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TURFGRASS TRENDS

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DISEASE CONTROL

# Root-knot nematodes on turf in the northeastern United States

*By Nathaniel Mitkowski, Ph.D.*

For many years, nematodes were not considered to cause significant disease on golf courses, particularly in the Northeast. While there are many reasons for this, management techniques, the subtle nature of most nematode damage (especially in northern climates) and the difficulty in researching nematode problems on a perennial host claim most of the responsibility for this gap in understanding (Nelson, 1995).

It is now known that nematodes can cause significant damage on many turf grasses. However, the diagnosis of nematode symptoms is still difficult and control of these plant pathogens can be time consuming, expensive and inconvenient.

While there are many species of nematodes that attack grasses, I have a particular interest in Meloidogyne graminis, a root-knot nematode. While seen infrequently in the past, it seems to be increasing in its incidence, an observation based on turf samples submitted to the University of Rhode Island Turf Diagnostic Lab and the Plant Disease Clinic at the University of Massachusetts .

**ABSTRACT**

Root-knot nematodes (*Meloidogyne graminis*) are gradually becoming more prevalent on golf courses throughout New England. These nematodes can be particularly damaging to turf, as a result of their intimate relationship with plant hosts. Symptomology is general in nature and difficult to diagnose. Typically, these and other nematodes are considered stress related diseases. Only through soil sampling and extractions can identification be made conclusively. Many grass species have been reported as being susceptible and no genetic resistance effective against *Meloidogyne graminis* has been identified. Control of these organisms can be a perennial problem and Nemacur is the only chemical registered for use on golf courses with nematode problems. Timing of application is also critical for efficacy against root-knot nematodes.

Unlike fungi, many nematode populations develop relatively slowly and damage may only be observed during periods of high stress. In Rhode Island, levels of Meloidogyne graminis are still relatively low and this particular nematode is only found sporadically. However, these unique organisms can be difficult to manage when encountered and can develop very high populations in turf. For these reasons, it is worth examining the management and control of these organisms.

## Biology

Root-knot nematodes (Meloidogyne spp.) are distributed widely throughout the United States and can cause significant damage on a wide variety

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of plant species (Goodey et al., 1965; Walters and Barker, 1994). They are generally recognized as one of the most destructive of the plant-parasitic nematodes because of the intimate relationship they establish with their plant hosts.

While the great majority of plant-parasitic nematodes spend their lives in the soil, probing into plant roots with their stylet and moving about multiple feeding sites, root-knot nematodes enter into plant roots and permanently set up camp. They inject molecules into plant cells which cause dramatic changes in plant physiology, effectively hijacking the roots (Dropkin, 1989; de Guiran and Ritter, 1979; McClure, 1977).

To feed the nematode continuously, plants respond by forming "giant cells" (Endo, 1971). Acting as large sinks, these cells draw in nutrients from the surrounding area and funnel them to the nematode. The nematode continues to develop as the plant roots are altered and eventually the swollen female and the giant cells form the characteristic gall or knot, which gives the nematode its name.

***Symptoms of a highly virulent isolate of Meloidogyne hapla infecting lettuce.***

Eggs are produced throughout the lifespan of the female and are either deposited into the surrounding soil or remain embedded in the root tissue. Often they can be seen appearing to adhere to the gall as egg masses.

In terms of reproductive capacity, no other nematode comes close. While the number of eggs produced by a single root-knot nematode can vary widely, populations of nematodes can often average anywhere from 500 to 2,000 eggs per female. Millions of nematodes can be produced on a single plant. The lifecycle of root-knot nematodes is highly dependent upon soil temperatures, but in the Northeast, the lifecycle can be as short as three weeks. Thus, there is a significant potential for large numbers of nematodes to be produced in a single season.

## Distribution

Although there are over fifty recognized species of Meloidogyne, only two are regularly found in the Northeast: Meloidogyne hapla and Meloidogyne graminis. For the most part, root-knot nematodes are tropical to subtropical organisms.

While growers, horticulturalists and superintendents in warmer climates have to contend with numerous root-knot nematodes, temperate winters are an impedance to most Meloidogyne species and a large number of other nematodes (Van Gundy, 1985). In addition, southern root-knot nematodes tend to be more aggressive and have a shorter lifecycle (and thus more generations) than northern root-knot nematodes.

Root-knot nematodes generally have very wide host ranges, making it difficult to identify non-host crops or resistant germplasm. However, the presence of only these two root-knot nematodes in the Northeast does provide some reprieve. Golf course superintendents also have an additional advantage: Meloidogyne hapla (which causes significant losses on onions, carrots and other vegetables) will not reproduce on grasses (Widmer et al., 1999). Conversely, however, Meloidogyne graminis will reproduce on nothing but grasses (MacGowan, 1984).

## Damage and symptoms

In order to understand the type of damage root-knot nematodes can cause, it is necessary to consider their mode of parasitism. When manipulating plant roots into generating giant cells, the stele or vascular system of the plant is being usurped. Nematode feeding is focused upon the xylem parenchyma (Dropkin, 1989). The ultimate result is a considerable disruption in the water and nutrient uptake of infected plants.

Symptoms are generally consistent with this type of damage. On very hot days, especially when minimal amounts of water have been applied, plants will wilt easily. Symptoms can also be very general, such as a reduction in vigor, chlorosis and plant stunting. Because of reduced nutrient uptake, nematode damage may mimic nutrient deficiencies which will not respond to fertilizer applications.

In southern states, however, Meloidogyne graminis can cause very dramatic symptoms. On St. Augustine grass, the nematode may outright kill grass in large patches (MacGowan, 1984).

The majority of nematodes can only be diagnosed through soil sampling. Nematodes are microscopic organisms and in order to confirm their presence they must be extracted from the soil and observed under the microscope. Because root-knot nematodes cause such dramatic symptoms on host plants, however, root galling can sometimes be used to diagnose them. The disadvantage to identifying root-knot nematodes solely on the basis of root galling is that galling occurs three to four weeks after infection. If a visual inspection of the roots is made prior to this time, galls will not be observed and the nematodes will escape detection.

In addition, galls on grass roots are commonly very small and difficult to see. For these reasons, it is best to sample for root-knot nematodes as if they were any other nematode, by taking a minimum of five to ten one-inch cores per green (spread across each green) and forwarding them to your local turf diagnostic lab or nematode diagnostic lab. Processing of soil samples for nematode diagnosis is a relatively time consuming effort however, so be cognizant of the costs involved in having many greens diagnosed.

## Control

Controlling Meloidogyne graminis can be very difficult. Nematode eggs will remain in plant roots or in the soil throughout the winter. When spring arrives, nematodes will hatch and penetrate plant roots near the area of cell elongation.

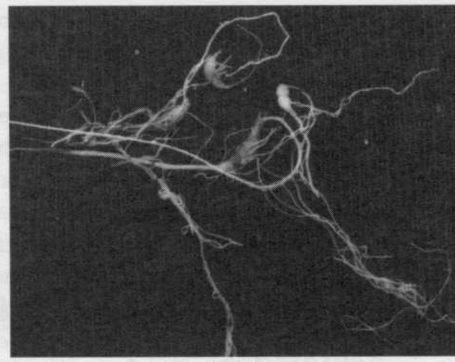
Once feeding has been initiated, chemical controls will have very little effect. Therefore, the critical time for application of nematicides is in the spring, before nematodes have entered the roots.

There is currently only one nematicide registered for use on golf course greens which will work against root-knot nematodes, Nemacur. While Nemacur can be extremely effective, it is highly toxic to people and has a 24 REI. Consequently, greens to which it has been applied must be temporarily shut down. And unfortunately, Nemacur will not eliminate the problem, only reduce the number of nematodes in the soil.

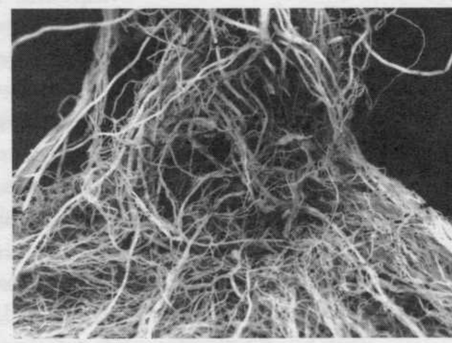
Areas with chronic problems will require multiple applications of the pesticide. While it has yet to be reported in the Northeast, in the South, increased biodegradation of Nemacur has been observed under high application rates. Soils repeatedly treated with the pesticide will develop populations of microorganisms capable of degrading the pesticide and thus limiting its usefulness. This type of "resistance" to a chemical is biologically very different from typical fungal resistance to pesticides, but is functionally similar.

Another option exercised by superintendents is fumigation. While only practical during renovations, this option may have severe consequences in the future. When fumigation is utilized, the majority of soil-borne organisms are killed, not only plant-parasitic nematodes.

From a short-term perspective, this will remedy the problem. However, if plant-parasitic nematodes are reintroduced (which is not uncommon), they may cause more problems than before fumigation. This is because the act of fumigating the soil has removed all of the native antagonists of the plant-parasitic nematodes. While it is unclear how much control antagonists exercise over plant-parasitic nematodes, it is possible that



***Typical galls of Meloidogyne graminis, produced on wheat. Galls produced by this nematode are more delicate and relatively cyclindrical, as compared to those caused by M. hapla.***



***A low level of Meloidogyne graminis infection on wheat, indicated by sparse galling. Galls are commonly observed as slight swellings on turfgrass roots and frequently are not even observed.***

*Cultural practices can alleviate some of the damage caused by root-knot nematodes, but generally these practices are inconsistent with the demands of players.*

they may be able to keep populations below damage threshold levels in some instances.

When fields are fumigated in preparation for high value annual crops, the same cycle will occur. However, because these crops are harvested every year, fumigation can be undertaken every few years, a luxury golf course superintendents do not have.

Cultural practices can alleviate some of the damage caused by root-knot nematodes, but generally these practices are inconsistent with the demands of players. Simply put, grass that is under minimal stress will still support populations of plant-parasitic nematodes but will be less likely to show symptoms. This means raising the height of cut and limiting the amount of play, options which are generally not feasible.

## Hopes for the future

One of the research aspects I hope to focus on in the future will be to examine the genetics and pathogenicity of Meloidogyne graminis. The ultimate goal of this research will be to identify techniques to manage this and other plant-parasitic nematodes on turf using strategies other than chemical controls.

One method that may show promise is the use of resistant germplasm, which could be developed into commercial varieties and be easily over seeded into established turf stands. In addition, there are many golf courses where the levels of plant-parasitic nematodes remain well below damage thresholds. The reason for this is not well understood.

Investigations into the effect of golf course management and microbial communities on plant-parasitic nematodes may lend some insight into useful management practices.

*Nathaniel Mitkowski received his B.S. from the Department of Plant Pathology at the University of Massachusetts in 1997. It was here that he got his first exposure to turf pathology, as a student of Dr. Gail Schumann. He received his Ph.D. from the Department of Plant Pathology at Cornell University in 2001. There, his research focused on nematode diseases of vegetable crops, particularly Meloidogyne hapla. He was recently hired by the University of Rhode Island as an Assistant Professor to fulfill the role of Turf and Ornamentals Pathologist. Beginning in 2002 he will oversee the direction of the URI Turf Diagnostic Laboratory.*

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# Mechanical maintenance of bowling greens

*By Robert Chesham*

***A single cylinder roller can accentuate contours. This photo was taken at a Bowls club in Shrewsbury, England.***

The mechanical maintenance of a bowling green can never be an exact science. Because we work so much with the weather and varying soil conditions, what works on one bowling green will not necessarily be successful on another.

Let's follow the bowling green year from early spring to autumn renovation work. Much of what is done on a bowling green in England will apply to fine sports turf management elsewhere. And while there are over 3000 bowling greens in England, most will be surprised to know there are about managed 100 bowling greens in the USA.

Bowlers are amongst the keenest and most critical users of fine turf. Regular maintenance using effective, reliable, machinery gives them a green on which they can play their best.

## Late winter/early spring

It is essential, when there is a little woolly growth on the bowling green, to keep it well mown. It should never be cut down to bowling height but should always be topped off. This will help to keep at bay some of the diseases that may occur in the grass.

At this time it is a good thing to use a six-foot drag brush, probably once or twice a week, to brush the green so that the blades of grass are actually swept. This stops moisture forming on the grass and will help to keep away diseases. We can never eradicate diseases such as fusarium, but we can minimize them.

As we approach the start of the bowling season, brushing should be done more often prior to mowing. The drag brush will not only remove the dew particles from the leaf of the grass, it will also spread any worm casts that may be on the green and will lift the grasses to a certain extent, so that the mower will give a nice even, level cut. Alternatively a hand drag-mat can be used for the same purpose.

Depending on weather conditions, but normally in early April, an application of lawn sand should be applied to the bowling green. This will kill any moss that has occurred during the winter period. About two weeks after the application, when the moss on the bowling green has blackened off, use a dethatcher such as a Rotorake fitted with thatch removal reel to remove the moss. Normally two or three passes is sufficient. Remember we will be bowling in four-five weeks time so we must not hit it too hard but must still try to get as much moss out as possible.

At this time of year it doesn't really matter in which direction we scarify but if we intend to do two or three passes the first pass will go in whatever direction is thought necessary; this can then be referred to as the 12 o'clock position. The second run should be at a shallow diagonal. Think of a clock face, the first run was 12 o'clock, the second run 1 o'clock. If we need a third run we can put that in at 11 o'clock. After scarification with the thatch removal reels, fit the brush reel and go over the green once more. This will pick up any debris that has been left behind. The next operation is to cut the green, again not quite down to bowling green height, as we are still several weeks away from start of play.

During the winter and into early spring we should spike the green fairly regularly, again depending on weather conditions, using slit tines. slit tines are the best to use in the closed season to give maximum aeration. As the bowling season approaches we will then turn to the round solid tine to continue our aeration program. A round solid tine, especially the 7mm diameter pencil tine will give far less disturbance to the green or the run of the wood, whilst still allowing air, nutrients and water to reach the roots of the grass plant.

## Spring

As we come out of the winter period into spring, any areas which are a little thin can be roughed up, using a hand rake, and lightly spiked using a hand fork with solid tines, before putting down a little seed covered with a thin layer of top dressing.

Scars left from fusarium, generally speaking, will grow through. If they are really bad, again they could do with a little bit of localized seeding and repair work. This can be done using hand tools and the Aerdrain fork to spike the areas. It is essential, however, before any work is done to fusarium patches to make sure the fusarium is dead. otherwise it can spread across the green.

It is also a good idea to use a hand roller or powered roller, to gradually correct undulations or movement which may have occurred in the bowling green due to frost and adverse weather conditions. The first couple of rolls should be done in different directions. Again it is a good thing to think of a clock face. First we run at 12 o'clock, a second run maybe at 2 o'clock and a third at 9 o'clock so we cover the whole of the bowling green at various angles and gently push it down to create a truer, level surface.

About a week to 10 days before the start of the season drop the mower down to bowling height and start to mow on a regular basis.

Generally speaking bowling greens are mowed corner to corner. This is so that the woods will not pick up the line of the mower. It is often a good thing to vary this line of cut if possible. Instead of going corner to corner go from one corner to half way along the first rink to the right of the corner, the next time half way along to the left, so we are not quite on a corner to corner basis. If we vary these mowing directions we are less likely to get tracking from the mower, if the green is a little bit soft, especially at the start of the season. Think of that clock face again - 12 o'clock first cut, 11 second cut, 1 third cut.

## The bowling season

As the bowling season progresses we need to dethatch lightly, again using a Rotorake, this time fitted with the thatch control reel. The thatch control reel has very thin blades with a quarter-inch spacing across the width of the machine. This allows a very light verticutting action to either cut off or stand up any laterally growing or coarse grasses.

Ideally this thatch control job should be done every 10 to 14 days throughout the bowling season, always followed with the mower. As this operation is carried out during the bowling season, it is very important to get the direction of travel correct. We do not want to dethatch straight up and down rinks or straight across as this will affect the run of the wood. The best way to work with the thatch control reel is to start off at say the bottom right hand corner of the green and aim for a position half way across the top of the green so that the direction of the dethatching is off the direction of the woods and is off the direction of the mowing.

As we progress through the summer and the bowling season, the aerator should be fitted with round solid tines. The 7mm pencil tines are probably even better for summer use. By spiking with these tines we allow water and nutrients to be taken to the base of the grass plant rather than to sit in the thatch layer on the top of the green.

Also during the summer, as conditions get drier we can make use of a spiker slitter. The spiker slitter is used to put small surface slits into the green, probably no deeper than a half inch. This allows water to go through the thatch layer to the root of the plant.

No bowling green is ever flat; it always has slight undulations. As the weather conditions dry out and we use the watering system, the water tends to run off the high spots on to the low spots. The high spots thus become drier, the low spots obviously become wetter and the difference in height is accentuated so our bowling green becomes even more uneven. By using the spiker slitter at least once or, preferably twice a week, in various directions, we can make the bowling green absorb and dissipate water at a uniform rate.

Whenever you fertilize the green or apply a wetting agent, run the spiker slitter over first so that the nutrient is again taken towards the root of the plant.

During the bowling season, we will have areas, especially on flat rink greens, that tend to wear. It is far better to treat this wear as it appears rather than leave it to the end of the season.

Small worn areas can be roughed up using a hand rake. We can then put down a little seed, cover with a light top dressing, rub in, so we will get some growth to the repair and not such a badly worn spot.

Throughout the summer make use of the Trulevel or Eroll rollers. Depending on climatic conditions the green can be rolled, probably about once a fortnight or prior to important competitions, just to true and speed up the green.

*It is essential before any work is done to fusarium patches to make sure the fusarium is dead.*

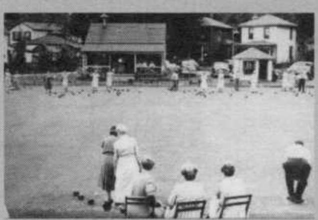
## Autumn renovation

After a good season of bowling and after the prize-giving and final dinner, it is time to start the annual renovation. One of the main problems these days, is that bowlers wish to bowl later and later into the autumn; some clubs not finishing until early October. It is always best to stop as early as possible to get the remedial maintenance program under way.

The first job is to dethatch the green. Fit new blades so that they will take out the maximum amount of debris.

Cut the green to bowling height and then start to dethatch. Do not work too deeply. The blades should go through the thatch and just mark the top of the soil layer. It is far more effective to do several runs rather than

### A BIT OF HISTORY



It is believed that lawn bowling dates back to Egyptian times, but it may have originated in France, to be taken to England by the conquering Normans in 1066. Other think that it may stem from a game played by roman soldiers using stones. Over a period of time the stones became balls and were rolled rather than thrown.

Bowling became so popular in England that King Edward the III banned it in 1361 because it was interfering with compulsory archery practice. In the reign of Queen Victoria in the late 19th century, all prohibitions on lawn bowling were lifted and became very popular with all classes. Bowlers were considered to be up-right, moral people and were respected.

It is recorded that Williamsburg, VA had a bowling green in 1632 with another being built in what is now Bowling Green, VA. After the Revolution it lost popularity but was re-introduced to America around 1876. The American Lawn Bowls Association was founded in 1915.

one deep pass that may cut out the roots, etc. Again, first run at 12 o'clock, second run at 11 o'clock, third run at 1 o'clock so we have, in fact, covered the whole area of the bowling green three times.

Most of the debris will be picked up by the grass box on the Rotorake. Any which has been dropped on the ends can be picked up by hand. In my experience the majority of bowling greens will need to be dethatched again. So probably we would put in at least another two runs or, even another three runs, to really clear off every bit of debris and rubbish from the surface of the green.

Once this has been achieved we then fit the brush reel to the rake and run the machine over again to clean up any debris left behind.

*When a reputable top-dressing has been decided upon, stick to it for at least five years. Don't chop and change. One top-dressing will not necessarily be compatible with another.*

If we have decided to hollow tine the green, now is the time to do it. Normal depth for hollow tining a bowling green would probably be four inches with a pattern of 3 x 3 or 4 x 4 depending on the machine used. Once this coring has taken place, the cores need to be removed from the green. There are various methods of picking them up and it is essential.

Many questions are asked about how often we should hollow tine a bowling green. It is becoming more and more necessary. In some cases now, where heavy usage occurs, it needs to be done every year but, in the majority of cases, probably every second year. Once we have hollow tined, if there are any parts that have taken extra wear, or the odd corner that we cannot get to with the big machines, then take the hand fork, fitted with hollow tines, and do these parts by hand.

Now is the time to overseed. Again this is something that really ought to be done every year. We don't have to put down vast quantities of seed, just enough so that the green has got some rejuvenation properties. Take advice from a good seed merchant to obtain a mix of seed suitable for the soil types and weather conditions in your area.

Once the seed has been put down, top dress. Whatever type of top-dressing is used, it should be spread evenly over the green at the required rate. After spreading the top dressing, if possible, let it dry for 30 or 60 minutes in the wind. Once it has dried, it is much easier to rub in using a drag mat or brush, to fill all the holes we have made with the hollow tines.

It is essential that top-dressing is rubbed right in to the base of the grass sward and into the holes, so the tedious job of drag brushing/matting has to be done in several different directions. It must be done properly to achieve maximum benefit.

If the bowling green is not to be hollow tined this year, then it ought to be slit tined. This should be done in at least two different directions, preferably three, again working on the clock principle. Once the bowling green has been slit wide open, we put on the top dressing. Obviously we do not need as much top dressing when we have slit-tined the green as when we hollow tine.

There are many makes of top dressing available on the market and the choice for the individual club has to be made depending on cost, quality, etc.

When purchasing top-dressing, ask your dealer what it contains: ask about particle size of the sand used and pH value. Most dealers will give a sample for testing. If they won't, then go elsewhere. When a reputable top-dressing has been decided upon, stick to it for at least five years. Don't chop and change. One type of top-dressing will not necessarily be compatible with another. the biggest problem is variation of sand particle shape and size. Consult your Turf Advisor.

## Autumn/winter

Once the green is 'put to bed,' leave it alone for a few weeks, just keeping an eye on it to make sure we don't get any fungal attacks, checking it about twice a week.

The grass will gradually come back through the top dressing so that we will

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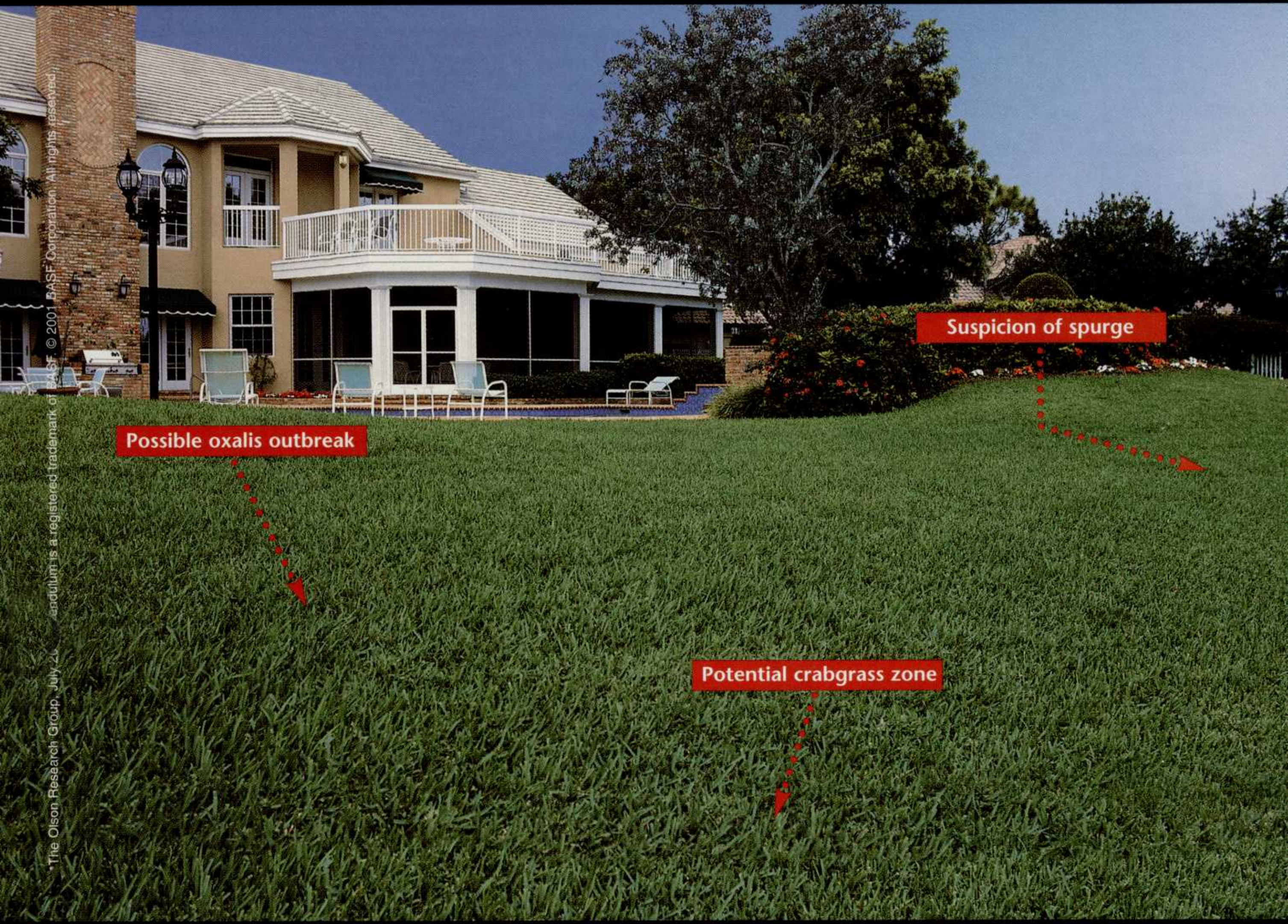


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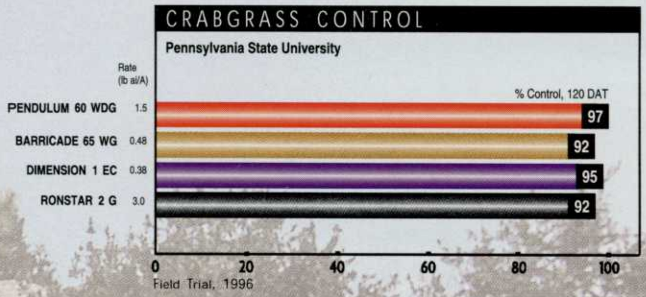


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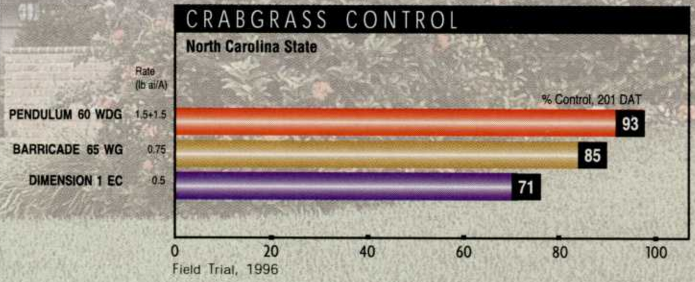


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BASF

have to get the mower out again and top off. We don't need to go down anywhere near bowling green height but we do need to keep it topped off at winter height.

About four to five weeks after renovation (depending on weather conditions), it is time to start our

Autumn/Winter slitting program with chisel ended slit tines. We would normally carry out this program on a two-week rotation right through the autumn and winter. The only time to stop this slitting is if the weather deteriorates badly and we have frost. Then it is best to leave the machine in the shed.

The slitting program can be followed through the winter and into early spring, to keep the bowling green open and allow oxygen to the roots.

if we get heavy rain then the green will be more able to withstand bad weather. The grass roots will have somewhere to grow and we will strengthen up our sward ready for next year's bowling season.

Deep slitting can be done again in November/December but should not be used after Christmas. The deep slits may be evident at the start of bowling. Do not allow the grass to get too long and always be on the look out for disease.

If an outbreak of fusarium is spotted, treat immediately. Remember, in winter, when the grass is dormant, use a contact fungicide and in the growing season use a systemic fungicide.

*Ideally, the thatch control job should be done every 10 to 14 days throughout the bowling season, always followed with the mower.*

Finally, remember that colorful flower beds, weed-free paths and trimmed hedges enhance the green and complete the bowlers' pleasure.

*Author Robert Chesham has worked for SISIS, one of Europe's leading manufacturers of turf maintenance machinery, for 25 y ears and specializes in bowling green maintenance. Its US-subsidiary company SISIS INC, is based at Clemson University in South Carolina.*

# Do "low-drift" nozzles work — an update

*By Erdal Ozkan*

The spray drift problem goes back nearly 50 years when pesticides were invented. It has become a more serious concern in recent years mostly because of the new genetically modified plants that are resistant to certain pesticides. A small amount of such pesticides drifting from the genetically modified crop field to the adjacent field of regular crop can cause serious damage.

Drift can never be completely eliminated, however, it can be reduced to minimum if pesticides are applied under favorable weather conditions and by adopting some of the many proven drift reduction strategies. One of these strategies is switching to new low-drift nozzles. The question we often hear when we make this recommendation is: "Do they really work?"

The answer is yes, if your goal is to reduce drift. Droplet size measurements and wind tunnel tests here in Ohio and elsewhere show that low-drift nozzles significantly reduce drift. However, their impact on pesticide efficacy is still not well documented. Following is a review of what these low-drift nozzles are, and what makes them more effective in reducing drift than conventional nozzles.

Wind speed aside, spray droplet size is the next most important factor affecting drift. Droplet size where drift potential becomes insignificant depends on wind speeds, but research has shown that drift is far less likely to be a problem when the spray is made up of droplets 200 microns and larger in size.

Unfortunately all conventional nozzles in use today do produce droplets in a wide range of sizes. With some popular conventional nozzles, the proportion of small, drift-prone droplets is large. Selecting a nozzle with an orifice that is several times larger may solve the drift problem, but we may not be able to achieve a satisfactory pest control because we are using too large droplets.

One of the advantages of these low-drift nozzles is we reduce the number very small droplets without affecting the proportion of very large droplets significantly. These nozzles are designed to create larger droplets at the same flow rate and operating pressure than comparable standard flat-fan nozzles. This has been accomplished by adding a pre-orifice to the nozzle tip assembly just ahead of the conventional discharge orifice. The pre-orifice reduces pressure at the exit orifice creating larger droplets to reduce drift significantly. A schematic of these nozzles is shown below.

We have completed extensive tests in Ohio to determine the differences in droplet sizes between conventional nozzles and low-drift nozzles. Several other university researchers have also conducted similar tests. All of these studies indicate that low drift nozzles reduce the number of drift-prone droplets. For example, results from our studies indicated that volume of spray contained in drift-prone droplets (smaller than 150 microns) was reduced by 87% when a 0.2 gal/min flow rate capacity Low-Drift nozzle was operated at 40 psi compared to a comparable size Standard flat-fan nozzle operated at the same pressure.

The figure attached shows the percent of spray volume contained in droplets smaller than 100 micron in diameter for a conventional and three low-drift nozzles. Droplets smaller than 100 micron are likely to drift in most cases of spraying. Therefore, one can interpret the graph as percent of spray volume lost when using a conventional XR Flat-fan nozzle versus low-drift nozzles (Turbo TeeJet, TurboDrop and AI TeeJet) with two different flow rates (0.2 and 0.4 gpm at 40 psi). (TurboDrop and AI TeeJet nozzles are air induction nozzles).

As shown on the figure below, when using 0.2 gpm size nozzles, one can reduce drift (or loss) of spray volume from 25% (with the conventional XR nozzle) to about 2.5% with any of the two air induction nozzles (TurboDrop or AI Teejet). This is a 10-fold reduction in drift potential.

TT (Turbo TeeJet) nozzle is the least expensive of the low-drift nozzles available in the market at this time. As shown on the figure above, they are not as effective as the air induction nozzles for a given size and pressure. It is possible to achieve better performance simply by selecting one size larger nozzle and operating it at a lower pressure. For example, operating a 0.3 gpm size nozzle at 25 psi will give the same flow rate as a 0.2 gpm nozzle running at 40 psi. The difference is in the percent of the drift prone droplets which will be reduced by about 2/3 by choosing a larger size nozzle and operating it at a lower pressure.

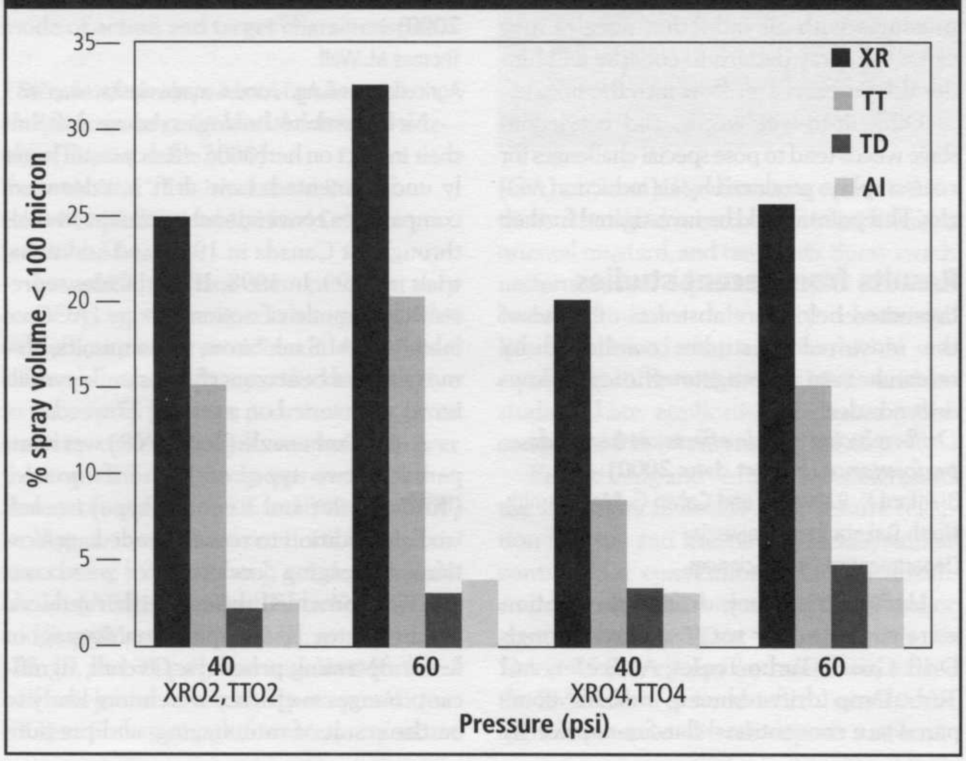
*Leaving the wind speed aside, spray droplet size is the next most important factor affecting drift.*

## How about pest control?

There is limited data on performance of low-drift nozzles in achieving biological efficacy from pesticides.

Only in the last two years researchers in several universities have conducted research to evaluate low-drift nozzles for pesticide efficacy. Unfortunately, it is difficult to draw solid conclusions from these

**FIGURE 1. % SPRAY VOLUME < 100 MICRON FROM CONVENTIONAL (XR), TURBO TEEJET (TT), TURBODROP (TD), AND AL TEEJET NOZZLES (FOR SIZES 11002 AND 11004)**



limited studies because they are only based on one or two years' data and the test procedures are not uniform (different pesticides, different rates, different climate etc.). However, it is possible to draw following general conclusions from this limited data:

In most cases, air induction and turbo flat-fan tips performed equally well or better than the extended range conventional flat-fan tips.

Overall, significant changes in efficacy were more likely to be the result of rate, staging, and pressure changes than of nozzle choice.

When low-drift nozzles perform less than satisfactory, it is not known whether efficacy reductions are due to poor spray patterns, poor coverage, or an inability to target small weeds.

It appears that Turbo TeeJet and air induction nozzles are suitable for use with glyphosate.

Although most air induction nozzles can be operated at minimum pressures of 25 to 30 psi, they provide better efficacy if they are operated at 60 to 80 psi. Under higher pressures, air-inclusion becomes more pronounced, with relatively minor changes in spray drift potential.

Using lower than the recommended pressures with air induction nozzles may cause the spray pattern to collapse and hinder the process of air flow into the nozzle.

Difficult-to-wet weeds, and cotyledon-stage weeds tend to pose special challenges for coarser sprays produced by air induction nozzles. This point should be investigated further.

## Results from recent studies

Presented below are abstracts of some of the most recent studies conducted by researchers to investigate efficacy of low-drift nozzles.

***Drift-reducing nozzle effects on herbicide performance*** **(Report date: 2000)**

Bradford K. Ramsdale and Calvin G. Messersmith
North Dakota State University
Department of Plant Sciences

Herbicide efficacy, drift, and retention were evaluated for spray applied through Drift Guard, Turbo TeeJet, AI TeeJet, and TurbuDrop drift-reducing nozzles compared to a conventional flat-fan nozzle. By reducing the amount of spray in fine droplets, the Turbo TeeJet, AI TeeJet, and TurboDrop sprayer nozzles reduced spray drift more than Drift Guard or conventional nozzles. Total spray coverage detected on water-sensitive cards was greatest for conventional and Drift Guard nozzles compared to Turbo TeeJet, AI TeeJet, and TurboDrop nozzles.

Retention of spray mixtures without adjuvants on weeds was greater for treatments applied with conventional and Drift Guard nozzles compared to Turbo TeeJet, AI TeeJet, and TurboDrop nozzles. However, spray retention with adjuvants was similar among all nozzle types when averaged over spray adjuvant and two weed species. Total spray retention was greatest at 20 gal/acre, but herbicide retention was greatest for spray applied at 5 or 10 gal/acre than at 20 gal/acre. Consequently, herbicide efficacy may be greater for spray applied at 5 or 10 gal/acre as well.

Paraquat and glyphosate efficacy, representing contact and translocated herbicides respectively, was not influenced by changes in nozzle type regardless of spray volume.

***Should we recommend use of low drift nozzles with herbicides?*** **(Report date: 2000)**

Thomas M. Wolf
Agriculture and Agri-Food Canada, Saskatoon, SK.

New nozzle technologies reduce drift, but their impact on herbicide efficacy is still largely undocumented. Low drift nozzles were compared to conventional nozzles in 34 trials throughout Canada in 1998, and additional trials in 1999. In 1998, 19 herbicides representing 6 mode of action groups (ACCase inhibitors, ALS inhibitors, auxin mimics, bromoxynil and bentazon, glyphosate, bipyridiliums) were tested on a total of 27 weeds.

A standard nozzle (TeeJet XR) was compared to two types of low drift nozzles (Turbo TeeJet and a venturi-type) in each trial. In addition to recommended application, challenging conditions for weed control were provided through either reduced product rates, later application staging, or lower operating pressures. Overall, significant changes in efficacy were more likely to be the result of rate, staging, and pressure changes than of nozzle choice. When nozzle choice had an impact, low-drift nozzles most often performed less well than the standard, although changes in weed control were rarely greater than 10%. ACCase inhibitors showed the most sensitivity to nozzle choice, with significant loss of control with low-drift nozzles in 60% of cases.

The remaining products were less sensitive, responding to nozzle choice in approximately 12% of cases. Low-drift nozzles performed equally well compared to the standard under challenging conditions for ALS inhibitors, auxin mimics, and the EPSPS inhibitor. For ACCase inhibitors and bromoxynil and bentazon, challenging conditions provided a disadvantage to the low-drift nozzles. Difficult-to-wet weeds were usually, but not always, implicated in instances of reduced control.

Higher spray pressure generally improved graminicide performance without significantly increasing drift potential. However, overall lower performance was still apparent for the coarsest venturi sprays. These results suggest that the successful implementation of low-drift technologies will depend on proper nozzle selection and operation, with reference to herbicide mode of action and target characteristics.

### OVERALL STRATEGIES TO REDUCE DRIFT

Using low-drift nozzles is only one of the many options available to us to reduce drift. Here is a list of drift reduction strategies which one can adopt to keep drift under control:

- Use nozzles that produce coarser droplets when applying pesticides on targets that do not require small, uniformly distributed droplets.
- Keep spray volume up, and use nozzles with larger orifices. Most manufacturers now sell what they call low-drift nozzles. Switch to these nozzles the next time you are buying new nozzles. Keep more than one size and type of nozzle on the boom ready to switch when the need arises.
- Follow recent changes in equipment and technology such as air-assisted and electrostatic sprayers that are developed for drift reduction in mind. Adopt some of these technologies when you feel it is time to do so.
- Keep the boom closer to the spray target. Nozzles with wider spray angle will allow you to do that.
- Keep spray pressure down, and make sure pressure gauges are accurate.
- Follow label recommendations to avoid drift with highly volatile pesticides.
- Avoid spraying on extremely hot, dry and windy days, especially if sensitive vegetation is nearby. Try spraying in mornings and late afternoons. Although is may not be practical, from the drift reduction aspect, the best time to spray is at night.
- Avoid spraying near sensitive crops that are downwind. Leave a buffer strip of 50 to 100 feet, and spray the strip later when the wind shifts.
- If you don't already have one, get yourself a reliable wind speed meters. Only then can you find out how high the wind speed is.

***The role of spray pressure and nozzle choice in weed control with low-drift nozzles.*** **(Report date: 2000)**

Thomas M. Wolf*, Eric Johnson, and Brian C. Caldwell, Agriculture and Agri-Food Canada, Saskatoon, SK.

Low-drift nozzles can produce very coarse sprays that may result in poor herbicide efficacy under some conditions. It is not known whether efficacy reductions are due to poor spray patterns, poor coverage, or an inability to target small weeds. To answer these questions, a study was conducted as Saskatoon and Scott, SK in 1999 and 2000, looking at the interactive effects of application timing [early vs. late]; nozzle [Air Bubble Jet (ABJ), Greenleaf TurboDrop (TD), and SprayMaster Ultra (SM)]; spray pressure [20, 40, and 75 psi]; herbicide rate [full and half rate]; and herbicide [paraquat/diquat (PD) at Saskatoon, glufosinate-ammonium (GA) at Scott]. Results were evaluated on three simulated weeds: tame buckwheat, oriental mustard, and tame oats. Spray swath uniformity and deposited droplet size were evaluated under laboratory conditions. Results showed that each herbicide was equally sensitive to the application variables studied. Late application increased weed control for PD, but reduced it for GA.

Early timing and reduced rates increased the sensitivity to nozzle and pressure selection for oats and mustard. Overall, similar control to a conventional flat fan nozzle could be achieved with the ABJ at 40 psi or greater, with the TD at 75 psi, or with the SM at 75 psi, except on tame oats, where the SM had lower weed control event at the highest pressure. Swath deposit uniformi-

*Volume of spray contained in drift-prone droplets (smaller than 150 microns) was reduced by 87% when a 0.2 gal/min flow rate capacity low-drift nozzle was operated at 40 psi compared to a comparable size standard flat-fan nozzle operated at the same pressure.*

ty, as measured by Coefficient of Variation (CV) was best with the TD (10%), intermediate for the ABJ (23%) and worst for the SM (28%). Increased pressure increased uniformity, except for the SM, where the intermediate pressure had the best uniformity (CV=20%). Spray coverage on water sensitive paper was similar for all nozzles (about 19%), and did not increase with pressure. Deposited Volume Median Diameter (VMD) was lowest for the ABJ, and highest for the SM, and decreased with pressure, although they were always higher than a conventional flat fan nozzle at 40 psi.

Weed control was related to swath deposit uniformity, but this alone was not a consistent predictor. Multiple regression demonstrated that effects of deposit CV and droplet density interacted, and together could predict between 62 and 80% of weed control variation for GA.

***Weed control in herbicide tolerant canola with low-drift nozzles* (Report date: 1999)**

Thomas M. Wolf, Brian C. Caldwell, Guy Lafond, and Eric Johnson
Agriculture and Agri-Food Canada, Saskatoon, SK.

Coarser sprays are a proven means of reducing herbicide spray drift. To verify the biological performance of these nozzles, efficacy and retention studies were conducted at Saskatoon, SK. Glyphosate and glufosinate-ammonium sprays were applied to simulated weeds in 10 gpa using five different application methods: (a) a conventional spray (TeeJet XR8002), (b) a drift-reducing adjuvant spray, (c) low drift nozzle #1 (Turbo TeeJet TT11002), (d) low drift nozzle #2 (TurboDrop TD110015 'venturi' nozzle), and (e) a twin fluid nozzle (AirJet).

In additional experiments, eight different 'venturi' tips were compared to a standard flat fan nozzle. 'Venturi' tips with an 015 flow rate were operated at approximately 60 psi, whereas a flat fan nozzle with an 02 flow rate was operated at 35 psi. Overall, glyphosate efficacy was similar on broadleaf and grass species for all nozzles.

Glufosinate-ammonium performance was not affected by nozzles for broadleaf species, but some reductions occurred on grass species, particularly with the coarsest sprays. Increasing spray pressure ameliorated the reductions in glufosinate-ammonium efficacy for some, but not all, nozzles. Efficacy was not always related to spray retention *per se*, but also depended on deposit uniformity. According to these data, it appears that most low-drift or venturi tips are suitable for use with glyphosate. Coarser sprays may cause efficacy reductions with glufosinate-ammonium on grassy weeds, particularly if applied at low pressures.

***Flat fan nozzle selection and spacing on sprayers.* (Report date: 1995)**

Robert N. Klein and Donald J. Thrailkill
University of Nebraska WCREC, North Platte, NE 69101

Postemergence herbicides require adequate and uniform coverage. Preplant incorporated herbicides require the least coverage, therefore large spray droplets could be used. Nozzles which produce large spray droplets, such as Spraying Systems new turbo floods, could be used effectively for preplant soil incorporated herbicides.

Research by the University of Nebraska has shown that at ten gpa or less the turbo flood nozzles did not give adequate coverage with a paraquat and atrazine tank mix (at 0.31 and 0.5 lb/a, respectively plus a nonionic surfactant at 0.25% v/v) for postemergence applications. Two other nozzles types (XR and Drift Guard) at three gallonages (10, 7.5 and 5 gpa) showed acceptable to excellent weed control.

*Dr. Erdal Ozkan is a Professor at Food Agricultural and Biological Engineering Department at the Ohio State University. He was at Iowa State University for six years before joining OSU in November 1985. He received his Masters and Doctorate degrees in Agricultural Engineering at University of Missouri. In Ohio, he provides leadership in development and implementation of Extension educational programs related to new developments in pesticide application technology. He is the author or co-author of 39 journal articles, four book chapters, 48 Extension publications, 16 software and has made over 60 technical presentations at national and international conferences.*

# I should know better...

**Curt Harler**
***Managing Editor***

*By Curt Harler/Managing Editor*

At my age, I should know better than to write this editorial. It'll get me in the dog house with about 15 percent of our readership, my editor, and my wife — all of whom are females.

But I'll never have as sizable and as intelligent a group to pose this question to, so here goes: Why is it okay for women to buy men saws, hammers, lawn mowers or shop vacuums for Christmas and birthdays, but it's not okay for men to buy women such items as irons, blenders or home vacuums at the same time?

I've known since I was about 10 years old that home appliances are off-limits as gifts for women. Yet I've received a pile of home appliances (all appreciated) as gifts. The typical explanation I've gotten in the past seems to run along these lines: A chain saw (hammer, shop vac) is such a nice, masculine gift. It's perfect for an outdoorsy, macho guy like you.

This holiday season, the makers of Armor All (those wonderful cleaning products for cars) have gone so far as to offer a gift pack of polishes, tire brighteners and waxes — aimed at the female buyer looking for a gift for her mechanically-minded man. Can you imagine a guy offering a woman a gift pack of Cascade, Tide and Johnson's floor wax?

When I've tried to explain there is nothing more feminine and appreciated in the morning than a woman using her new toaster oven to make breakfast, all I get is glares. When I mention that a certain multi-function mixer represents the height of home economics and gourmet technology, I know I've lost more points than I've gained.

So, I take my hammer or chain saw, trudge out back, and set to work — looking so masculine, cute and defeated. Do you think the Supreme Court would be interested in hearing my case?

In any case, happy holidays to all our readers, and best of wishes to everyone — male and female — for a safe, profitable and prosperous 2002.

*Best wishes to everyone for a safe, profitable and prosperous 2002.*

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