2.500	8/10.000	6/8.000	15/20.000
Olive tree (*Olea europea*)	150/500	10/15.000	6/8.000	10/12.000
Citrus fruit (*Citrus spp*)	1.600/4.200	15/20.000	10/15.000	15/18.000
Apple tree (*Malus communis*)	3.000/5.000	10/12.000	4/5.000	10/15.000
Golf course (*Agrostis stolon. fws*)		7/8.000	0	6/7.000
Golf course (mix fws)		6/7.000	0	5/6.000
Golf Course (Bermuda fws)		6/7.000	0	6/7.000

CHEMICALS

Introduction

In order to rich an environment friendly turf maintenance as regards chemicals, Golf Course Superintendents usually apply the Integrated Pest Management (IPM).

IPM can be defined as a system to fight against pests, fungi and weeds. Once the cause of the damage has been established, an economic threshold is set (below which is not necessary to take action).

CHEMICALS

Introduction

Then all the cultural, biological, chemical and physical techniques are evaluated and used in order to successfully keep pests under control.

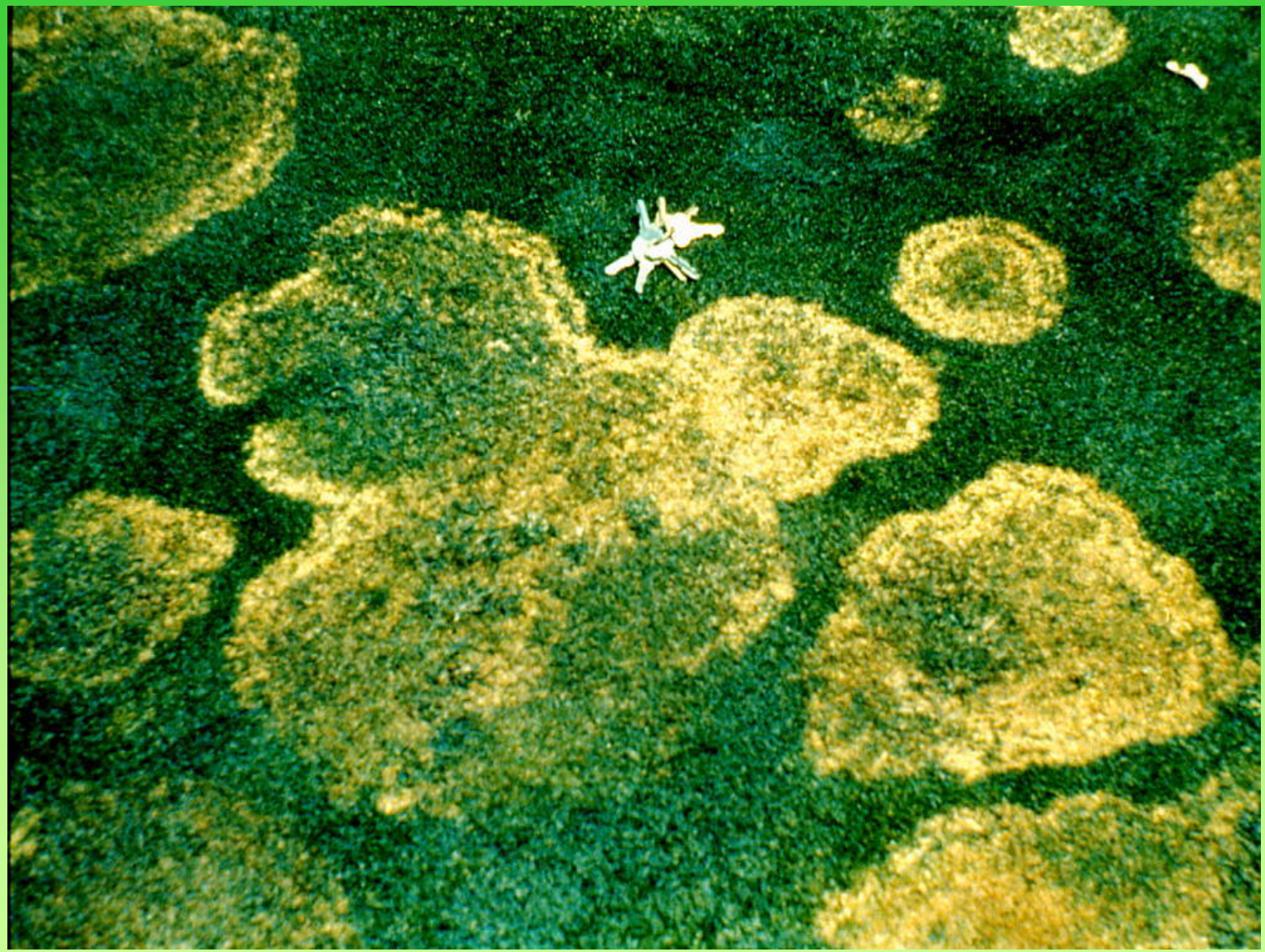
Therefore, these strategies are not designed to completely eradicate the pathogen, but to keep it below a threshold of damage.

CHEMICALS

IPM

IPM strategies are chosen according to:

- Their success potential
- The characteristics of the site
- The health of workers and the people in general
- The health of flora and fauna
- Their cost effectiveness
- Environmental sensitivity (water bodies, rare wildlife…)



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CHEMICALS

IPM strategy

The basic components of IPM are:

- Collection of historical data
- Knowledge of pathogens or weeds
- Diagnosis
- Continuous monitoring
- Evaluation of factors able to promote the activity of pathogens and weeds

CHEMICALS

IPM strategy

The basic components of IPM are:

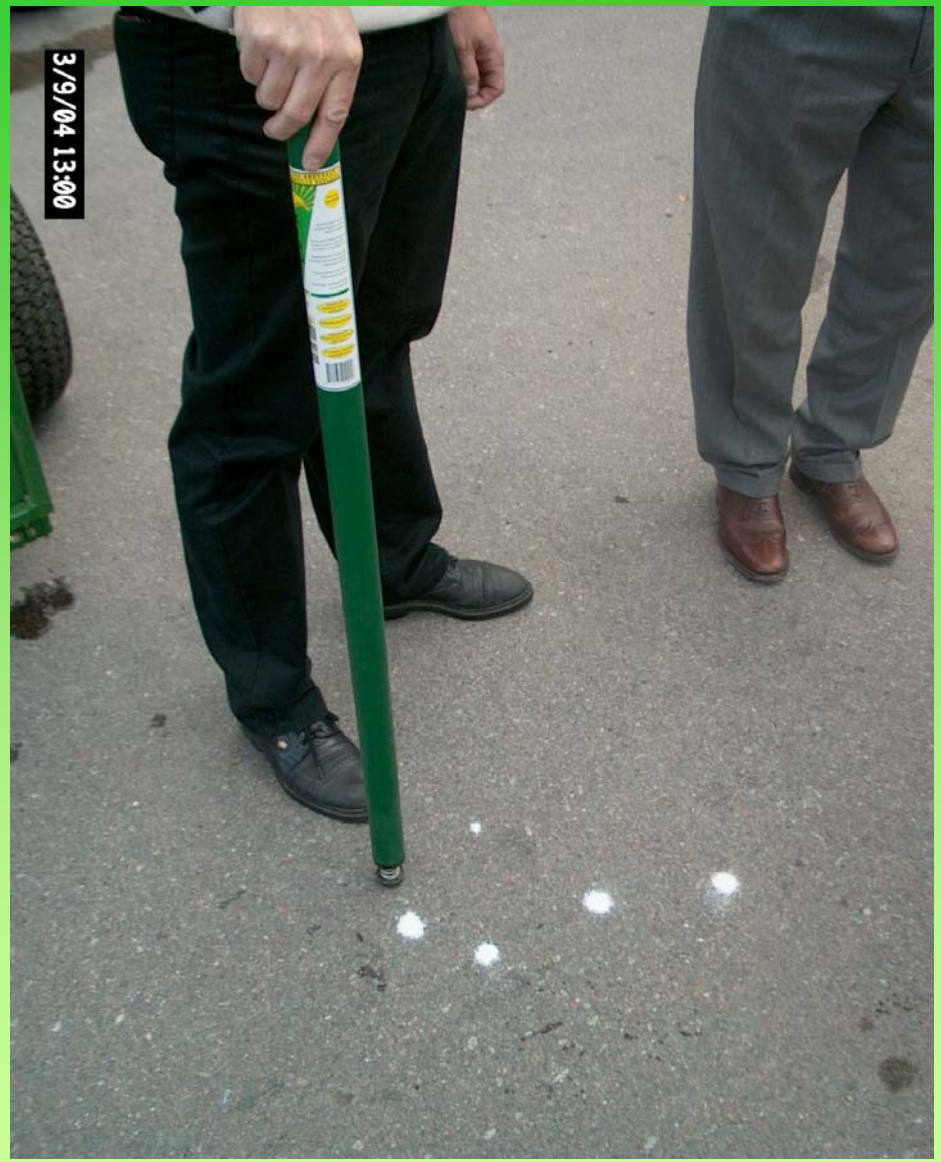
- Economic threshold
- Selection of management strategies
- Training of maintenance staff
- Timing and location of the actions
- Evaluation of results obtained

CHEMICALS

IPM

There are six different type of IPM actions for turf:

- Regulatory (certified seed, free of weeds)
- Genetic (species and cvs tolerant to that pest)
- Cultural (maintain the turf without any stress)
- Physical (isolating infected area, steam)
- Biological (promoting natural competition)
- Chemical (the last option using pesticides)



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CHEMICALS

Chemicals on golf course

Avg. annual chemicals needs in a golf course with: Bermuda fws, 100 ha surface. (Croce, 2004)

Type	Surface (ha)	Herbicides	Fungicides	Insecticides
GREENS	1,10	0	51	10
COLLARS	0,32	0	11	3
TEES	1,21	0	53	11
FAIRWAYS	14,22	23	84	103
SEMIROUGH	17,03	0	0	0
Tot in mainten.	**33,88**	**23**	**199**	**127**
ROUGH	12,42	0	0	0
T. playing sur.	**46,30**	**23**	**199**	**127**
Natural areas	53,70	0	0	0
TOTAL	**100,00**	**23**	**199**	**127**

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CHEMICALS

Chemicals on golf course

Avg. annual chemicals needs in a golf course with: Creep.bent. fws, 100 ha surface. (Croce, 2004)

Type	Surface (ha)	Herbicides	Fungicides	Insecticides
GREENS	1,10	0	75	12
COLLARS	0,32	0	22	3
TEES	1,21	0	65	12
FAIRWAYS	14,22	60	280	80
SEMIROUGH	17,03	0	0	0
Tot in mainten.	**33,88**	**60**	**442**	**107**
ROUGH	12,42	0	0	0
T. playing sur.	**46,30**	**60**	**442**	**107**
Natural areas	53,70	0	0	0
TOTAL	**100,00**	**60**	**442**	**107**

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CHEMICALS

Chemicals on golf course

Avg. annual chemicals needs in a golf course with: Mix fws, 100 ha surface. (Croce, 2004)

Type	Surface (ha)	Herbicides	Fungicides	Insecticides
GREENS	1,10	0	81	12
COLLARS	0,32	0	16	3
TEES	1,21	7	46	12
FAIRWAYS	14,22	101	93	80
SEMIROUGH	17,03	0	0	0
Tot in mainten.	**33,88**	**108**	**236**	**107**
ROUGH	12,42	0	0	0
T. playing sur.	**46,30**	**108**	**236**	**107**
Natural areas	53,70	0	0	0
TOTAL	**100,00**	**108**	**236**	**107**

Paolo Croce

Golf Environment Europe

CHEMICALS

Annual chemicals consumption (kg) among crops in Mediterranean Regions based on 100 ha surface , mean data – Croce P., Mocioni M. - 2005).

Crops	Herbicides	Fungicides	Insecticides	TOTAL
Wheat	400	100	150	650
Hard Corn	400	0	0	400
Corn	500	0 / 200	0 / 150	500 / 850
Rice	4.000 / 6.000	1.000 / 2.000	0 / 300	5.000/8.300
Red beet	2.450	760	250	3.460
Soybean	1.000	0	0	1.000
Sunflower	1.400	0	0	1.400
Tobacco	450	90	0	540
G.C. Agrostis fws	60	442	107	609
G.C. Mix fws	108	236	107	451
G.C. Bermuda fws	23	199	127	349

The final goal of Superintendents

'Optimising the playing quality of the golf course in harmony with the conservation of its natural environment under economically sound management.'

The R&A Golf Course Committee 2004

Golf Environment Europe