

# **Evaluation of Plant Growth Responses to IBR Solid & Liquid Compost Formulations\***

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**June 2000**

**\*Note: This report contains all the information regarding turf growth and the anti fungal activity of IBR products. This report was removed from the report titled “Evaluation of Plant Growth Responses to IBR Solid and Liquid Compost Formulations”.**

**On behalf of International Bio Recovery Corporation  
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## Executive Summary

These trials were designed to assess the plant growth response of a range of plant species to fertilization with several formulations of powder, pelleted and liquid products from International Bio-Recovery Corporation (IBR). The following conclusions are derived from the data presented in the report:

- The plant responses observed in this study with several species were sufficiently uniform to support the conclusion that batch to batch variability in the IBR solid formulations these trials was not a concern. The only instance where one of the solid formulations outperformed the other two was the significantly increased biomass of all three conifer species fertilized with IBR3.
- The IBR solid formulations as used in these trials did not affect germination and stand establishment of any species tested (in marked contrast to Fish<sup>®</sup> pellets). Nor was there any apparent effect on the nodulation of legumes.
- Bentgrass and bluegrass grew well and had desirable turfgrass quality characteristics when fertilized with IBR solid + weekly applications of diluted IBR liquid. The IBR formulations also showed evidence of extended nutrient release. The treatment combination outperformed the current inorganic industry standard, as well as the most common organic alternative (Sustane<sup>®</sup> + 21-5-21) in these trials
- Putative suppressive microflora were isolated from “compost teas” made with both the IBR solid and stabilized liquid formulations. Representative strains of these microflora strongly inhibited the growth of 10 different plant pathogens representing the four major fungal taxonomic groups.

## **INTRODUCTION**

The experiments described in this report were undertaken with the following objectives:

1. To determine the growth response of a variety of plant species to different batches of the IBR unsupplemented powder compared to the response to commercially available fertilizers applied at the same rate of nitrogen
2. To determine whether the stabilized IBR liquid formulation could be applied as a side dressing to compensate partially for the slow release nature of the IBR powders.
3. To determine whether the IBR powder and liquid formulations contain microflora that are suppressive to common plant pathogenic fungi.

## **METHODS AND MATERIALS**

### **Evaluating Plant Growth Responses To IBR Formulations**

Several different compost formulations provided as numbered samples by IBR (Table 1) were compared to commercial fertilizers and an unfertilized control under greenhouse conditions. Standard UBC greenhouse floodbench mix, comprised of 10% v/v steamed (pasteurized) field soil, 10% v/v Perlite and 80% v/v Pro-mix (Premier Peat), was used.

The target level of fertilization for turf was recommended by Dr. Brian Holl at UBC. Two assumptions were made in designing the fertility treatments: the first was that the level of nitrogen provided would be the growth limiting factor., and the second that the amount of soil in the mix was sufficient to provide the micronutrients required. Because the different formulations had varying N-P-K ratios, the amounts added were calculated to provide the equivalent amount of nitrogen regardless of the formulation. The inorganic and pelleted fertilizer formulations were pulverized in mortars and pestles. The resulting ground samples and the IBR powder samples were worked into the top 1 cm of the soil mix in each pot.

**Table 1.** Fertilizer formulations evaluated in greenhouse trials using a variety of plant species

Fertilizer	NPK ratio	Source
IBR unsupplemented powder 1	4-1-1	IBR
IBR unsupplemented powder 2	4-1-1	IBR
IBR unsupplemented powder	4-1-1	IBR
IBR supplemented powder 1	6-2-4	IBR
IBR supplemented powder 2	6-2-4	IBR
IBR supplemented powder 3	6-2-4	IBR
IBR supplemented pellets 1	6-2-4	IBR
IBR supplemented pellets 2	6-2-4	IBR
IBR supplemented pellets 3	6-2-4	IBR
IBR liquid	1.5-0.05-2	IBR
Inorganic fertilizer	6-8-6	Art Knapp All Purpose Plant Food
Fish Pellets	8-5-1	Alaska Fish Fertilizer

The two turf species were grown in washed river sand in 30x 30 cm plastic trays with perforated bottoms. The six treatments for turf included the three IBR unsupplemented powders, inorganic fertilizer (16-4-16) and the organic turf fertilizer Sustane® (a processed turkey compost), as well as two negative controls. The latter received no initial fertilizer, but were supplemented with liquid 21-5-21(325 mg/L)(Plant Products Company, Brampton ON) and iron (FeSO<sub>4</sub>.H<sub>2</sub>O)(15 mg/L) or 1/8 dilution liquid IBR in the irrigation water on a weekly basis, and watered in to remove salts from the foliage. The experimental fertilizers were worked into the top 1 cm of the sand immediately prior to seeding.

In addition to clippings yields, the turf was evaluated at intervals for quality and/or colour using the National Turf Evaluation Program (NTEP) visual rating system (scale = 1-9, where 9 is highest).

### **Planting, Growing and Harvesting**

Several seeds of the large-seeded species were planted into each pot at a depth appropriate for the species and the seeded pots watered in (Table 2). The pots were carefully thinned to one seedling per pot after emergence. Tomato and marigold seedlings were propagated in seed trays under supplemental illumination and transplanted into pots when they were > 4cm in height. Pansy seedlings (approximately 8 weeks old), obtained in plugs from Genesis Plant Propagators,

Langley, BC, were transplanted directly into 10 cm pots. The conifers seeds were stratified by placing them in running cold water for at least 24 hours, blotting dry and storing at 4° C for 3- 4 weeks prior to direct seeding into Super Cells.

The plantings were checked daily and pots were watered individually on an "as needed" basis. In all experiments except the turf trials each fertilizer treatment was replicated 15 times in a completely random design. Each turf trial had 6 replicates arranged in a randomized complete block design. Plants were grown out under supplemental illumination (16 hour photoperiod) provided by cool white fluorescent lamps. Beans, peas and cucumbers as they reached maturity were harvested from the individual plants and the cumulative fruit dry weights maintained for each plant.

At the termination of the experiment for each species the same procedure was used. Immature fruits, if present, were harvested and bagged separately. Roots systems were carefully separated from the soil. Root harvests were not included in the pea trial. It was evident in the initial harvests that the root systems were quite fine and fragile; losses during harvest were unpredictable and variable. It was, therefore, determined that these data would not reflect the *in situ* condition and no further effort was made to retain the root systems. The roots and shoots of each plant were separated at the soil line or cotyledonary node (for radishes) and bagged individually. Dry weights were determined after at least 3 - 4 days drying at 80 C.

**Table 2.** Plant species and seed sources used in the evaluation of plant response to different IBR composts and fertilizer treatments

Plant species	Seed/plant source	Pot (cm)
Creeping bentgrass <i>Agrostis palustris</i> Huds. cv Penncross	Richardson Seeds	30 x 30 cm
Kentucky bluegrass <i>Poa pratensis</i> L. cv Shamrock	Richardson Seeds	trays

### Suppressive Microflora Bioassay

Preliminary experiments established that the relative growth rates of the fungi and microbes in the compost teas dictated how the bioassays should be set up. Slow-growing test fungi had to be pre-inoculated prior to inoculation with the compost tea suspensions whereas the reverse was required for some very rapidly growing test fungi. Most of the test fungi with intermediate growth rates could be inoculated at the same time as the compost tea suspensions. Four plant pathogenic species, *Colletotrichum lindemuthianum*, *Didymella bryoniae*, *Pythium aphanidermatum* and *Rhizoctonia solani* representing the four major taxonomic groups of fungi, were selected as the test fungi to be used for preliminary screening, and a standard protocol was developed. Aliquots of vigorously stirred compost tea suspensions were streaked along a 2 cm line onto duplicate, dry, potato dextrose plates agar (PDA Difco) plates. Disks (4 mm in diameter) were aseptically cut from actively growing cultures of the test fungi and placed fungus-side down at a fixed distance from the streak line. *R. solani* and *D. bryoneae* were inoculated 2.5 cm away from, and at the same time as the compost tea streak. *C. lindemuthianum* was inoculated 1.5 cm away from but 2 days prior to the addition of compost tea streak and *P. aphanidermatum* was inoculated 2.5 cm away from the streak but 2 days after addition of the compost tea streak. A control plate of each fungus without a compost streak was also prepared for comparison. The dual culture plates were examined every 2 days for visual indications of growth inhibition. Mixtures of organisms present in the compost tea streak adjacent to areas of obvious growth inhibition were sampled and dilution streaks made on PDA until isolated colonies were obtained. Representative colonies were selected and transferred to nutrient agar (Difco) and PDA slants for storage until they could be tested further.

Compost teas were prepared containing 0.5%, 1.0% 5.0% and 10% IBR Unsupplemented Powder 1, IBR Supplemented Powder 1 and IBR Supplemented Pellets 1 on a w/v basis. Similarly, dilutions of 1:100, 1:500 and 1:1000 of the IBR liquid were prepared. The suspensions were mixed thoroughly for 15 minutes and "0" time samples were applied to dual culture bioassay plates as described above. These same compost tea suspensions were sampled after 1, 2, 3 and 9 weeks. Between samplings the compost tea suspensions were incubated in still culture at room temperature in approximately 300 ml quantities in 2 litre flasks capped with aluminum foil. Prior to each sampling and during the sampling process, the suspensions were vigorously mixed.

The same protocol was used to retest some of the more promising isolates obtained against the full test panel of fungal plant pathogens (Table 3). The dual culture plates were examined every 2 days and a rating system devised to reflect the degree and permanence of the growth inhibition observed.

### **Statistical Analysis**

All data were subjected to statistical analysis using the ANOVA program in *Statistix® for Windows* (Analytical Software FLA).

**Table 3.** Test panel of plant pathogenic fungi used in the dual culture bioassay to detect microorganisms capable of inhibiting fungal growth

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<b>Fungus</b>	<b>Time of inoculation relative to inoculation of compost streak</b>
<i>Botrytis cinerea</i>	2 days after
<i>Colletotrichum lindemuthianum</i>	2 days prior to
<i>Didymella bryoniae</i>	simultaneous
<i>Fusarium oxysporum</i> f.sp <i>lycopersici</i>	simultaneous
<i>Fusarium oxysporum</i> f.sp <i>radicis-lycopersici</i>	simultaneous
<i>Pythium aphanidermatum</i>	2 days after
<i>Rhizoctonia solani</i>	simultaneous
<i>Sclerotinia sclerotiorum</i>	2 days after
<i>Thielaviopsis basicola</i>	simultaneous
<i>Verticillium dahliae</i>	2 days prior to

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## **RESULTS**

### **Growth Responses**

Surprising diversity was observed in the growth responses of the different test plant species to the fertilizers evaluated in this trial. Although the rates of fertilizer application were standardized to the rate of nitrogen recommended for the crop, sometimes striking differences in growth were observed between different fertilizer treatments. It was apparent that at least under the conditions of this trial, some plant species showed either superior growth or were severely inhibited depending upon the fertilizer treatment. Plant species will be discussed in groups that share common characteristics.

#### ***Turf [Appendix Tables 48-53]***

The mean dry weights of clippings taken from the bluegrass trials initially were as expected - plants receiving the inorganic fertilizer treatment plus a weekly inorganic fertilizer side dressing had the highest mean followed by plants receiving the commercial organic turf fertilizer (Sustane®) plus the same side dressing (Appendix Table 48). In subsequent clippings, plants receiving these treatments declined as the nutrients were used or leached from the sand medium. Plots receiving the IBR treatments plus the weekly side dressing of diluted IBR liquid had increasing yields at each harvest and at the 102 day clipping were better than or equal to the inorganic fertilizer treatment, and significantly higher than any of the remaining treatments.

Of particular interest is the fact that in each of the later harvests and in the cumulative clippings, control plots receiving only supplemental diluted IBR liquid consistently out yielded the control plus inorganic fertilizer plots. In half of these examples the differences were significant statistically. Essentially identical results were obtained in the bentgrass experiment. The second, third and cumulative clippings from the IBR plus IBR liquid treatments were significantly higher than all other treatments including the inorganic fertilizer plus inorganic side-dressing treatment. The increased growth response of the liquid IBR side-dressing on the unfertilized control compared to the inorganic side dressing was also apparent in the bentgrass trial. These trials are consistent with previously reported trials by IBR that the compost-based materials are well suited for use on these common turf species.

The turf quality, density and colour assessments are summarized in Appendix Tables 49, 50, 52 and 53). Although there was some variation between batches, quality assessments for both bluegrass and bentgrass were generally superior for the IBR powder + IBR liquid treatments. The impact of the IBR treatment was also observed in the colour assessment; IBR powders 1

and 3 + IBR liquid (bluegrass) and IBR powders 1-3 + IBR liquid (bentgrass) were significantly darker green than all other treatments except for the Control + IBR liquid; this effect was particularly interesting as it suggests that the IBR liquid made a significant contribution to colour maintenance. The comparison of IBR powders + IBR liquid versus IBR powders + 21-5-21 is also consistent with the contribution of liquid to both colour development and overall turf quality.

Both the clippings data and the visual assessments suggest that the IBR materials have significant potential as turfgrass fertilizers and/or biostimulants.

### **Pathogen-Suppressive Microflora**

Over 200 isolates of putative suppressive fungi and bacteria were recovered from the compost teas made with both the IBR powder and the liquid formulations. Of the strains that have been isolated, cultured and re-tested, many continue to inhibit pathogen growth in dual culture plate tests. These suppressive organisms were recovered from freshly made teas, but were more frequently isolated from teas that had been aged for at least a week. Suppressive organisms could also be recovered from teas that were 10 weeks old. Teas made with 0.5% and 1.0% IBR unsupplemented powder, and teas made with the 1:500 and 1:1000 dilutions of the IBR liquid appeared to have a higher occurrence of inhibitory species at any given sampling period. Isolates with similar visual appearance and growth characteristics were recovered from teas of different ages. Further experiments will be necessary to determine whether or not there is succession of suppressive microbes in teas and whether teas of certain ages are more inhibitory than others.

Inhibition was observed to occur in a variety of patterns (Table 4 and Figure 1) depending upon the specific pairing of suppressive microbe and pathogen. When radial growth was inhibited, some fungi responded by producing aerial mycelium that filled the plate and eventually fell over into the zone of inhibition. The inhibition rating depended to some extent upon when the plates were observed. (Figure 2). For example, time was required for the necessary growth to occur to distinguish between classes 1 and 2 and between classes 3 and 4. Using our rating system, it was apparent that some suppressive strains were active against a wide range of fungal plant pathogens whereas others inhibited only a few of the fungi in the test panel (Table 5). Furthermore, growth of test panel fungi such as *T. basicola*, was inhibited by all organisms, whereas growth of others (*B. cinerea* and *S. sclerotiorum*) was inhibited by only a few test strains. Some suppressive strains of both fungi and bacteria appear to permanently stop vegetative growth while the inhibition caused by others appears to lessen with time allowing

pathogen regrowth. This observation suggests that the mechanisms of inhibition may vary amongst the suppressive strains, and/or that there is a concentration-dependent component to the observed inhibition. Whether such inhibitory effects function in protecting the associated plants from these pathogens *in vivo* was beyond the scope of the present work but suggests that it is an exciting possibility.

**Table 4.** Types of inhibition zones observed in dual culture plates with plant pathogen suppressive strains recovered from compost teas made with IBR solid or liquid formulations

Rating	Criterion
0	No inhibition - pathogen grows through the test antagonist streak
1	Pathogen grows normally to the edge of the test antagonist colony and around it but not through it so that mycelia of the two organisms are touching
2	Pathogen grows normally to the edge of test antagonist colony and around it but a small clear zone (1-2mm) permanently separates the two organisms
3	Pathogen growth inhibited initially at a distance but inhibition breaks down with time and the pathogen regrows (often poorly) around the test antagonist
4	Pathogen growth is stopped at a distance and a large clear zone separates the two organisms. The test antagonist with prolonged culture may grow towards the pathogen to reduce the clear zone.

**Table 5.** Activity spectrum after 19 days of representative suppressive strains recovered from compost teas made from IBR powder or liquid tested against a panel of plant pathogenic fungi

<b>Inhibition rating on a fungal test panel comprised of the following*</b>										
<b>Strain</b>	Botr	Coll	Didy	Fol	Forl	Pyth	Rhiz	Scler	Thiel	Vert
Cl26	1	2	4	1	1	4	0	4	4	1
Pa30	0	3	3	3	3	3	0	0	4	3
Pa38	1	3	3	3	3	0	3	0	4	1
Pa65	1	4	4	1	1	4	1	2	4	4
Rs8	4	4	4	3	4	4	4	4	4	4
Rs41	1	4	1	1	1	4	2	2	4	4
Ss3	4	4	4	4	4	4	4	4	4	4
Vd2	4	4	4	4	4	4	4	4	4	4
301	4	4	3	3	4	4	4	4	4	nt
Fol12	0	3	3	0	0	3	2	0	4	nt

\* Inhibition rating from 0 (none) to 4 (large clear zone between organisms) (see Table 4)  
 Botr = *Botrytis cinerea*; Coll = *Colletotrichum lindemuthianum*; Didy = *Didymella bryoniae*; Fol = *Fusarium oxysporum* f.sp. *lycopersici*; Forl = *Fusarium oxysporum* f.sp. *radicis-lycopersici*; Pyth = *Pythium aphanidermatum*; Rhiz = *Rhizoctonia solani*; Scler = *Sclerotinia sclerotiorum*; Thiel = *Thielaviopsis basicola*; Vert = *Verticillium dahliae*



**Figure 1.** Examples illustrating the types of growth inhibition observed and the rating assigned to each. Ratings (left to right) top row 0 and 1; middle row 4, 4 and 4; and bottom row 1, 1, and 2.



**Figure 2.** Photographs of the same test panel of fungi to show the effect of time on the rating assigned.  
 (a) taken after 6 days, and  
 (b) taken after 11 days.  
 Note that the right plate in the middle row and the left plate in the bottom row of photograph (a) have exchanged places in (b)

## DISCUSSION

With one possible exception, the plant species grown in these trials showed consistent responses to all three IBR solid formulations. The exception was the apparent, positive differential response of the three conifer species to the IBR3 formulation. Mean biomasses of lodgepole pine and spruce receiving IBR3 were statistically equivalent to the top-ranked Osmocote<sup>®</sup> treatment while that of Douglas-fir was intermediate. The mean biomasses of spruce and Douglas-fir receiving the IBR1 and IBR2 formulations and lodgepole pine receiving IBR1 were significantly lower than those of the Osmocote<sup>®</sup> treatment. Otherwise, all the plants in this trial responded similarly to the IBR formulations, but the magnitudes of the responses were variable.

In the bentgrass and bluegrass trials where by the final harvest date the the IBR + IBR liquid treatments were significantly better than the inorganic or Sustane<sup>®</sup> treatments. The positive growth response of the diluted IBR liquid treatment on the unfertilized control compared to the same amount of nitrogen applied as a liquid inorganic supplement to the control is worth noting. These results support the results of an earlier preliminary trial suggesting that grass species respond favorably to the IBR material.

The strong positive effect of the IBR formulations on the turf species might be due in part to lower microbial competition for nutrients in the washed sand growing medium compared to the peat-based flood bench medium, and more rapid mineralization of organic nitrogen. Furthermore, the sand substrate would have significantly fewer competing microbial communities compared to the peat-based medium. These observations are also consistent with the information that we have available regarding the potential for nitrogen immobilization by the active microbial components of the composts. In the sand medium in which the turf was grown, microbial populations would be less well established. In the absence of other organic materials (such as the peat in the growing mix used for other species), it is likely that these microbial populations would provide a benefit to the plants through the mineralization release of nitrogen from the compost. If similar trials are conducted in the future, selection of a growing medium that provides a relatively microbially "inert" starting point (e.g. sand or Turface<sup>®</sup>) is recommended, and quantifying the microbial populations present in the rhizosphere should be undertaken.

It is important to note that in spite of the considerable microflora present in the compost teas and the excessive microflora was recovered from the pansy growing medium, there was no evidence of it having a negative effect on nodulation or stand establishment. While the Fish<sup>®</sup> pellets

similarly incorporated into the top 1 cm of the growing medium proved to be harmful to lethal for peas, beans, lettuce, cucumber and marigolds, none of the IBR treatments caused germination or stand establishment problems. Based on these trials, the IBR materials would appear to be suitable for use in soilless seedling mixes.

The presence of a microflora in both IBR formulations and our detection of a range of putative suppressive isolates is of considerable importance. Both negative and positive effects could be operative. The presence of an active microflora will result in short term immobilization of plant-available nutrients and may partially explain the variability in the trials and the smaller than expected growth responses with some plant species. The variability and response patterns are likely to be exacerbated in short-term trials where microbial activity is an essential feature of nutrient release.

However, if a portion of this microflora is as suppressive *in vivo* as it would appear to be in the dual culture assays, its presence should be a genuine asset for seed germination and stand establishment. Some of the bacteria and fungi isolated from the IBR materials were able to inhibit the growth of all 10 plant pathogenic fungi that were included in the test panel; all of these fungi cause economically important plant diseases. While these same putative suppressive strains were not tested against important plant pathogenic bacterial species, there is reason to suspect that some will also be suppressive against bacteria because they inhibited the growth of other bacteria in the mixed populations growing on the original isolation plates. Whether these isolated suppressive strains will provide protection against pathogen invasion of plants *in vivo* remains to be determined, but the possibility is an intriguing one and should be explored further.

## CONCLUSIONS

1. The plant responses observed in this study with several species were sufficiently uniform to support the conclusion that batch to batch variability in the IBR solid formulations these trials was not a concern. The only instance where one of the solid formulations outperformed the other two was the significantly increased biomass of all three conifer species fertilized with IBR3.
2. The IBR solid formulations as used in these trials did not affect germination and stand establishment of any species tested (in marked contrast to Fish<sup>®</sup> pellets). Nor was there any apparent effect on the nodulation of legumes.
3. Bentgrass and bluegrass grew well and had desirable turfgrass quality characteristics when fertilized with IBR solid + weekly applications of diluted IBR liquid. The IBR formulations also showed evidence of extended nutrient release. The treatment combination outperformed the current inorganic industry standard, as well as the most common organic alternative (Sustane<sup>®</sup> + 21-5-21) in these trials
4. Putative suppressive microflora were isolated from “compost teas” made with both the IBR solid and stabilized liquid formulations. Representative strains of these microflora strongly inhibited the growth of 10 different plant pathogens representing the four major fungal taxonomic groups.

## **Appendix Tables**

**Appendix Table 48.** Mean clippings yield of greenhouse-grown bluegrass receiving different fertilizer treatments

<b>Treatment</b>	<b>Mean dry weight (g)</b>
First harvest after 51 days	
Inorganic fertilizer + 21-5-21	1.81 a*
SUSTANE <sup>®</sup> 5-2-4 + 21-5-21	1.74 ab
IBR-Unsupplemented Powder 2 + IBR Liquid (1/8x)	1.67 ab
IBR-Unsupplemented Powder 1 + IBR Liquid (1/8x)	1.43 abc
IBR-Unsupplemented Powder 3 + IBR Liquid (1/8x)	1.27 bc
IBR-Unsupplemented Powder 1 + 21-5-21	1.15 cd
IBR-Unsupplemented Powder 2 + 21-5-21	1.02 cde
Control + IBR Liquid (1/8x)	0.779 def
IBR-Unsupplemented Powder 3 + 21-5-21	0.643 ef
Control + 21-5-21	0.360 f
Second harvest after 68 days	
Inorganic fertilizer + 21-5-21	3.170 a
IBR-Unsupplemented Powder 1 + IBR Liquid (1/8x)	3.164 a
IBR-Unsupplemented Powder 2 + IBR Liquid (1/8x)	3.076 a
IBR-Unsupplemented Powder 3 + IBR Liquid (1/8x)	2.460 b
SUSTANE <sup>®</sup> 5-2-4 + 21-5-21	2.293 b
IBR-Unsupplemented Powder 1 + 21-5-21	1.539 c
IBR-Unsupplemented Powder 2 + 21-5-21	1.407 c
IBR-Unsupplemented Powder 3 + 21-5-21	0.150 cd
Control + IBR Liquid (1/8x)	0.812 de
Control + 21-5-21	0.443 e
Third harvest after 102 days	
IBR-Unsupplemented Powder 2 + IBR Liquid (1/8x)	6.13 a
IBR-Unsupplemented Powder 3 + IBR Liquid (1/8x)	6.06 a
IBR-Unsupplemented Powder 1 + IBR Liquid (1/8x)	5.53 a
Inorganic fertilizer + 21-5-21	3.64 a
SUSTANE <sup>®</sup> 5-2-4 + 21-5-21	3.12 b
IBR-Unsupplemented Powder 2 + 21-5-21	2.55 bc
IBR-Unsupplemented Powder 1 + 21-5-21	2.36 bc
IBR-Unsupplemented Powder 3 + 21-5-21	2.35 c
Control + IBR Liquid (1/8x)	1.99 c
Control + 21-5-21	0.676 d
Cumulative harvest after 102 days	
IBR-Unsupplemented Powder 2 + IBR Liquid (1/8x)	10.88 a
IBR-Unsupplemented Powder 1 + IBR Liquid (1/8x)	10.12 a
IBR-Unsupplemented Powder 3 + IBR Liquid (1/8x)	9.79 ab
Inorganic fertilizer + 21-5-21	8.62 b
SUSTANE <sup>®</sup> 5-2-4 + 21-5-21	7.15 c
IBR-Unsupplemented Powder 1 + 21-5-21	5.05 d
IBR-Unsupplemented Powder 2 + 21-5-21	4.98 d
IBR-Unsupplemented Powder 3 + 21-5-21	4.14 d
Control + IBR Liquid (1/8x)	3.58 e
Control + 21-5-21	1.48 f

\* Means (n = 6) at any harvest date sharing the same letter are not significantly different by LSD (P < 0.05)

**Appendix Table 49.** Quality and density of greenhouse-grown bluegrass receiving different fertilizer treatments.

<b>Treatment</b>	<b>Quality (9/03/00)</b>	<b>Density (9/03/00)</b>
IBR-US Powder 1 + IBR Liquid (1/8x)	5.0 a*	4.0 abc*
IBR-US Powder 3 + IBR Liquid (1/8x)	5.0 a	4.3 a
IBR-US Powder 1 + 21-5-21	4.8 ab	4.2 ab
IBR-US Powder 2 + IBR Liquid (1/8x)	4.5 abc	4.0 abc
IBR-US Powder 2 + 21-5-21	4.3 abc	4.0 abc
Control + IBR Liquid (1/8x)	4.3 abc	3.8 abcd
Inorganic fertilizer + 21-5-21	4.2 bc	3.8 abc
SUSTANE <sup>®</sup> 5-2-4 + 21-5-21	4.2 bc	3.5 bcd
IBR-US Powder 3 + 21-5-21	3.8 c	3.3 cd
Control + 21-5-21	2.5 d	3.0 d

\* Means (n = 6) within each column that share the same letter are not significantly different by LSD (P< 0.05)

**Appendix Table 50.** Quality and colour of greenhouse-grown bluegrass receiving different fertilizer treatments.

<b>Treatment</b>	<b>Quality (25/04/00)</b>	<b>Colour (9/06/00)</b>
IBR-US Powder 3 + IBR Liquid (1/8x)	7.1 a*	6.8 a*
IBR-US Powder 1 + IBR Liquid (1/8x)	7.0 a	7.0 a
IBR-US Powder 2 + IBR Liquid (1/8x)	6.5 abc	5.8 b
Inorganic fertilizer + 21-5-21	4.8 bc	5.0 b
SUSTANE <sup>®</sup> 5-2-4 + 21-5-21	3.7 bc	5.0 b
IBR-US Powder 2 + 21-5-21	3.5 abc	5.2 b
IBR-US Powder 1 + 21-5-21	3.3 ab	5.2 b
IBR-US Powder 3 + 21-5-21	3.0 c	5.5 b
Control + IBR Liquid (1/8x)	2.8 abc	7.3 a
Control + 21-5-21	2.0 d	5.2 b

\* Means (n = 6) within each column that share the same letter are not significantly different by LSD (P< 0.05)

**Appendix Table 51.** Mean clippings yield of greenhouse-grown bentgrass receiving different fertilizer treatments

Treatment	Mean dry weight (g)
First harvest after 49 days	
Inorganic fertilizer + 21-5-21	3.16 a*
IBR-Unsupplemented Powder 3 + IBR Liquid (1/8x)	2.71 ab
IBR-Unsupplemented Powder 1 + IBR Liquid (1/8x)	2.61 abc
IBR-Unsupplemented Powder 2 + IBR Liquid (1/8x)	2.24 abcd
SUSTANE <sup>®</sup> 5-2-4 + 21-5-21	1.95 bcde
IBR-Unsupplemented Powder 1 + 21-5-21	1.74 cde
IBR-Unsupplemented Powder 2 + 21-5-21	1.60 def
Control + IBR Liquid (1/8x)	1.30 ef
Control + 21-5-21	0.803 f
IBR-Unsupplemented Powder 3 + 21-5-21	0.688 f
Second harvest after 69 days	
IBR-Unsupplemented Powder 1 + IBR Liquid (1/8x)	4.00 a
IBR-Unsupplemented Powder 2 + IBR Liquid (1/8x)	3.92 a
IBR-Unsupplemented Powder 3 + IBR Liquid (1/8x)	3.90 a
Inorganic fertilizer + 21-5-21	2.96 b
SUSTANE <sup>®</sup> 5-2-4 + 21-5-21	2.49 bc
IBR-Unsupplemented Powder 2 + 21-5-21	2.06 c
IBR-Unsupplemented Powder 1 + 21-5-21	1.92 c
IBR-Unsupplemented Powder 3 + 21-5-21	1.88 c
Control + IBR Liquid (1/8x)	1.86 c
Control + 21-5-21	0.680 d
Third harvest after 100 days	
IBR-Unsupplemented Powder 3 + IBR Liquid (1/8x)	4.51 a
IBR-Unsupplemented Powder 1 + IBR Liquid (1/8x)	4.42 a
IBR-Unsupplemented Powder 2 + IBR Liquid (1/8x)	4.28 a
IBR-Unsupplemented Powder 3 + 21-5-21	2.08 b
IBR-Unsupplemented Powder 2 + 21-5-21	2.08 b
Control + IBR Liquid (1/8x)	2.03 bc
Inorganic fertilizer + 21-5-21	2.01 bc
IBR-Unsupplemented Powder 1 + 21-5-21	1.85 bc
SUSTANE <sup>®</sup> 5-2-4 + 21-5-21	1.82 bc
Control + 21-5-21	1.02 c
Cumulative harvest after 100 days	
IBR-Unsupplemented Powder 3 + IBR Liquid (1/8x)	11.11 a
IBR-Unsupplemented Powder 1 + IBR Liquid (1/8x)	11.04 a
IBR-Unsupplemented Powder 2 + IBR Liquid (1/8x))	10.44 a
Inorganic fertilizer + 21-5-21	8.13 b
SUSTANE <sup>®</sup> 5-2-4 + 21-5-21	6.26 c
IBR-Unsupplemented Powder 2 + 21-5-21	5.74 cd
IBR-Unsupplemented Powder 1 + 21-5-21	5.52 cd
Control + IBR Liquid (1/8x)	5.19 cd
IBR-Unsupplemented Powder 3 + 21-5-21	4.65 d
Control + 21-5-21	2.51 e

\* Means (n = 6) at any harvest date sharing the same letter are not significantly different by LSD (P< 0.05)

**Appendix Table 52.** Quality analysis of greenhouse-grown bentgrass receiving different fertilizer treatments

Treatment	Quality (9/03/00)	Quality (25/04/00)
IBR-US Powder 1 + 21-5-21	6.0 a*	3.0 c*
IBR-US Powder 3 + IBR Liquid (1/8x)	6.0 a	5.2 ab
Inorganic fertilizer + 21-5-21	5.3 ab	3.0 c
SUSTANE® 5-2-4 + 21-5-21	5.3 ab	3.3 c
IBR Powder 1 + IBR Liquid (1/8x)	5.2 ab	5.7 a
IBR-US Powder 2 + IBR Liquid (1/8x)	5.2 ab	6.1 a
IBR-US Powder 2 + 21-5-21	4.9 bc	3.7 c
Control + 21-5-21	4.8 bc	2.7 c
Control + IBR Liquid (1/8x)	4.5 bc	3.0 c
IBR-US Powder 3 + 21-5-21	4.0 c	4.0 bc

\* Means (n = 6) within each column that share the same letter are not significantly different by LSD (P< 0.05)

**Appendix Table 53.** Quality and colour of greenhouse-grown bentgrass receiving different fertilizer treatments.

Treatment	Quality (9/06/00)	Colour (9/06/00)
IBR-US Powder 1 + IBR Liquid (1/8x)	7.7 a*	7.8 a*
IBR-US Powder 3 + IBR Liquid (1/8x)	6.8 ab	7.8 a
IBR-US Powder 2 + IBR Liquid (1/8x)	5.5 bc	7.2 a
IBR-US Powder 3 + 21-5-21	5.3 c	5.2 bc
IBR-US Powder 1 + 21-5-21	5.3 c	5.3 bc
IBR-US Powder 2 + 21-5-21	4.3 cd	5.7 b
Control + IBR Liquid (1/8x)	4.2 cd	7.7 a
SUSTANE® 5-2-4 + 21-5-21	3.8 de	4.8 c
Inorganic fertilizer + 21-5-21	3.7 de	5.2 bc
Control + 21-5-21	2.5 e	5.0 bc

\* Means (n = 6) within each column that share the same letter are not significantly different by LSD (P< 0.05)