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information regarding fertilization, cutting height, weed control, aeration, liming and irrigation. The information included both past and present management practices.

Average hardness data for position and field type for all recording periods are shown in Table 1. With a heavier object, there was a significant difference in hardness between areas inside and outside the hashmarks. Impact values were higher inside the hashmarks throughout the study. These higher values were associated with less turf cover, drier soil and/or more compact soil. The least amount of differences were in March measurements. This was attributed to the greater amount of frost heaving on the inside areas, which were bare or less densely covered with turf than the outside areas. The soil was loosened, causing lower impact values. As the year progressed, the differences increased.

With the heavier object, impact values for game fields were lower than for practice fields. The greatest differences were in November, following football season. Greater differences between field types as the year progressed were attributed to more intensive practice field use.

Impact values for the lighter hammer followed the same patterns.

In general, the lowest values reflected a combination of dense turf, low soil bulk density and high soil moisture.

And artificial turf?

As observed in Table 2, values obtained at various times on a new artificial turf field fell within the range of the natural high school fields. A practice field that had frozen was much harder than either artificial or natural unfrozen turf. Values for floor surfaces in a home were higher than values for the high school fields. It should be noted that variation would also be expected for different artificial turf surfaces or floor surfaces in homes.

Values for shear resistance (traction) are shown in Table 3. On each measurement date, these values were lower—although not always significantly lower—for practice fields and positions inside the hashmarks (except for November, 1987).

Turf or soil giving way under foot would be associated with lower shear values. Certain impacts between players might make it better for the soil or turf surface yield than a player's joints. From the standpoint of efficiency of play, the variation in footing, as indicated by a range of shear values for the same field, could affect performance as players move from one area of the field to another.

Maintenance levels

It is unfortunate that practice fields, used more than game fields, received less maintenance. Such findings indicate that in turfgrass management decisions, game field appearance may receive more attention than playing quality of both practice and game fields. Fortuately, much of the maintenance work aimed at appearance also improves the playing surface. However, a need to educate field managers on the role of turfgrass management in providing a good playing

Field hardness was most significant between hashmarks, a result of less turf cover, drier soil and/or more compact soil.

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TABLE 1.

Hardness values for field type and position, November 1986-November 1987.

Field type and position	Nov 86	Mar 87	Jun 87	Aug 87	Nov 87
	Hardness: 2.25 kg hammer				
	gmax				
Game	65**	57	79	76	76**
Practice	80	59	90	94	94
Inside	85**	60**	90**	92**	98**
Outside	60	56	78	77	72
	Hardness: 0.5 kg hammer				
	Nov 86	Mar 87	Jun 87	Aug 87	Nov 87
	gmax				
Game	102**	78	105	96*	120**
Practice	123	82	127	125	157
Inside	137**	85**	132**	120*	166**
Outside	89	76	99	101	110

* Significantly different at the 5% level.
** Significantly different at the 1% level.
gmax = maximum deceleration.

Source: The authors

TABLE 2.

Impact values for high school fields vs. impact values for other surfaces.

Surface	Hammer 0.5 kg	2.2 kg
	gmax	
High school fields	50-286	33-167
Artificial turf	109-172	60-91
Frozen practice field	404	303
Tiled, concrete basement floor	1,440	1,280
Carpet and pad on tiled concrete floor	260	190
Carpet and pad on hardwood floor	86	134

gmax = maximum deceleration.

Source: The authors

TABLE 3.

Traction (shear resistance) values for field type and position, November 1986-November 1987.

Field type and position	Traction (shear resistance) Nov 86	Mar 87	Jun 87	Aug 87	Nov 87
	kPa				
Game	69	68	80*	62	82
Practice	68	62	68	58	78
Inside	67	57**	68**	55**	82
Outside	70	73	80	64	78

* Significantly different at the 5% level.
** Significantly different at the 1% level.
kPa = kilopascals (1 kPa = 0.145 lb in2)

Source: The authors

surface still exists.

Game fields were in better condition than practice fields. They had lower bulk densities, fewer weeds and more turf cover. Differences indicated that areas inside the hashmarks had more wear.

None of the fields in the study had modified soil. Native soils were all medium- to fine-textured loam, silt loam, silty clay loam and clay loam.

Variables

Variables were calculated in five categories: overall, game, practice, inside hashmarks and outside hashmarks. In general, an overall correlation existed between maintenance practices and vegetative variables. Fields receiving the best maintenance had the lowest weed cover and highest total turf cover. The correlation of N fertilization and aeration indicated that when one of these important maintenance inputs was intensified, so was the other.

A positive correlation was found between soil moisture and aeration levels. (Increased moisture probably reflects greater infiltation and less runoff on aerified fields.) There was slight correlation between field hardness and maintenance practices (As aeration and fertilization levels increased, field hardness decreased.)

Field hardness seemed to be affected most by percentage of soil moisture. In general, soil moisture correlated better with hardness as measured by the lighter hammer. In addition, an increase in bulk density was asociated with an increase in a field's impact value. Correlations between hardness and bulk density were not as great as those between hadness and percentage of soil moisture.

In general, then, when soil nutrient levels, N fertilization, core cultivation and weed and turf cover varied to indicate better maintenance practices, that variation accompanied a decrease in hardness.

For the most part, shear resistance values were not significantly correlated with maintenance practices, but for positions inside the hashmarks there was some indication that shear values decreased as weed cover increased. Weed populations were observed to be higher on worn areas where the turfgrass root system would be insufficient to create a high shear resistance. Field hardness and shear resistance relationships were both variable and slight.

Correlation between dates of the measured characteristics (hardness, traction, moisture, bulk density and weed cover) was variable. **LM**

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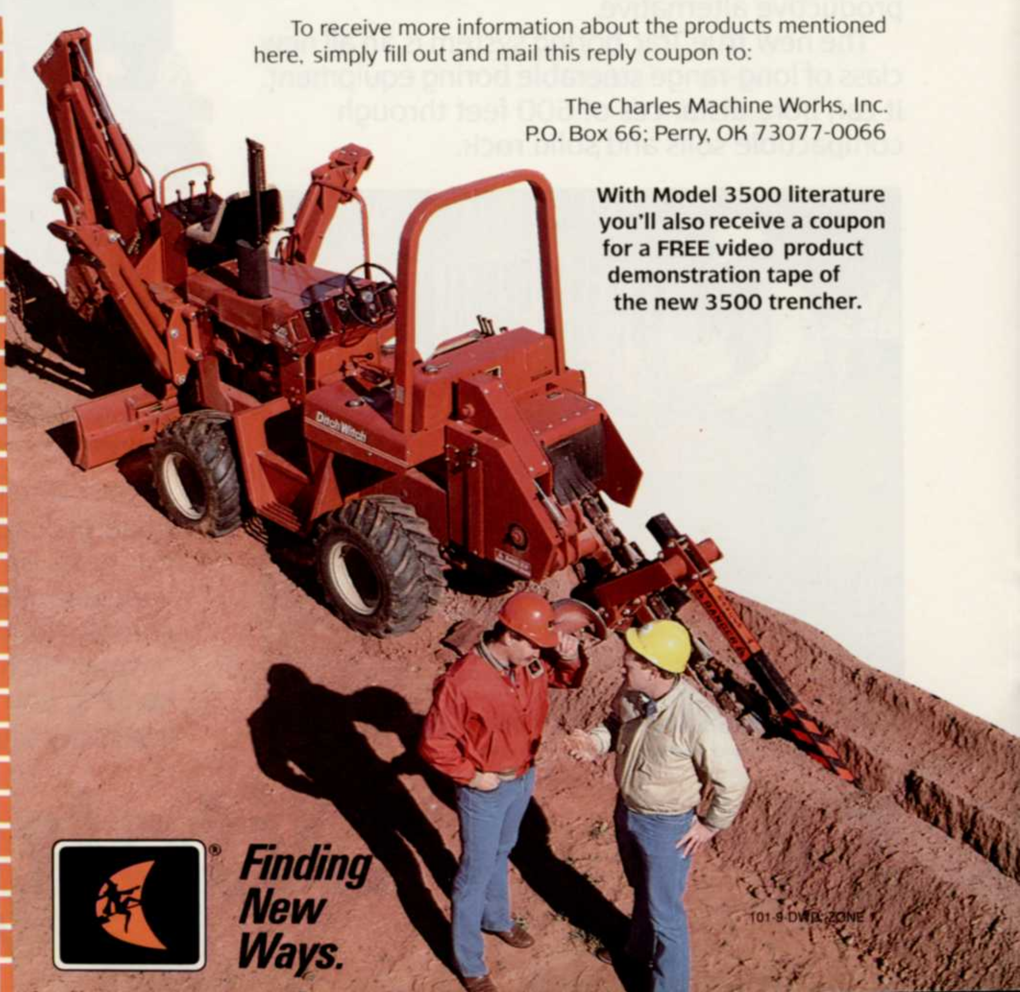


Finding New Ways.

THE DEMAND FOR DIESEL

by Dennis Bourgoin and Tom Kane

The need for exceptional durability and long-term reliability without costly downtime is not new for the landscape industry. However, the trend toward compact, lightweight, high-speed diesel engines to handle landscape equipment applications, is.

Initially, there was reluctance to accept diesel power for smaller turf equipment. The primary engine used for landscape mowers was the air-cooled gasoline engine because it was lightweight and compact and offered a high horsepower-to-weight ratio. Without a cooling system to maintain, it was the exclusive choice to power turf equipment until the emergence of the small, lightweight, liquid-cooled diesel engine.

The major difference between gasoline and diesel engines is the method used to ignite the fuel/air mixture.

- A diesel engine introduces air only into the cylinder for compression, then injects a precisely-controlled amount of fuel into this red-hot compressed air. The burning of this expanding mixture acts on the pistons, turning the crankshaft, thereby producing horsepower and torque.
- In a gasoline engine, the air and fuel are mixed in the carburetor. At the proper time this mixture is ignited by the ignition system and spark plugs. From this point on, the power and torque are derived in the same way as a diesel.

Although both engines appear to be similar in the way they produce power, there are some subtle but important differences. Diesel engines compared to air-cooled gasoline engines offer several advantages:

Diesel fuel helps lubricate some of the engine parts further, adding to engine life.

Heavy-duty components. Diesel components are designed and built stronger to withstand the strenuous demands of the engine's higher compression ratios and inherent higher cylinder pressures. Longer engine life and durability are the benefits.

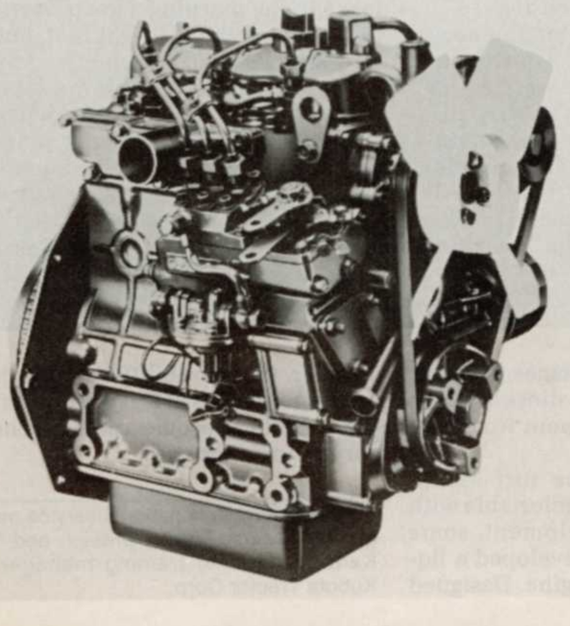
Lower fuel consumption. Engine heat is used more efficiently by diesels, resulting in less fuel consumption and longer mowing time between fills. Typically, diesels are 30 to 35 percent heat-efficient whereas air-cooled gasoline engines are approximately 25 to 28 percent heat-efficient. This savings is realized not only in annual fuel costs but also saves labor dollars spent on frequent refueling and downtime.

Less maintenance. With no ignition system on a diesel to tune, this potential failure point is eliminated. The carburetor, another potential failure point, is totally eliminated on a diesel. No adjustments are normally needed on a diesel if due care is given to the fuel filter, oil changes and air cleaner system. A diesel will outlast gasoline units if good service maintenance procedures are practiced.

Torque characteristics. The torque curve on a diesel engine is generally flatter than a gasoline engine torque curve. This means that the torque does not drop off excessively at lower or higher rpms. The benefit to the landscaper is powerful cutting even in wet conditions.

Fuel. Diesel fuel (#2D) does not readily ignite. It is safer to handle and can be stored over long periods of time, even over a season. Diesel fuel also helps lubricate some of the engine parts further, adding to the life.

Although the initial purchase cost is higher for diesel-powered equipment than air-colled gasoline units, the up-front investment is often returned. The



Diesel (left) or gasoline (right) engine for your landscaping equipment? More contractors are finding the benefits of diesel engines outweighing those of gasoline engines.

What the industry is saying: To diesel or not to diesel?

It is no longer myth but fact: diesel power is catching on in the lawn and landscape industry.

"Kubota is the overall dominating diesel engine," says Mark Martin of DeBra Turf Equipment, Ft. Lauderdale, Fla. "Kawasaki is big in walk-behind rotaries, but Briggs & Stratton is just in the small stuff now."

When buying equipment, various factors must be considered by the prospective buyer, beginning with initial cost. Gasoline engines, of course, are less expensive out the door than diesel. Other considerations:

- horsepower;
- torque;
- physical size of the engine;
- noise level;
- serviceability;
- dependability;
- parts availability;
- cost of replacement parts; and
- use level (how many hours per week?).

Here is what some industry people are saying about diesel and gasoline engines:

Bill Lee, director of marketing for commercial equipment, Deere & Co.: "We believe that small operators may want to look at liquid-cooled gasoline engines. They are more durable now than when they first came out. In the mowing contractor market where you're not doing that heavy drafting or heavy loading, the mower will wear out its moving parts before either diesels or liquid-cooled gasoline engines. And you don't necessarily have to have 'gas hogs' just because you have gas engines.

"What it comes down to is that, if a guy's fleet is all gas and the business is doing well, he probably won't make the change. If the organization has already begun to make the transition to diesel, it will continue to drive toward diesel."

'Diesel is the way everybody would like to go, though not everybody has the money. They like their longevity and lower maintenance costs.'

Mike Currin
Greenscape
Fayetteville, N.C.

Michael Currin, Greenscape, Fayetteville, N.C.: "We are representative of a lot of landscape contractors. Many of our vehicles are bought second-hand and that affects whether we buy gas or diesel. We very rarely buy new vehicles or tractors. We just can't justify it. So usually, we don't have a choice.

"The big problem we found with diesels is their air filters. If people don't pay attention to that, they're in trouble."

Ron Kujawa, KEI Enterprises, Cudahy, Wisc.: "We're switching to diesel in all our vehicles one ton and above. On our large out-front mowers, we believe the Kubota 340 engine (28½ hp) is outstanding. It puts out so much torque that it's comparable to a larger engine.

Ron Kujawa

"Diesel engines have more torque and less maintenance. There is a higher initial cost, but we feel it's worth it. If there's a drawback to diesel power, it's that you have fewer places to get the fuel.

"But the first-time buyer of used equipment will be relegated to what's available, and that will most likely be gas power."

"Diesel is the way everybody would like to go," adds Martin. Not everybody has the money, but it's at least in the back of their minds. People are leaning toward diesels because of their longevity, lower maintenance costs and fuel economy.

"We're seeing landscapers going to diesel engines on riding rotaries in the 72-inch class. They feel that, in the long run, diesels can take the abuse. And if it lasts that much longer, it makes them more competitive."

Don Oliver, Dally Landscaping, Lodi, Calif.: "I have one Toro mower that's diesel. The other three riders are gasoline-powered. We've had wrong fuel problems twice already. Guys pick up the wrong surplus gas can when they leave in the morning. I keep warning them to take the right fuel, but they still get it mixed up."

Despite little problems like those at Dally, diesel engine sales are on the rise. It's no wonder. Martin reports mechanical problems with just three engines since DeBra has been selling diesel—and that's less than 1 percent of the total engines sold. □

diesel unit offers cost savings through a lower annual fuel cost, longer engine life between overhauls, fewer maintenance dollars, excellent power characteristics and—perhaps most importantly—potentially less downtime.

For many light-duty applicators, air-cooled gasoline-powered equipment will be the right choice. However, the many advantages of quiet, compact, high-speed diesels make diesel-powered equipment worthy of close consideration.

Realizing that some turf equipment users are more comfortable with gasoline-powered equipment, some manufacturers have developed a liquid-cooled gasoline engine. Designed to offer the durability of the diesel with the familiarity of a gasoline engine, this has become a popular choice for the turf industry. **LM**

Dennis Bourgoin is national service manager for Kubota Engine Division and Tom Kane is national training manager for Kubota Tractor Corp.

Figure 1. Experimental golf green at the University of Minnesota Golf Course following topdressing. Sections of different soils are evident from color of topdressing material.

Figure 2. Experimental golf green in August 1986, when bentgrass on all soil mixtures was in excellent condition.

Figure 3. Damaged turf growing in soil mixture No. 5 (right half of photo) compared to the relatively undamaged turf growing in soil mixture No.3 in April 1987.

ADVENTURES IN WATER STRESS

Drought conditions and failure of the irrigation system produce interesting findings on an experimental green in the Midwest.

by Don Taylor, Ph.D., University of Wisconsin, River Falls

The drought of 1988 will likely be remembered for a long time by turfgrass managers and golf course superintendents across the United States. Unirrigated turfgrass through the north central region suffered damage as a result of the drought. Even irrigated turfgrass areas sometimes had difficulty keeping up with the water demand.

Hot, dry conditions during spring, 1987 and summer, 1988 plus irrigation problems gave some interesting results on water stress damage at an experimental green on the University of Minnesota Golf Course.

Here's what happened.

In the early 1980s, golf course superintendents in Minnesota were having difficulties establishing and maintaining a dense creeping bentgrass stand on golf greens constructed with high sand-content soil. The Minnesota Golf Course Superintendents Association investigated but failed to identify the underlying problem. So members decided to construct an experimental green to determine the long-term growth of creeping bengrass on five soil mixtures.

The green was constructed according to U.S.G.A. guidelines, save one. It was divided into five sections, and five different soil mixtures were used in the rootzone layer (Figure 1). The five soil mixtures used on the green are described in Table 1.

The green was constructed in the summer, 1984 and seeded with Penncross creeping bentgrass in September.

Originally, it was thought that nutritional differences or development of excessively compacted soil conditions might lead to differences in establishment and growth of creeping bentgrass. But after four years of bentgrass growth, nutritional differences have remained minimal on each of the soil mixtures.

Soil compaction problems (as measured by root growth and water infiltration rates) appear to be nonexistent on any of the soil mixtures. However, the unusual weather condi-

TABLE 1.
Soil mixtures used in the experimental green.

Soil Mix #	Description
1	3-1-1 by volume sand-soil-peat. sand - fine mortar sand. soil - silt loam (21% sand, 66% silt, and 13% clay). peat - Northern reed-sedge peat. The resulting mixture by weight was 80% sand, 17% silt and 3% clay.
2	5-1-1 by volume sand-soil-peat. sand - uniform, medium silica sand. soil - sandy loam (58% sand, 26% silt, and 16% clay). peat - Northern reed-sedge peat. The resulting mixture by weight was 94% sand, 4% silt and 2% clay.
3	85-15 by volume sand-peat. sand - fine mortar sand. peat - Northern reed-sedge peat. The resulting mixture by weight was 97% sand, 2% silt and 1% clay.
4	85-15 by volume sand-peat. sand - uniform, medium silica sand. peat - Northern reed-sedge peat. The resulting mixture by weight was 98% sand, 2% silt and 0% clay.
5	100% sand with peat tilled into the surface 4 inches. sand - fine mortar sand. peat - sphagnum peat. The resulting mixture in the surface 4 inches, by weight, was 99% sand, 1% silt and 0% clay.

TABLE 2
Water holding capacity of the soil mixtures used on the golf green.

Soil Mixture	Available water holding capacity (-30 mbar to -15 bar)	Inches of water available in 12 inch root zone
	g water/g soil	inches
1	0.20	3.4
2	0.13	2.2
3	0.11	1.8
4	0.10	1.7
5 (surface 4 inches)	0.09	1.3
5 (below 4 inches)	0.07	

tions of the past two years have led to visible differences in response to water stress among the soil mixtures.

Golf greens are often constructed—as this experimental green was—with 12 inches of rootzone soil mixture underlaid by two inches of coarse sand, which in turn is underlaid by four inches of gravel with drain tile installed.

The coarse sand and gravel layers increase the amount of water retained in the rootzone soil mixture. This is usually desirable since most soil mixtures used are very high in sand content and have low water-holding capacities.

Water available to the plants in a layered golf green is higher than what would be available in a deep soil profile with no layers. To estimate the amount of water available to plants in this green, water held between tensions of 30 millibars (equivalent to drainage at the surface of 12 inches of mix over a saturated layer) and 15 bars (the point usually considered so dry that plants can no longer extract the water) was measured. Assuming a bulk density of 1.4 $g/cm.^3$ in all mixtures, the inches of water available to plants in the soil mixtures are shown in Table 2.

Water infiltration rates were measured on the green in 1986 and 1988. Rates varied dramatically between soil mixtures with soil mixture No. 5 having the highest infiltration rate (30.1 inches/hr. in 1986 and 25.3 inches/hr. in 1988) and soil mixture No. 1 having the lowest infiltration rate (2.8 inches/hr. in 1986 and 1.3 inches/hr. in 1988).

During 1986, the first year turfgrass growth was carefully monitored, bentgrass growth on all five soil mixtures was superb with no differences between plots. Figure 2 shows the golf green as it appeared in August, 1986.

In April, 1987, indications of possible problems occurred when the weather turned warm and dry very early. After a winter of almost no snow cover, March was very warm with an average temperature of 38.7°F, 9.5° above normal. Bentgrass throughout the experimental golf green turned a beautiful dark green in March, providing a stark contrast to the dormant, or dead, annual bluegrass on the fairways and approaches.

March and April were not only warmer than usual but also drier. Rainfall measured in Minneapolis was 0.3 inches in March and 0.2 inches in April, about 1 and 2 inches, respectively, below normal for those months.

In mid-April, before the irrigation system had been turned on for the season, bentgrass growing on soil mixture No. 5 started going into water stress. Despite running hoses from the clubhouse to water the green while the irrigation system was being checked, turf loss occurred on soil mixture No. 5. Figure 3, taken on April 22, shows the damaged turf on soil mixture No. 5 (right half of photo) along with the undamaged turf on soil mixture No. 3 (left half of photo). The lines dividing soil mixture No. 5 and the two bordering plots were distinct and obvious with the damaged plants restricted to soil mixture No. 5. Once