

CONSTRUCTION AND MAINTENANCE OF TURFGRASS AREAS IN BRITAIN AND WESTERN EUROPE*

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Britain's well known natural ability to produce green grass throughout the year is in some ways a handicap. With us grass just grows and the approach of a great many people (including especially those who control expenditure) is conditioned by this to a rather marked degree. The fact that the grass may be annual meadow-grass (*Poa annua* or Annual blue grass), or that surface conditions are entirely unsuitable, or that drainage is abominable tends to be regarded as divinely ordained or alternatively the fault of the groundsman. In some Continental countries it is coolly accepted (without apparent evidence) that it is impossible to have grass tennis courts simply because no one has got down to trying properly. Such attitudes of mind have held back progress substantially but after years of uphill plodding we at Bingley can now see a marked change in attitude and approach. There is now a lively and growing interest in research and education.

Western European conditions generally differ only moderately from those of Britain and generally Europeans have copied British practice closely and indeed the advisory service of the STRI (Sports Turf Research Institute) is widely used on the Continent.

Variations in climate do have their implications, of course. In North and East Europe winter hardiness figures prominently, in Southern Europe the problems are related to low rainfall and higher temperatures which under artificial watering lead to marked disease problems.

The average rainfall in England and Wales is about 36 in. (21 in. to 102 in. according to district). Sunshine varies from 926 hours in the North of Scotland to 1840 hours in the Isle of Wight. Our coldest months are January and February and our warmest July and August. The lowest monthly average temperature of 35.9° F was recorded at Dumfries in Scotland in February and the highest of 64.4° F at Southend in England during August.

CONSTRUCTION PROCEDURES

When an organization requires a new golf course, it calls in a golf course architect to examine the site and to design a course. Usually he is also required to get out detailed specifications on which to seek tenders and to supervise until completion. Again usually the Institute is consulted on technical matters and commissioned to help in the supervision. There are variations on this theme, however. One architect has an associated contracting firm and offers a package deal — "design and construct a golf course." He does, however, get out a

proper specification for the contracting side to work to. Another architect gets out very brief specifications and suggests that a particular firm be given the job. Some clubs have paid for a design only, thereafter advancing by devious ill-organized procedures. In golf course construction there is a built-in reluctance to face the high capital costs in making a good job from the beginning, it being said that extra work will be done by the staff over the years. In fact, of course, even if everything is done well in the first place, there's still a lot for the staff to do for years! The item which has suffered most is drainage — many golf courses have been constructed and are still being constructed with inadequate drainage of tees, fairways and greens, even on low-lying wet clay land. Recommendations to drain existing courses are not always accepted on the grounds that they have managed all right for fifty years!

The British approach to new playing fields and sports ground is rather different. We still have backwoodsmen, particularly in small local authorities, who consider that an area of land constitutes a playing field even if it is a peat bog or a steeply sloping hillside! However, the average position is very different indeed — it is accepted that pitches must be reasonably level so that grading is nearly always required and the axiom that "land drainage is always required unless proved otherwise" is widely accepted. Equally the need for proper detailed specifications, experienced specialist playing field contractors and intelligent supervision is fully appreciated in the main. Unfortunately, theory and practice don't always coincide and we at Bingley are often called in to advise how to put right new grounds which have gone badly wrong.

In golf course construction and in playing field construction, the main troubles arise from mishandling the site in the British climate. Grading is only practicable when heavy machinery is used and this costs money even when idle! Construction work is done mainly in the summer but we do not have a settled dry summer very often — wet periods are by no means rare. Under the pressure of economics, and often under pressure from the client who wants the job completed quickly, contractors tend to work when the earth is wet, thus emphasizing the compaction and damage to soil structure which is almost inseparable from the use of heavy machinery. Intensive sub-soil cultivation in the later stages of construction, i.e. after top soil spreading, can do much to remedy the situation but this is just becoming appreciated.

Top soil amelioration with sand and peat is accepted as a good thing but considerations of cost frequently

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it impossible to do this adequately if at all. A strange difficulty frequently encountered is the absence of good ploughmen among the contractor's staff and it is often surprisingly difficult to get any of the normal top soil cultivation work done to a good standard.

Soil tests are made to determine whether there is need for lime and to guide in recommendations for fertilizer pre-treatment which quite often takes the form of a granular complete fertilizer, e.g. one containing 10% N, 15% P₂O₅ and 10% K₂O at the rate of 400 to 600 pounds per acre.

Mixtures of grass seeds are commonly sown and it is an interesting coincidence that throughout Europe a large proportion of the fine grasses used — chewings fescue and colonial bentgrass — come from Oregon. Oregon chewings fescue has performed quite well but, with an increasing awareness of the value of improved varieties now becoming widespread, there is now a demand for better chewings fescue such as Highlind which is possibly being grown for seed in Oregon now. As regards colonial bentgrass, Highland is still highly regarded, new varieties available as yet showing little pronounced superiority. For fine turf mixtures (bowling greens, golf greens, fine lawns, cricket tables) the usual mixture is:

- 8 parts chewings fescue
- 2 parts colonial bentgrass

sown at the rate of 1 oz. per sq. yd. The two grasses a good blend and if the chewings fescue does not persist, it has nevertheless served as a good nursecrop for the bent which is slow to establish and hence if sown alone offers an invitation to invasion by weeds and weed grasses. Creeping bent (*Agrostis stolonifera*) is rarely used in Britain but on the Mediterranean it does stand the conditions better than colonial bent (*Agrostis tenuis*) and many Spanish golf courses, for instance, are established from stolons of a local creeping bent.

For lawns and sports areas which are not mown too closely, e.g. 1/2-3/4 in. a medium range type of mixture might be used, such as:

- 2 part chewings fescue (*Festuca rubra* var. *fallax*)
- 2 parts creeping red fescue (*Festuca rubra* ssp. *rubra*)
- 2 parts crested dogtail (*Cynosurus cristatus*)
- 2 parts rough-stalked meadow-grass (*Poa trivialis*)
- 2 parts colonial bentgrass (*Agrostis tenuis*)

Unfortunately, commercial supplies of crested dogtail and rough-stalked meadow-grass seem to have lost their persistency and a good Kentucky bluegrass may be substituted to give a mixture such as:

- 3 parts chewings fescue (*Festuca rubra* var. *fallax*)
- 3 parts creeping red fescue (*Festuca rubra* ssp. *rubra*)
- 2 parts Kentucky bluegrass (*Poa pratensis*)
- 2 parts colonial bentgrass (*Agrostis tenuis*)

The above mixtures are usually sown at about 1 oz. per sq. yd. Creeping red fescue is sometimes sown in fine turf mixtures but in our experience has very poor persistency under the heights of cut of 3/16 in. such as used for very fine turf.

For general purposes such as football grounds and open parks, mixtures such as the following are used:

- 35 lb. perennial ryegrass (using a good variety such as S-23)

- 28 lb. chewings fescue (usually Oregon)
- 28 lb. creeping red fescue (a good variety such as the British S-59)
- 14 lb. Kentucky bluegrass (e.g. the Dutch variety Prato or Merion)
- 7 lb. Colonial bentgrass (usually Oregon)

112 lb.

for use at 150 pounds per acre (1/2 oz. per sq. yd.). In addition to the grasses mentioned above, some use is made of sheep's fescue (*Festuca ovina*), hard fescue (*Festuca duriuscula*) and fine-leaved sheep's fescue (*Festuca capillata*). The public continues to ask merchants for grasses suitable for use in shade conditions and despite the fact that it does not persist under mowing conditions at all, wood meadow-grass (*Poa nemoralis*) is still widely sold.

As referred to previously, good named varieties are being increasingly demanded when they are available but there is still a considerable trade in very ordinary grass seed. At the present time, grass seed sold in Britain is not subject to the Seed Act which covers agricultural seeds and which demand disclosure of the contents of the mixtures. Changes in the Law are possible and some firms have anticipated this by disclosing the contents of their mixtures of which they may list six to twelve different priced commodities for different purposes.

Except in the South of Europe, establishment of turf from stolons is very rare indeed. Turfing, however, is fairly common in the preparation of new areas of turf which are to be intensively used, e.g. cricket tables and bowling greens. Until recently, we have had no specialist growers of turf in Britain and even now there are very few who work in quite a small way. There are, of course, people who deal in turf — people who acquire existing turf from chalk downs, from semi-moorland, from old pastures or from sea marshes on certain areas of the coast. There is a tradition that bowling greens should be laid with sea marsh turf, this being probably due to effective sales promotion in the past coupled with certain attractive characteristics of the material. This turf contains fine grasses (a blend of creeping red fescue and creeping bent) and because of the earth in which it grows (a stone-free, fine sand or silt), it is easy to cut and lay uniformly so that a newly laid bowling green is soon ready for first class use. The area from which the turf is taken is left to natural regeneration, possibly with some help from fertilizers and/or over-seeding with hand collected seed from the marshes. The turf laid on the bowling green deteriorates in composition fairly rapidly and usually, after about five years, it is mainly annual bluegrass (*Poa annua*). Nowadays some bowling greens are produced from inland turf or by sowing grass seed but the old tradition dies hard. Incidentally, trouble with dollar spot disease in Britain is related almost entirely to the fescue of bowling greens of sea marsh origin.

Cricket tables (typically 30 yards square) are most commonly produced from inland turf supplied to an "approved" quality which means that the client accepts the best that turns up locally. He looks for a preponderance

of fine grasses growing in heavy soil without weeds or too much fibre, since cricket is played almost directly on earth.

New tennis courts may be turfed but are probably produced more often from seed, possibly because of the cost factor.

AFTER CARE OF NEW TURF AREAS

It has become increasingly realized in recent years that turf newly established from seed needs generous amounts of nitrogenous fertilizer. On extensive areas this may take the form of three or four dressings of sulphate of ammonia or high nitrogen granular complete fertilizer in the first year. On finer areas, mixtures of sulphate of ammonia with dried blood and hoof and horn meal are generally used. Other practical requirements are, of course, regular mowing and appropriate top dressing of bowling greens, tennis courts and cricket tables to produce smooth surfaces — these are not always easy to arrange because owners do not seem to appreciate that they need ground staff before they are using the ground!

MANAGEMENT

Whether we are dealing with sports grounds or golf courses, the playing surface and its properties are the items which are of consequence. 'Management in the first place must be directed specifically to producing the playing surface required but clearly should take into consideration minimizing of problems arising from weeds, pests and diseases.

Regular mowing is the management factor which, above all else, distinguishes cultivated turf and the composition of a sward is very much influenced by it, since grasses and weeds vary in their tolerance to mowing. In Europe it is not really sufficiently appreciated that different grass species and even individual varieties of grasses may vary in their tolerance to different height of cut and sometimes grasses are sown which have no chance of persisting under the mowing regime required. Frequency of mowing is also important in maintaining a thick, hard wearing sward. In British conditions fine turf needs to be mown two or three times a week according to growth conditions and sports fields at least once per week, although some Education Authorities, for example, do not always succeed in achieving this. Infrequent mowing or over-keen mowing, relative to the grass species present, obviously weakens turf and lets in weeds, including moss. Allowing cuttings to fly increases weed incidence and here one has to include the controversial annual meadow-grass (*Poa annua*). Under our conditions, the soft, luscious surface produced and the decomposing cuttings also encourage earth worms, whilst the same conditions and the increased amount of annual meadow-grass encourage *Fusarium* patch disease when the weather conditions are suitable. Boxing off cuttings is regarded as impracticable on extensive areas of turf but there the grass species are often different; the grass being longer is better rooted and has better vigor and there is usually less intensive feeding.

TOP DRESSING

Top dressing with bulky material is regarded as an important aspect of turf maintenance. As well as contributing to the value of the area for its purpose, a smooth surface makes for even mowing and better appearance. Although rolling is necessary to some extent to smooth

out and firm up surfaces, top dressing is considered the best way of providing a smooth surface. On extensive areas of football pitches, it may be sandy soil or sand. For fine turf such as lawns, bowling greens and golf greens, properly prepared compost is considered far superior to other materials but in modern times substitute top dressing is often used, e.g.

3 parts sharp lime free sand	} by volume
2 parts light loam soil	
1 part fine granulated peat	

the actual mix, of course, depending on the materials available locally and economically. On cricket tables the requirements are rather different and a rather heavy soil is used which will roll out smooth when moist, hold together well under the severe user requirements, and produce an adequately high bounce of the cricket ball.

ROLLING

Rolling, and repeated heavy rolling at that, is undoubtedly an important requirement for the production of good cricket wickets and it will be readily appreciated that this produces problems in drainage. On other turf areas, occasional light rolling is normally preferred so as to avoid trouble with compaction and drainage impedance. Some rolling is nevertheless required for many games to produce or to restore the surface required. On golf courses the greens probably only get rolled once a year in the spring to settle them up after the winter weather and it is believed that many greens do not even get this, sufficient firming up being obtained from play and equipment.

AERATION

The term aeration is commonly used to describe the operations of spiking, etc., which are routine maintenance. An important characteristic under British conditions is that making these holes not only lets air in but also helps water out and through to the drains. Regular spiking, e.g. at weekly intervals, is therefore carried out during the whole of the winter playing season on football pitches, hockey pitches and similar. On fine turf areas, insufficient aeration is probably done on the whole since many clubs regard one spiking in the autumn as constituting aeration. Hollow tine forking is, of course, the best way of relieving compression and facilitating passage of air and moisture but its effects on playing conditions are not always acceptable, particularly for cricket tables, and, of course, it has been clearly demonstrated that the openings in the turf left by hollow tine forking facilitate the entry of weeds and weed grasses.

FERTILIZER TREATMENT

Cultivated turf generally receives fertilizer treatment at intervals and the kind, amount and timing have important effects. There is a tendency for many people to regard the use of fertilizer as the be-all and end-all of turf management. It is an important factor but it is only one factor and there are others at least as important. It is interesting to note that British practice and the practice in some parts of America seem to differ rather a lot. We find unacceptable the idea that we have heard propounded that the correct amount of fertilizer, particularly nitrogen, is the maximum that can be got away with. Instead we strive after an optimum having regard to the consumer's pocket as well as his turf needs.

Trials by the Institute over the years have clearly dem-

onstrated the value under our conditions of a balanced mixture of straight inorganics (sulphate of ammonia, superphosphate and sulphat of potash) in maintaining a sward tough and hard wearing and also weed, worm, and disease free for a very long time. Bearing in mind user requirements such a mixture cannot be claimed to be perfect - control of weeds, pests and diseases does not automatically mean turf suitable for the purposes' intended — but certainly the mixture forms a sound basis for any treatment that is to be used.

Addition of a proportion of organics in mixture for fine turf helps to even out growth and produce a better color for winter and mid summer. Too much organic fertilizer has, however, been shown to favor weeds, worms and disease, particularly our worst, Fusarium patch. Research work at the Institute has also shown that spring fertilizer is the most significant fertilizer in effecting the permanent quality of the sward. For example, if we apply sulphate of ammonia in the spring and dried blood in the autumn, the kind of turf produced is quite different from the kind of turf produced if we apply dried blood in the spring and sulphate of ammonia in the autumn. Turf receiving only sulphate of ammonia tends to be firm and free of weeds, worms and diseases whilst turf receiving only dried blood is prone to all these. Plots treated with sulphate of ammonia in the spring and dried blood in the autumn bear a close resemblance to sulphate of ammonia plots, whilst plots treated in the spring with dried blood and in the autumn with sulphate of ammonia bear a close resemblance to dried blood plots. At Bingley we are doing work on various slow release nitrogen fertilizers and our tests indicate that the "synthetic organics," i.e. the ureaform fertilizers, produce long term results on turf similar to those obtained from natural organics. We have been disappointed with the persistency of the nitrogen from this type of fertilizer — we have had quick growth reaction as from sulphate of ammonia from about one-third of the nitrogen content, whereas there seems to have been little benefit from the other two-thirds.

On extensive areas of turf, such as football fields where cuttings are allowed to fly, thus adding organic matter and re-cycling plant foods, there is not the same need for organic fertilizers. In addition, there is usually a greater need for encouraging firm, dry conditions and on such areas nowadays straight granular fertilizers based on inorganics are commonly used, e.g. 10% N, 15% P₂O₅, 10% K₂O product at 300 pounds per acre.

Fertilizers, such as nitrate of soda, nitro-chalk and bone compounds, which tend to keep the soil pH high also tend to encourage weeds, worms and disease and are therefore used sparingly. Use of any fertilizer at all likely to encourage marked leaf growth in the autumn months, may have practical value sometimes but certainly leads to a greater incidence of Fusarium patch disease. Shortage of nitrogen on the other hand encourages red-thread disease which can often, in face, be dealt with most advantageously by a dressing of nitrogenous fertilizer. Dollar spot disease is not very common in Britain, occurring only on creeping red fescue of sea marsh origin but it is always most conspicuous in a low nitrogen regime and nitrogenous fertilizers will go far to at least disguise the symptoms. Shortage of nitrogen generally or in proportion to the

amount of phosphate and potash commonly leads to invasion by wild white clover (*Trifolium repens*), a weed which until the advent of CMPP has been difficult to eliminate.

Sulphate of iron in calcined form is sometimes added to fertilizer mixtures, particularly for fine turf. It helps to produce a tough type of growth of good color and helps to keep turf free of weeds, worms and disease. Sulphate of iron is a recognized constituent of the lawn sand type of weedkiller (which, at one time, was the only kind of weedkiller available) and it is not without its use for the control of moss and Fusarium patch disease. The reputation of sulphate of iron has suffered quite a lot through excessive use by some advocates. Regular heavy use leads to a turf consisting of desirable fine grasses but which is rather thin and possesses poor drought resistance.

Reference has been made to the undesirability of making regular use of fertilizers which tend to keep soil pH too high. There is little doubt that under British conditions some slight degree of acidity is of considerable help in maintaining a sward free of weeds, earthworms and diseases, although some weeds, such as sorrel (*Rumex acetosa*), are encouraged by over-acid conditions. As always, however, we have to face the fact that what we are interested in is the production of turf for a purpose and it may be necessary to maintain a pH higher than that theoretically necessary to grow good turf. Nevertheless, the use of lime is attended with such inconvenience and detriment to turf that it is normally embarked upon only after careful examination of the relevant factors. Even when lime is essential because the pH has become too low to grow the kind of grass and turf required, its use is frequently followed by some trouble with weeds or earthworms or fungal disease. Ophiobolus patch is a disease the incidence of which is often consequent upon the use of lime or other alkaline material, supporting factors being wetness and often low plant food status.

CONTROL OF WEEDS, PESTS AND DISEASES

At Bingley, we hold strongly the view that prevention is better than cure and that the best way of controlling weeds, pests and diseases is through management. Nevertheless, in an imperfect world, trouble is experienced with these things and appropriate chemical treatments have to be undertaken.

Our most common weeds are daisy (*Bellis perennis*), dandelion (*Taraxacum officinale*), catsear (*Hypochaeris radicata*), mouse-ear chickweed (*Cerustium vulgatum*), pearlwort (*Sagina procumbens*), wild white clover (*Trifolium repens*), creeping buttercup (*Ranunculus repens*) and moss. For the control of weeds, 2,4-D preparations are still commonly used but in most situations there is a mixed weed population including such weeds as clover (*Trifolium repens* which is resistant to 2,4-D but susceptible to CMPP (Mecoprop) . It is therefore not surprising to find that the most commonly used weedkillers are proprietary products containing both 2,4-D and CMPP. Even then there are still, of course, a few weeds which cause difficulties and trials have been going on with other chemicals. Ioxynil/CMPP has proved pretty useful for some weeds, e.g. parsley piert (*Alchemilla urvensis*) and speedwell (*Veronica filiformis*).

Moss is one of the weeds which seems to cause users most concern, often such concern being out of all proportion to the circumstances, i.e. a user may get very worried about a few square inches of moss and fail to notice patches of daisies (*Bellis perennis*) or Yorkshire fog (*Holcus Lanatus*) and lots of annual meadow-grass (*Poa annua*). There are, of course, many species of moss which occur in turf in Britain and for control management usually needs to be examined very closely, the incidence of moss being related to some weakness in the turf growing procedure. In the past, sulphate of iron has been used as a specific against moss and it is still used. Nowadays, however, a rather expensive treatment with a product containing Calomel (mercurous chloride) is often used.

Weed grasses present a problem which has not been solved. Some research work is taking place on this but there are no really good answers as yet.

The most widespread pest in Britain and most of Europe is the earthworm. There are, of course, several species of earthworms and it is the two or three which make casts which really worry us. Chemical treatments include Lead Arsenate at 2 oz. per sq. yd., Chlordane at 12 lbs. active ingredient per acre and Sevin at 3 lbs. active ingredient per acre. In Britain the only other pest of any real consequence is the leatherjacket (the grub of the crane fly [*Tipula* spp.]) which occasionally causes trouble on seaside golf courses where damage is done by the pests eating grass roots, particularly in the late autumn and early spring, the damage not being recognized until the shortage of root is revealed during dry weather the following May. Treatment is fairly simple with practically any soil insecticide, e.g. DDT, Benzene hexachloride, Aldrin, etc.

Occasional trouble is experienced from fever fly larvae (*Dilophus* and *Bibio* spp.) and from ants. Cutworms (the larvae of certain species of moths) are only to be seen in ones and twos in British turf but maspive attacks are encountered in the Southern parts of the Continent, thousands of grubs eating their way through the turf and ruining the playing surface. Ants have proved a considerable nuisance in the South of France, particularly on new sown ground. On the Continent wild boars may do considerable damage grubbing up cockchafer larvae and

in the Ardennes there are three golf courses which had to be completely fenced off to keep out these animals.

Fairy rings, often the bad ones caused by *Marasmius oreudes*, are not uncommon on old established golf courses but the laborious procedure of digging out or sterilizing with formaldehyde is only occasionally undertaken.

Referring back to the main diseases attacking turf, it is perhaps interesting to note that preventive applications of fungicide are not very common in Britain where greenskeepers and groundsmen tend to think that the necessity to incur the expense of fungicide treatment is a reflection on their skill in keeping the turf healthy!

COMPETENT STAFF

Efficient construction and management call for skilled staff and staff training has been conspicuous by its absence. In Britain, greenskeepers and head groundsmen have all reached their positions by promotion through the ranks without any real tuition. The one-week courses at Bingley have, of course, flourished for many years, however.

Some four years ago, a golf greenkeepers apprenticeship scheme was commenced. This involves a three-year training period with technical college tuition and finally a week's course at Bingley. The National Association of Groundsmen hasn't an apprenticeship scheme but has actively stirred up local authorities to produce tuition in the elements of the sciences involved in groundsmanship and runs its own examination scheme with a 3rd, 2nd and 1st class certificate and a Diploma, a holder of which would be deemed to be of a standard to become a County Playing Fields Officer capable of organizing maintenance of scores of school playing fields.

There is indeed a ferment at the moment as regards education for training in turf grass matters. Even contractors are affected since they come under a State sponsored Construction Industry Training scheme which calls for levies which are spent on training employees. This particular scheme (there are others) is aimed chiefly at the Building Industry but has caught up the playing field contractors.

Turf grass research is also arousing wider interest than formerly both in Britain and in Europe and it may well be that the next ten years will see greater advances than the last decade.

THE CHARACTERISTICS OF UREA FORMALDEHYDE

By VICTOR A. GIBEAULT

In the thirteenth century the game of lawn bowling was first introduced to the English public and with this new sport came the need for a flat, low-cut turfed area, preferably of grass. It was soon realized by the greenskeepers of that time that a healthy stand of grass was required to obtain a vigorous, pleasant colored, weed-free, disease-free sward. Fertilization of turfed areas was then founded.

Early turf fertilizers included animal manure, guano,

nitrate of soda, industrial wastes, plant and animal processing wastes and untreated sewage sludges. The continuous supply of these products was a definite requirement especially for turf because nutrient incorporation occurred only once with this crop. Thus, frequent light applications of soluble materials or the use of organic materials were required. Unfortunately, the former often scorched the grass, yielded a blotchy appearance because of uneven distribution, and required numerous man-hours for application, while the latter were low analysis, bulky, difficult to handle materials. Contamination of the organics was also a problem. To reduce the man-hours needed and to

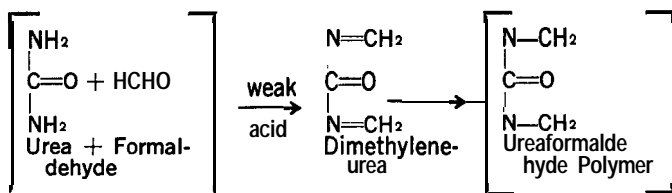
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insure even growth response, a nitrogen source would have to be developed which supplied the needed nutrient slowly and evenly over the entire growing season. It is not surprising therefore to note the enthusiasm of turf workers with the introduction of slow release nitrogen sources such as ureaformaldehyde.

This paper will survey some of the basic information on ureaformaldehyde in an attempt to further understanding of this particular nitrogen source..

SYNTHESIS

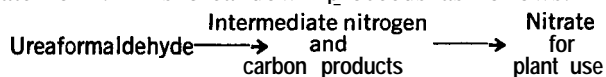
Ureaformaldehyde (hereafter referred to as ureaform or UF) is prepared by reacting the common agricultural nitrogen source, urea, with formaldehyde in the presence of a weak acid. This can be illustrated by the following formula (6).



A number of polymers form from this reaction; the type depends on the mol ratio of the reactants, the reaction temperature, the time the reaction is allowed to proceed, and the pH of the reacting mixture. Polymer length for fertilizer use is believed to vary from two to six units.

The mol ratio mentioned above is defined as the moles of urea to the moles of formaldehyde used in the preparation of the polymer. Mol ratios less than 1 yield resins that are used in plastics whereas Yee and Love (6) found that ratios above 1, especially between 1.18 and 1.36, could be used for fertilizers. They arrived at these conclusions following the evaluation of ratios from .88 to 2.0.

They showed that both the solubility and nitrification values increased with each increase in ratio. The rate of nitrification is particularly important since it governs the rate that UF nitrogen is converted to the plant available nitrate form. This breakdown proceeds as follows:



CHARACTERISTICS OF UREAFORM

The mol ratio is one means of evaluating the potential usefulness of UF types; the second is the activity index. Tysdale and Nelson (5) define the activity index (AI) by the following equation.

$$\text{AI} = \frac{\% \text{ Cold water insoluble} - \% \text{ Hot water insoluble}}{\% \text{ Cold water insoluble}} \times 100$$

where

% Cold water insoluble = % Nitrogen insoluble in 25°C water, and
 % Hot water insoluble = % Nitrogen insoluble in 9-100°C water.

For a UF to be considered a fertilizer, the AI must not be less than 40%. (Also, the product must contain at least 35% nitrogen). The suitability of UF types for fertilizer use is therefore dependent upon the quality and quantity of the cold water insoluble nitrogen, which is the source of slowly available nitrogen. The relationship between the activity index of various UF products and the rate that they are nitrified is illustrated in the following graph (5).

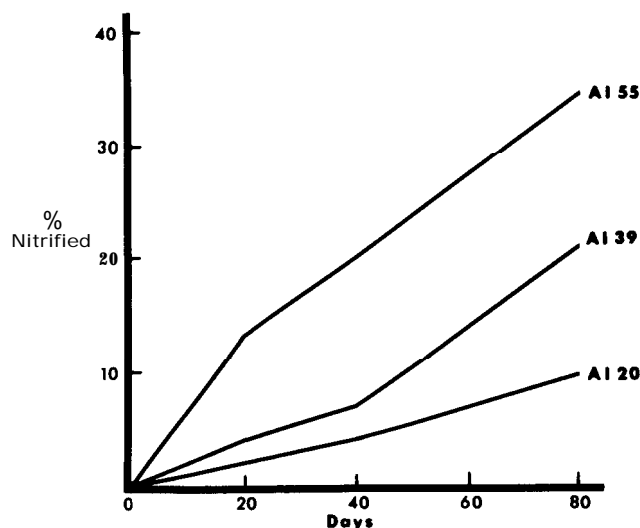


Figure 1. The nitrification of three ureaformaldehyde compounds.

The rate that UF products release nitrogen for plant use is directly related to the AI characterizing the respective products.

It should be stressed that not all ureaform nitrogen is in the insoluble forms mentioned above; in fact, a percentage, usually around 25%, is found as free urea or low-molecular-weight ureaformaldehyde. These constituents readily go into the soil solution and will give a plant response similar to other soluble nitrogen sources.

To combine some of the concepts previously discussed, typical UF fertilizer compound as given by Kralovec and Morgan (3) is presented:

Total Nitrogen (TN)	Percent 38.5
Insoluble Nitrogen (IN)	29.0
IN/TN	75:0
Availability Index	55-60
Free Urea	6.0
Water	3.0

The nitrification rate of the theoretical compound was shown to be affected by several environmental factors:

First, it was reported that a greater amount of insoluble UF nitrogen was nitrified at a soil pH of 6.1 in comparison to soils with a reaction of 7.3 or 5.0. This is graphically illustrated in Figure 2.

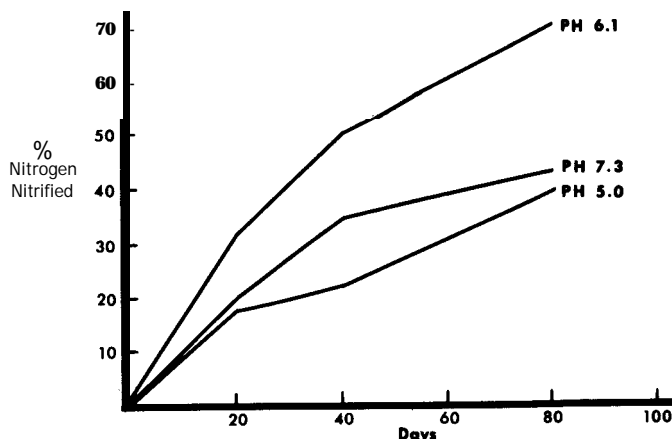


Figure 2. Soil nitrification of a ureaformaldehyde fertilizer compound as affected by initial pH.

Second, the presence of phosphorus and potassium was shown to increase the nitrification process. Figure 3 illustrates this fact.

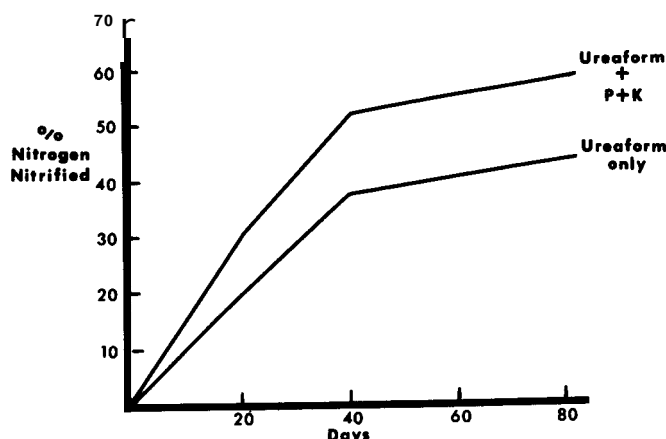


Figure 3. The nitrification of a ureaformaldehyde compound with/without phosphorus and potassium.

Although pH and the presence of potassium and phosphorus affect nitrification, Fuller and Clark (2) conclusively demonstrated that it was caused by microorganisms. They found that chemical hydrolysis, which is responsible for the nitrification of most soluble nitrogen sources, does not degrade the insoluble ureaformaldehyde. Therefore, it can be concluded that any environmental condition that hampers microorganism activity, such as low temperature, soil type, etc., will reduce the rate of nitrogen release. This has been reported both from observations and experiments.

Kralovec and Morgan also compared the nitrification rates of ureaform with urea, ammonium sulfate and a low mol ratio UF product. The results are presented in Figure 4.

Nitrogen was rapidly nitrified from the soluble sources whereas ureaform yielded a slow, uniform release of the nutrient. The amount of nitrate produced at one month from UF can probably be attributed to the soluble fraction. A low, unacceptable rate of release was observed from UF resin scrap.

USE AS A PRACTICAL FERTILIZER

The use of ureaform was tested on many crops but as Long and Volk (4) indicated, the cost and slow nitrogen supply made it prohibitive on many. High value plant material such as turfgrass and certain ornamentals could, they felt, make use of such a product.

PHOSPHATE NEEDS FOR TURFGRASS ESTABLISHMENT

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Phosphorus is an important plant nutrient in the establishment of a good turfgrass root system. Other functions of phosphorus such as respiration, seed development, protein formation and disease prevention are equally important, but during the early stages of plant

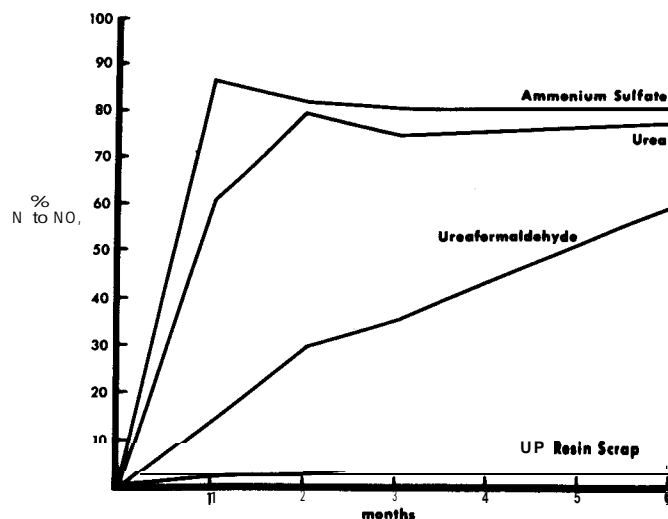


Figure 4. Nitrification rates of various nitrogen sources.

Following testing in California, Byrne and Lunt (1) reported that a residual level of UF must be maintained for uniform turfgrass growth. This level is necessary because only 6 to 7 percent of the ureaform is mineralized per month. They, in addition to all turf workers, have found UF safe to apply at higher than normal rates.

In conclusion, it can be stated that because of the high cost of labor and the desire for uniform turfgrass growth, a long lasting slow release fertilizer has a place in turf management. Ureaformaldehyde of the proper mol ratio and activity index yields an even supply of nitrogen for a comparatively long period of time, as do other, newer, slow release products. An understanding of these materials is essential to obtain the best results.

1. Byrne, T. and O. A. Lunt. Ureaformaldehyde: Controlled Availability Fertilizers. California Agriculture 16(3):10-11. 1962.
2. Fuller, W. H. and K. G. Clark. Microbiological Studies on Ureaformaldehyde Preparations. Soil Science Society of America Proceedings, 12:198-202. 1948.
3. Kralovec, R. D. and W. A. Morgan. Condensation Products of Urea and Formaldehyde as Fertilizer with Controlled Nitrogen Availability. Journal of Agriculture and Food Chemistry, 2:92-95. 1954.
4. Long, F. L. and G. M. Volk. Availability of Nitrogen from Condensation Products of Urea and Formaldehyde. Agronomy Journal, 55:155. 1963.
5. Tysdale, S. L. and W. L. Nelson. **Soil Fertility and Fertilizers**. New York: The MacMillan Company. 694 pages. 1966.
6. Yee, H. and K. S. Love. Nitrification of Urea-formaldehyde Reaction Products. Soil Science of America Proceedings, 11:389-392. 1946.

growth phosphorus should not be deficient because proper root development depends to a large extent upon phosphorus.

As a plant is establishing itself, its root system is very limited. These early roots come in contact with only a

few inches of surface soil which means that a relatively high level of phosphorus should be present. A lower level of soil phosphorus may be sufficient for older plants because their roots explore more soil surfaces.

Many of the non-woody plants have responded to phosphorus in the soils of California. These responses have, for the most part, been in agricultural crops but equivalent responses would be expected in turfgrasses. Soils in areas where plants are most likely to respond to phosphorus are the reddish brown soils on terrace lands along the edge of valleys, alluvial soils in narrow valleys, sandy soils, most upland soils, and soils which have considerable "cut and fill" areas.

Soil analysis can be helpful in determining the need for phosphorus. However, care should be taken to request that a method of phosphorus extraction be followed which has been correlated with turfgrass response. The sodium bicarbonate extraction method has been correlated with plant response to phosphorus. The results with several turfgrasses indicate that soils containing less than 5 ppm of phosphorus are deficient; those with 5 to 8 ppm may possibly be deficient; and those with more than 8 ppm have adequate phosphorus. If the surface 3 or 4 inches of soil contains at least 8 ppm, preferably more than 10 ppm, the soil will have adequate amounts of phosphorus to properly establish turfgrass. There is one exception to the results obtained by this method. If the soil has a pH of less than 5 the results may not be valid. Soil areas with these low pH values are not common in California but they do occur along the edge of bays and on coastal terraces.

Selection of soil sampling sites can also influence the

results obtained. Consideration should be given as to the depth of sample, time of sampling in relation to site preparation, number of samples to be taken, and how samples are to be composited.

Phosphorus does not move in the soil by leaching to any extent. Soon after addition to a soil, very soluble forms of the phosphorus combine with calcium, iron, aluminum, silica or organic compounds to form sparingly soluble phosphates. The kind of compounds formed and their solubility is determined to a large extent by the soil pH. Phosphorus is most available between pH of 5 and 7.5. In other words phosphorus added to the soil will go into what might be considered a storehouse for future use by the plant. If the soil pH is maintained in the favorable range for phosphorus availability, plants can draw on this source for a long time.

In view of what has been said so far, a reasonable approach to phosphorus fertilizer in preparation for turfgrass seeding is as follows: At the time of the final surface preparation, just before seeding, add 15 pounds of single super phosphate per 1000 sq. ft. and lightly work into the top 2 to 4 inches of soil. This will be more than adequate for good plant growth. None of the phosphate will be lost. Single super phosphate was selected because this fertilizer provides a small amount of gypsum which will help to improve soil structure and prevent crusting. If this is not considered necessary, then any high water soluble phosphorus fertilizer applied at the rate of 3 pounds of P₂O₅ per 1000 sq. ft. could be used. (Phosphorus in fertilizer is often given as percent P₂O₅ or a fertilizer with a formula of 0-20-0 would contain 20%

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