

BIOSTIMULANTS FUNCTION IN TURFGRASS NUTRITION

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MINERAL ELEMENTS

Most turfgrass agronomist has been trained in the concept of plant nutrition based on the philosophy of Justin von Liebig, the mid-nineteenth century chemist who became known as the “Father of Agricultural Chemistry”. He postulated that exhausted soil was simply the results of mineral nutrients removal. The giant mineral fertilizer industry was developed on the assumption that specific levels of mineral nutrients in plants are directly related to nutrient availability and impact plant performance. Most modern turfgrass agronomists have been involved in research concerning the impact of mineral fertilization on turfgrass. One readily may obtain results from studies dealing with various sources of nitrogen applied to turfgrasses as well as the ratios of major fertilizer elements on plant growth. However, the correlation between the rate which grass leaves grow because of fertility and turfgrass quality is poor (Mehall et al., 1984). Often heavy fertilized turfgrass that grows rapidly is more susceptible to environmental stresses than less fertilized slow growing grass (Green and Beard, 1969; Funk et al. 1967).

ORGANIC ASPECTS OF PLANT GROWTH

Recently interest has developed in the concept that suppression or enhancement of plant growth represents the effect of hormonal balance (Frankenberger and Arshad, 1995). Exogenous supplementation of biological active substances is a relatively new approach to managing turfgrass performance. Little is studied about the impact of endogenous hormonal balance of grasses and turf performance under different environments

Early work conducted in Russia has demonstrated the use of organic amendments stimulated plant growth (Krasil'nikov 1959). Plants treated with manure, compost, peat or sewage waste were richer in vitamins and other biological substances than those grown in non-treated soil (Rowlands and Wilkinson, 1930; Clark, 1935). Chester and Street, (1948) suggested factors other than mineral nutrients were responsible for the plant stimulation.

Beginning in early 1960, turfgrass researchers began documenting the performance of turfgrasses as related to endogenous plant organic substances as well as mineral nutrition. Some of the first investigations dealt with the interaction between fertilization and seasonal influence of the plant's carbohydrate content (Schmidt and Blaser, 1967). In environments that favor rapid foliar growth the non-structural carbohydrates of cool-season grasses were reduced. Rapid use of carbohydrates that stimulated shoot growth such as occurs during summer decreased the partitioning of energy available for root production. Fertilizing with nitrogen during late spring and summer exacerbates the utilization of carbohydrates that cause a reduction of root development and a subsequent reduction of turfgrass quality (Schmidt and Blaser 1969). Hull (1992) demonstrated that seasonal turfgrass growth patterns are not eliminated with elevated nitrogen fertilization. He speculated that suppression of summer growth of cool-season grasses also influence hormonal changes.

Powell et al. (1967) was among the first to report that N applied to cool-season turfgrass during the fall actually stimulated root development. This was attributed to the increased carbohydrates accumulation associated with elevated chlorophyll activity because of late season nitrogen availability during the winter months.

After a through review of reports of the effect organic amendments have on plant growth, Frankenberger and Arshad (1995) concluded that plant stimulation associated with application of organic materials cannot be

substituted by equivalent application of mineral nutrients. These authors pointed out that early researchers indicated vitamins were the possible activating substances. However, later research showed that hormones (auxins, cytokinins, gibberellins, ethylene and abscisic acid) were also important in influencing plant growth.

Our work when using processed seaweed, an excellent cytokinin source, indicated other metabolic enhancers were involved in addition to cytokinins (Goatley and Schmidt 1990b). We have investigated various materials that when applied in small quantities to turfgrasses stimulate growth that cannot be attributed to applications of traditional plant nutrients. These are referred to as biostimulants or metabolic enhancers. The most promising are seaweed extract, humic acid, amino acids, benzyladenine, trinexapac-ethyl, propiconazole, salicylic acid and silicates.

BIOSIMULANTS CONDITION TURFGRASSES TO BETTER TOLERATE ENVIRONMENTAL STRESSES

Research over the past decade at Virginia Tech has demonstrated that turfgrasses treated with selected metabolic enhancers (biostimulants) are better able to tolerate environmental stresses. We have shown that biostimulant treatments lessen the impact of turfgrass stressed by low soil moisture; (Zhang and Schmidt 1997, 1999, 2000a, 2000b); salinity (Nabati et al. 1994); heat (Zhang et al. 2002 a, b); cold (Schmidt and Chalmers, 1993); Dollar spot disease (Zhang et al. 2002c); high UV light intensity (Schmidt and Zhang 2001); herbicides (Schmidt and Luo 1993, Zhang et al. 2001) and nematodes (Sun et al., 1997). The primary benefit obtained from applying biostimulants to turfgrasses is the conditioning the grass to tolerate environmental and imposed stresses. Possibly these benefits stem from the fact that applications of metabolic enhancing materials induce an anti-senescence response (Goatley and Schmidt 1990a.).

To understand why these metabolic enhancers are beneficial to offset stress impact we need to explain how environmental stresses affect plants. Under favorable conditions the plants accept photons during the photosynthetic metabolic processes, producing water as a byproduct. Fluctuation of many environmental factors causes the photosynthetic process to produce excess photons than the photon-utilizing capacity of the plant, even during favorable environments. Plants have many systems to dissipate the energy of excess photons. However, under unfavorable environmental and endogenous conditions this photon-utilizing capacity can exceed the dissipating capacity of the plant resulting in the production and accumulation of a number of toxic oxygen species and free radicals (Asada 1996). These are strong oxidizing agents and damage lipids, proteins and DNA molecules and cause a loss of photosynthetic efficiency (senescence) and eventually plant death.

To avoid plant damage, prompt scavenging of accumulated active oxygen and free radicals is essential. Endogenous enhancement of antioxidants such as lipid soluble vitamin E and beta-carotene; water soluble vitamin C, and glutathione; enzymatic superoxide dismutase and catalase limit the overproduction of reactive oxygen species. Overproduction of free radicals often occurs in cool season grasses during the hot summer months (Zhang and Schmidt 2000a) when increase utilization of non-structural carbohydrates occur because of increased plant respirations and rapid foliar growth. The limit production of carbohydrates during this stress period (Wehner et al. 1988 and Schmidt and Blaser, 1967) reduces the development of antioxidants (Mozafar, 1994; Zhang and Schmidt, 2000a) and subsequent increase in free radicals.

Pretreatment with biostimulants change the hormonal balance to favor cytokinins and auxin production so that antioxidant production can continue when stress occurs. In our studies we showed that increased antioxidant content was a common factor associated with increased stress tolerance of biostimulant treated turfgrasses. The treatment with biostimulants triggered the enhancement of antioxidants for protection against adverse environmental conditions.

EXAMPLES OF BIOSTIMULANTS LESSENING STRESS IMPACT

SALINITY

Many warm and cool season turf are now are being irrigated with brackish water. As water is lost through evaporation salt accumulates in the soil and plant free radicals increase due to this salinity stress. Antioxidants stimulate by biostimulant treatments will help offset the toxic influence of the free radicals (Winston, 1990; Nabati et al., 1994) In addition, we have some evidence that uptake of sodium and chloride are reduced in biostimulant treated grass (Yan, 1993).

LOW SOIL MOISTURE

The tolerance of low soil moisture could be most evident and beneficial aspect associated with biostimulant treatments of turfgrasses (Zhang and Schmidt, 1999). Biostimulant treated plants retain more moisture than non-treated grasses when subjected to dry soil conditions (Zhang and Schmidt 2000b). Longer periods between irrigations may be programmed and less afternoon syringing to prevent wilting may be needed for biostimulant treated turf.

SOD SHELF LIFE ENHANCEMENT

A recent study was conducted to investigate the influences of selected biostimulant materials on Kentucky bluegrass sod subjected to 40C up to 96 hours (Zhang et al. 2002a). Results indicated that foliar application of the biostimulants enhanced the photochemical activity of pre-harvest sod and the subsequent post-transplant rooting (up to 56% increase). Regression analysis indicated that the Kentucky bluegrass with the highest pre-harvest photochemical activity suffered less and produced greater rooting after transplantation. Previous work showed that photochemical activity of creeping bentgrass was enhanced as the endogenous enzymatic antioxidant (superoxide dismutase) activity was increased with applications of metabolic stimulating materials (Zhang and Schmidt 2000a). Shelf life of cool-season turfgrass sod may be improved by enhancing pre-harvest photochemical activity with proper application of biostimulant materials.

PROTECTION AGAINST EXCESS UV LIGHT.

Reduced stratospheric ozone will result in a selective increase at the earth's surface of ultraviolet radiation in the spectral region 280 – 320 nm. Increased levels of UV-B radiation may affect the regulatory mechanisms of many plants, causing changes in photosynthesis and other metabolic processes (Teramura, 1996). Antioxidant compounds have been shown to protect plants from UV damage (Bornman et al., 1997). We have demonstrated that under controlled conditions that UV radiation reduced creeping bentgrass photochemical activity over 23% within 12 days (Schmidt and Zhang 2001). The detrimental effect of the UV radiation to the photosynthetic system was alleviated with foliar applications of salicylic acid alone or in combination with other metabolic enhancers. Also there is evidence that biostimulants Applied to cool-season turfgrass alleviate photochemical activity decline when exposed to high UV light intensity that transplanted sod may be subjected to during the summer months.

ENHANCING DISEASE TOLERANCE

Dollar spot disease on bentgrass was substantially reduced when creeping bentgrass was treated with applications of seaweed extract and humic acid (Zhang, et al.2002b). In a separate study, Dollar spot incidence on bentgrass was lessened with the antioxidant content of bentgrass increase associated with metabolic enhancer applications (Schmidt et al.1999). Indications based on these reports are that less fungicide may be required to offset the impact of disease when turf is treated with metabolic enhancers.

BIOSTIMULANT AND HERBICIDE TREATMENT

Preemergence herbicides may be safer on non-target plants when applied to biostimulant treated turf. (Schmidt and Luo, 1993). Seed treated with propiconazole or seaweed extract reduce injury when the preemergence herbicide, pendimethalin, was applied to juvenile Kentucky bluegrass. Application of metabolic enhancers significantly increased the photochemical activity (27%) of creeping bentgrass treated with post emergence herbicides indicating that non-target postemergence herbicidal injury may be reduced when turfgrasses are treated with selected biostimulants. (Zhang et al. 2001). The efficacy of low herbicidal dosages may be enhanced in controlling broadleaf weeds, such as white clover, when applied to turf treated with selected metabolic enhancing materials. Proper application of biostimulants could significantly reduce the required dosage of postemergence herbicides, thus reducing phytotoxicity of non-target plants, the potential of groundwater pollution as well as human exposure to excess herbicidal dosages.

Unpublished research under-way at Virginia Tech (Ervin and Zhang) indicates that the use of certain biostimulant materials with selected herbicides enables the control of bermudagrass without causing phytotoxicity to bentgrass. Once these results have been verified turfgrass managers will be able to safely control the invasion of bermudagrass into bentgrass areas, such as putting greens. Also these researchers have demonstrated that better eradications of bermudagrass maybe obtained with glyphosate when applied with selected biostimulants.

REDUCING NEMANTODE IMPACT WITH BIOSTIMULANTS

A study was initiated to evaluate the influence of seaweed concentrate on bentgrass subjected to nematode infection and low soil moisture (Sun et al. 1997). Drenching twice a month with 4 liters per hectare of 25% seaweed extract reduced yellowing, thinning, wilting and improved leaf water status and clipping yields of Root-knot and Lance nematode infected bentgrass. Rooting improvement of more that 40% was associated with this treatment applied to both nematode-infected bents. These results confirm other research reports that application of seaweed concentration suppressed nematode development when applied to other crops. Indications are that utilization of seaweed extracts could be an economical and non-toxic method to reduce the impact of nematode infestation of turfgrasses.

HOW OFTEN, HOW MUCH OF WHICH BIOSTIMULANT SHOULD BE APPLIED?

Since biostimulants are formulated from different materials at varying concentrations it is difficult to specify a particular biostimulant. **Selecting a biostimulant should be based on data generated by qualified independent researchers to verify the efficacy of the material.** At Virginia Tech we have shown that biostimulant materials that contain seaweed, humic acid, triazole fungicides, amino acids, potassium silicate, and most recently, low dosages of salicylic acid have demonstrated biostimulant properties. However, for the two most commonly use biological active ingredients, seaweed and humic acid, there are different sources and different procedures for extracting these materials, which impact turfgrasses differently.

Ideally, treatments should be made prior to the anticipated stress to insure the plant is conditioned to tolerate the adverse environment. Generally, we find that frequent low dosage applications give better results than high doses applied infrequently. The effect of a single biostimulant application can be expected to decrease gradually with time. There are some indications that better results are obtained when sequential treatments are made and the second year is better than the first. Monthly applications (three to six per year) should be programmed. Most biostimulant materials influence plant hormonal activity; therefore, overdosing could be harmful.

MIXING DIFFERENT MATERIALS THAT HAVE BIOSTIMULANT PROPERTIES

Our research has shown that mixing different biostimulating materials to be a good practice in some cases. The combination of triazole fungicide, humic acid and seaweed extract has provided excellent results (Zhang and Schmidt, 1999; Zhang et al. 2002b). Dosages of each of these materials when blended may be

lowered, and yet retain the efficacy of the biostimulant effect. This combination reduces the need for high triazole fungicides rates to control certain diseases (Ervin and Zhang 200x). The combination of the seaweed and humic acid generally has better biostimulating properties than either material alone.

The use of trinexapac-ethyl (Primo) to suppress turfgrass top growth has increased in popularity. We have shown that applications of trinexapac-ethyl have increased endogenous antioxidants, but not root growth as other biostimulant materials have (Zhang and Schmidt 2000a). The addition of seaweed extract with trinexapac-ethyl may encourage the development of roots under stress periods. Our current research has shown that the incorporation of salicylic acid with seaweed and humic acid enhanced biostimulant properties.

BIOSTIMULANT IMPACT ON TURFGRASS FERTILIZER PROGRAMS

Biostimulants do not necessarily supply all the essential nutrients in quantities a plant requires for optimum performance. **Again, I would like to stress the main function of the biostimulant is to condition the plant to better tolerate environmental stresses.** Although, the metabolic stimulation associated with applications of biostimulants may be considered an essential part of turfgrass nutrition, biostimulants should be programmed in conjunction with proper mineral fertilization. We do feel that biostimulants enhance the effectiveness of conventional fertilizers. Researchers indicate that less mineral fertilizers are required when biostimulants are used (Schmidt, 1992; Frankenberger and Arshad, 1995). This has practical and environmental impact. Applying less nitrogen than the conventional rates to the newer creeping bentgrasses results in reduced thatch development and possible subsequent deterioration of the turf.

Biostimulant treatments should be beneficial when used in conjunction with the “spoon feeding” technique of fertilizing bentgrass putting greens currently advocated by some superintendents. This is especially true during summer months when bentgrass antioxidant content is low. With the reduced application of mineral nutrients, the potential of soil-water contamination is reduced, resulting in good environmental practices.

CONCLUSION

It has been demonstrated that use of substances, other than mineral nutrients, that enhance plant metabolism enables the improvement of plant nutrition. The utilization of these substances enables the turfgrass manager to improve the conditioning of the plant to tolerate adverse environmental stresses. This conditioning is associated with the development of endogenous antioxidants beyond what the plant would normally produce to suppress the production of toxic radicals and active oxygens generated by environmental stresses. Biostimulants (metabolic enhancers) are additional tools the turfgrass manager may use in the production of quality turf under adverse conditions.

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