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Abstract

To effectively control weeds found in a turf it is first necessary to correctly identify them. A computer program, WEEDER, was built using the artificial intelligence system AGASSISTANT to provide a means for effectively identifying grass weed and turf species through the recognition of selected variables. WEEDER has a rule-based, non-hierarchical knowledge base concerning 37 grass species commonly found in turfs throughout the USA. Each species is represented by 11 or fewer variables. In order to measure the value of WEEDER for identifying unknown grasses in comparison to a commonly used method, the dichotomous identification key, 41 volunteers were assigned to one of two groups; (i) those with any previous experience in plant diagnosis or any formal training in plant science; and (ii) those with no experience or training. Each individual identified four unknown grasses; creeping bentgrass (*Agrostis palustris* Huds.); perennial ryegrass (*Lolium perrene* L.); zoysiagrass (*Zoysia japonica* L.); and large crabgrass (*Digitaria sanguinalis* [L.] Scop.) using WEEDER or a printed identification key. The maximum mean of either group to identify a grass species was 55% of the specimens, which were examined by participants with plant science training using WEEDER. Participants with some plant science training had a higher mean identification of each species (23% identified) than participants with no training (18%) when using the identification key. Little difference in their ability to identify the unknown species was found between the two groups when they were using WEEDER. There was a significant increase in the mean ability of all participants to identify an unknown grass using WEEDER (50%) rather than the identification key (20%) after rules for the four species were modified. A demonstrated advantage of WEEDER over the printed key was its ability to be easily modified to increase its usefulness. The mean percentage of correctly identified grasses by all participants increased from 11 to 50% after rules pertaining to the unknown grasses were modified to reflect variable values most consistently selected. No significant dependency on a participant group was found for correctly identifying a grass species when using WEEDER after the rules were modified. Further testing of WEEDER is required to determine if the modified rules are consistent with additional grass sample and user populations.

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In the design of an effective weed-control program for turf, it is first necessary to correctly identify the species present and to determine the extent of their populations. Morse (1971) outlines five basic identification methods for determining unknown plant species. The first is expert determination, which is generally regarded as the most reliable of all identification techniques. This method merely transfers the responsibility of identification to an appropriate expert. This service can be slow and costly, and is often limited by the availability of an expert. Second, immediate recognition approaches expert determination and accuracy. This is the ability of an individual to recognize an unknown weed by past examples of identification. For some taxonomic groups and immature plants, however, this method of identification is very difficult and in all cases requires extensive past experience. The third method is comparison of an unknown specimen with identified species or illustrations. It offers a rapid, simple diagnosis and is often useful for many commonly found weeds. Fourth, an identification key is based on the development of appropriate descriptive phrases of morphological or biochemical character-variables (hereafter referred to as variables). Identification keys generally take the form of groupings of similar morphological variables from which the user must select the variable which best matches that present on the unknown sample. The selection of this variable then leads to the next set of identifying characteristics. This process is followed until enough variables have been identified to suggest the identification of the specimen. The last identification technique is a diagnostic table or polyclave. Diagnostic tables are a matrix of rows of species and columns of identifying variables. Users of diagnostic tables can identify the listed variables in any order they wish. Currently, the use of an identification key or expert determination are the most commonly used methods to identify grasses found in turf by inexperienced turf managers.

Morse (1971) lists two major faults of identification keys; (i) they require a user to utilize certain variables whether or not they are convenient or can be identified; and (ii) they implicitly rely on rigid descriptions of specimens. Occasional variation in a population can cause a gross misidentification.

In a list of relative merits of both identification keys and diagnostic tables Payne and Preece (1980) stated that the diagnostic table was superior to a key because it offered a choice in the order of characters to be used for identification. They also suggested that keys are more convenient to use.

Expert or advisory computer systems might offer the benefits of both identification keys and diagnostic tables in one tool. The use of expert systems techniques offers a new, unique method for assisting with species identification (Atkinson and Gammerman, 1987; Fermanian et al., 1988). The relative merits of an expert or advisory system is its ability to allow the user to select variables that are available on the unknown specimen. They can operate on various levels of uncertainty providing a more efficient mechanism for identification. They can be easily modified to reflect local variation in the values of variables for included species. WEEDER, a computer advisory system for turf managers, students, and scientists has been shown to require only a minimum number of variables for identifying grass species commonly found in turf (Fermanian et al., 1988).

In order to test these underlying assumptions of WEEDER, the following were objectives of this study; (i) to determine if WEEDER is more effective for grass identification in turf than a paper identification key; (ii) to determine if WEEDER is of greater assistance to users without plant science training or formal education in plant identification for grass identification rather than a printed key; and (iii) to determine if WEEDER can be easily modified to improve its performance and success rate.

Methods and Materials

Development of WEEDER

There are approximately 100 to 150 weeds considered to be pests in turf in the USA (Shurtleff et al., 1987). Of this group, the grass family is represented by at least 37 species. This subgroup of turf grasses and weeds was selected for the domain of WEEDER. The subdivision of turf weeds was necessary due to the limitation of AGASSISTANT to accommodate large domains in its initial version. WEEDER was constructed using the expert system building tool, AGASSISTANT (Fermanian et al., 1988). WEEDER can only be run within AGASSISTANT operating on an IBM PC or XT (International Business Machines Corporation, Endicott, NY) under PC-DOS 3.x (International Business Machines Corporation, Endicott, NY) equipped with a hard or fixed disk and a minimum of 512 KB of RAM. AGASSISTANT is a comprehensive artificial intelligence system for personal computers in the general area of agriculture. Knowledge is represented in AGASSISTANT in rules with the general form of:

If condition *then* conclusion

More specifically, if a set of individual conditions or a single condition is satisfied or partially satisfied, then a particular conclusion is acted upon. The system developer must assign a value or confidence level (CL) between 0 and 100 to each subcondition, which represents the degree of confidence the expert has that each subcondition alone supports the conclusion. A value of zero represents no support, while a value of 100 represents absolute support. The CL of all satisfied subconditions are combined to support the conclusion of the rule (Fermanian et al., 1988). Further implementation details, a User's Guide, and the AGASSISTANT software may be obtained from the authors for a minimal cost ($30) to cover handling and shipping. Send orders to: Dr. T. W. Fermanian, Univ of Illinois, 1201 S. Dorner Drive, Urbana, IL 61801, USA. At present, several of the planned capabilities of AGASSISTANT have not been completely or fully evaluated, however, the program is fully capable of operating on domains of equal size and complexity as WEEDER.

In order to prepare the identification knowledge of WEEDER used in AGASSISTANT a data matrix was developed including each potential grass species. Eleven identifying variables (columns), both vegetative and floral, were determined for each species (rows). The variables selected were those thought to be most easily recognized in the field without supportive equipment (Shurtleff et al., 1987). Information for this table was obtained from many sources including textbooks, weed identification manuals, botanical manuals, and the author's experience.

Rules for WEEDER were developed utilizing both the learning module of AGASSISTANT and direct construction. Separate rule sets were formed, first by inducing a set of characteristic rules, and then by inducing a set of discriminate rules (Katz et al., 1987). Based on the author's experience, a single rule was selected from either set, modified if appropriate, a CL value added, and then written to a single rule set, which was used in the initial evaluation (Table 1).

Rules in AGASSISTANT are concluded (fired) when the CL reaches a preset threshold (Fermanian et al., 1988). This confirmation threshold is set by the system developers and is domain dependent. A threshold of 85 was initially selected for WEEDER as a starting point for testing the system. This value was within the range of similarity values (60 to 90% ± 5%) generally observed in on-line identification keys (Pankhurst, 1978). While the final threshold value selected is important for the future use of WEEDER, it did not effect its evaluation in this study. Rules with the two highest CLs and that matched the specimen were considered correct even if they did not exceed the 85% threshold.

Grass identification in turf is often only available through the use of vegetative variables. This is due to the frequent mowing of the turf, which removes any floral portions of the plant. WEEDER allows the user to select either vegetative, or a combination of floral and vegetative variables at the beginning of each session. This is done through a "does-not-apply" question, which is always asked first in the consultation (Fermanian et al., 1988).

Validation of WEEDER

In order to measure the relative efficiency of WEEDER for identifying unknown grasses, a study was conducted in which individuals were asked to identify specimens of the same four grass species. Four grasses were selected randomly from a set of fifteen grass species collected in central Illinois. The four species selected were creeping bentgrass, perennial ryegrass, zoysiagrass, and large crabgrass. The grasses were transplanted to 4 × 4 cm plastic pots and held in a greenhouse for 2 wk.

Forty-one volunteers were assigned to one of two groups. If they had any previous experience in plant diagnosis or any formal training in plant science (20 volunteers) they were separated from volunteers who had no biological or plant science training or experience (21 volunteers). Each individual randomly selected two of the four unknown species for identification using WEEDER. A paper identification key (Shurtleff et al., 1987) was used to identify the remaining two species.

Along with the four unknown grass specimens, each participant was supplied with a low-power dissecting microscope, appropriate probes and dissecting equipment, and a book with representative diagrams of all the potential values of the selected variables. Each individual was allowed up to 30 min to identify each weed. Fifteen min was reserved for a demonstration of each variable and an explanation of how it could be identified. For the plants identified through the identification key each participant supplied only their first, and possibly a second, choice, as suggested by the key. The identification was considered successful if either choice was correct. Grasses identified with WEEDER, however, offered participants the ability to indicate the order of all 37 grasses. For WEEDER, if either of the two species with the highest CL values was the correct identification, it was considered successful even if the final CL was less than the WEEDER threshold (85). Frequency analyses of identified grasses were conducted for each participant group and each identification tool to determine their fit to a Chi square (χ^2) distribution.

Based on the consistency of participant identified variables for each plant (i.e. variables most often correctly selected), rules representing the four unknown species were adjusted (Table 1) by changing the CL values and, in some cases, adding local disjunctions (e.g. Ligule is toothed *or* acute). The set of correctly identified grasses, as determined using the adjusted rules, was then reevaluated for their fit to a χ^2 distribution as previously described.

Results and Discussion

WEEDER has the ability to rank all the grasses in its knowledge base from the species most likely to represent the unknown grass to the one least likely. Table 2 presents the percentage of identified grasses by species using either WEEDER or the identification key. The identification key, a tool commonly used by the participants in the study with plant science training, showed the highest average rate of success (21%) for identifying a species in the initial evaluation. The success rate of the participants with plant science training to identify a species using the key was shown to be dependent on the species identified (Table 2). The mean success rate of the same group in identifying any species using WEEDER was 15% and showed no evidence of an association with the species identified (Table 2; $P = 0.99$). While the mean success rate (7%) for the non-plant science group using WEEDER was consid-

Table 1. Rules representing four grass species used in the evaluation of WEEDER before and after their modification.

WEEDER rules			
Initial		Modified†	
Weed is Bentgrass if:	CL‡	Weed is Bentgrass if:	CL
1. Ligule is round,	65	1. Ligule is round *or toothed*,§	65
2. Sheath is round,	65	2. Sheath is round,	65
3. Glumes are longer,	65	3. Glumes are longer,	65
4. Habit is stolon,	60	4. Habit is stolon,	**40**
5. Disarticu is above,	55	5. Disarticu is above,	55
6. Collar is narrow,	50	6. Collar is narrow,	**70**
7. Florets is 1,	45	7. Florets is 1,	45
8. Flower is panicle,	45	8. Flower is panicle,	45
9. Blade _ width is fine,	35	9. Blade _ width is fine,	**70**
10. Vernation is rolled.	30	10. Vernation is rolled.	**70**
Weed is Per _ Ryegrass if:		Weed is Per _ Ryegrass if:	
1. Ligule is round,	85	1. Ligule is round *or truncate*,	**25**
2. Auricle is short,	80	2. Auricle is short,	80
3. Florets is 6 to 10,	80	3. Florets is 6 to 10,	80
4. Flower is spike,	75	4. Flower is spike,	75
5. Vernation is folded,	50	5. Vernation is folded,	50
6. Habit is bunch,	40	6. Habit is bunch,	40
7. Collar is broad or divided,	35	7. Collar is broad or divided,	**75**
8. Sheath is compressed,	30	8. Sheath is compressed,	**70**
9. Blade _ width is fine to medium,	30	9. Blade _ width is fine to medium,	**70**
10. Disarticu is above,	35	10. Disarticu is above,	35
11. Glumes are shorter.	25	11. Glumes are shorter.	25
Weed is Zoysiagrass if:		Weed is Zoysiagrass if:	
1. Habit is rhiz _ stolon,	80	1. Habit is rhiz _ stolon *or rhizome*,	80
2. Glumes are longer,	80	2. Glumes are longer,	80
3. Awns are present,	75	3. Awns are present,	75
4. Flower is spike,	70	4. Flower is spike,	70
5. Sheath is round,	70	5. Sheath is round,	70
6. Ligule is ciliate,	60	6. Ligule is ciliate,	60
7. Florets is 1,	55	7. Florets is 1,	55
8. Blade _ width is medium,	50	8. Blade _ width is *fine to* medium,	50
9. Collar is broad	50	9. Collar is broad,	**70**
10. Disarticu is below,	45	10. Disarticu is below,	45
11. Vernation is rolled.	35	11. Vernation is rolled.	**75**
Weed is Lg _ Crabgrass if:		Weed is Lg _ Crabgrass if:	
1. Ligule is toothed or acute,	65	1. Ligule is toothed or acute,	65
2. Blade _ width is coarse,	60	2. Blade _ width is *medium*,	60
3. Flower is spike,	60	3. Flower is spike,	60
4. Sheath is compressed,	50	4. Sheath is compressed,	50
5. Habit is bunch,	40	5. Habit is bunch,	**60**
6. Disarticu is below,	40	6. Disarticu is below,	40
7. Collar is broad,	35	7. Collar is broad *or divided*,	35
8. Florets is 1,	35	8. Florets is 1,	35
9. Vernation is rolled,	35	9. Vernation is rolled.	**75**
10. Glumes are shorter.	20	10. Glumes are shorter.	20

† Rules were modified after initial frequency analyses of chosen values.
‡ Confidence level assigned by system developers.
§ Portions of the rules that were modified appear in bold.

erably less, it also indicated no evidence of any association with the species identified (Table 2; $P = 0.80$).

Rules for identifying the four grass species examined were modified (Table 1) to improve their success rate by increasing the CLs of the variables which were most often correctly identified in the initial evaluation, and by adding any values which were correctly identified often but had not been included in the original rules. Rules for identifying the other 33 species were not modified. The results of these changes showed a very large gain in the percentage of correctly identified grasses as shown in Table 2. On the average for both groups the percentage of correctly identified grasses rose from 11 to 50% when using WEEDER, as compared with the 20% mean for grasses correctly identified with the identification key (Table 3).

A summary of the mean correctly identified grasses by both groups using either tool is shown in Table 3. While no significant indication of dependence on either the identification tool or participant group was shown using the initial rules, a very significant dependence ($P < 0.01$) on the identification tool used after rule modification indicates the potential advantage of WEEDER over the identification key for all participants. No significant indication of dependence on participant group was found for correctly identifying a grass species after the rules were modified.

An analysis of the frequency of the selected values for each variable by either group of participants using either identification tool showed no significant dependency on individual values for any variable. In several cases, such as the toothed value of the ligule variable for bentgrass (selected for 53% of the bentgrass specimens) and the fine value of the blade width variable for zoysiagrass (selected 94%), the identified variable value was quite different from the one provided in the original rule. In addition, many of the variables which had low CLs in the original rules were most readily identified by the participants. For example, the original CL for the vernation-rolled pair for zoysiagrass was 35, but was selected in 82% of the identifications.

Table 4 indicates the average change in CL when the rules were modified. In most cases, modifying a rule slightly elevated the CL. Changes to the perennial ryegrass rule, however, resulted in a lower average CL, but a higher percentage of correctly identified specimens. The mean CL of the perennial ryegrass rule was lower after modification due to the lower CL assigned to the ligule variable. The ligule variable was reduced because it was not often correctly identified by participants of either group. It should be noted that even though the average CL for all the species was less than 85, species were still correctly identified as the first or second choice.

Unlike the approach of Atkinson and Gammerman (1987), which combined heuristic knowledge of taxa habitats with an on-line key, WEEDER uses heuristic knowledge only. This minimizes the number of decisions a user is required to make, which is an important function of a knowledge based system (Atkinson and Gammerman, 1987).

One of the most prominent findings of this inves-

Table 3. Mean percentage of all correctly identified grass species using either WEEDER or an identification key by participants with either plant science training or without plant science training.

Selected frequency group	Mean correctly identified species: Initial rules	Modified rules
	%	
Identification tool		
WEEDER†	11	50
Identification key	20	20‡
χ^2	2.3	16.8
	NS	**
Participant group		
Plant science training§	19	39
No plant science training	13	32
χ^2	2.7	1.9
	NS	NS

*,** Significant at the 0.05 and 0.01 levels, respectively. NS = not significant at the 0.05 level.
† For both participant groups.
‡ Since the modification of a identification key is not practical, the same values were used for the "Modified rules" evaluation.
§ For both identification tools.

Table 2. Percentage of each correctly identified grass species using either WEEDER or an identification key by participants with either plant science training or without plant science training.

Grass species	Plant science training: Initial rules	Plant science training: Modified rules	No plant science training: Initial rules	No plant science training: Modified rules	Groups combined: Initial rules	Groups combined: Modified rules
	% correctly identified					
WEEDER						
Bentgrass	13	63	9	56	11	58
Per. ryegrass	13	38	9	46	11	42
Zoysiagrass	17	75	0	80	9	77
Large crabgrass	17	42	10	0	14	23
χ^2	.13	4.0	1.0	13.5	1.3	.78
	NS	NS	NS	**	NS	NS
Identification key						
Bentgrass	17	—†	10	—	14	—
Per. ryegrass	42	—	40	—	41	—
Zoysiagrass	25	—	10	—	16	—
Large crabgrass	0	—	10	—	5	—
χ^2	7.1	—	2.7	—	1.5	—
	*	—	NS	—	NS	—

*,** Significant at the 0.05 and 0.01 levels, respectively. NS = not significant at the 0.05 level.
† The identification key was not modified.

Table 4. Mean confidence level (CL) of correctly identified grass species using either WEEDER or an identification key by participants with either plant science training or without plant science training.

Species	Participant group					
	Plant science training		No plant science training		Groups combined	
	Initial rules	Modified rules	Initial rules	Modified rules	Initial rules	Modified rules
	mean CL†					
Bentgrass	58	65	47	71	53	68
P. ryegrass	87	67	99	58	93	61
Zoysiagrass	74	77	—‡	81	—	79
Large crabgrass	58	83	32	—	56	—
Mean of all species	68	75	66	72	67	73

† Confidence level for each rule as calculated by WEEDER.
‡ Species was not first or second choice for any specimen identified.

tigation was the relatively poor performance in the identification of unknown grasses by individuals regardless of their training. Because the mean correct identification of any species by any participant group using WEEDER was less than 60%, it is not known if an expert level performance was achieved. Additional studies are necessary to determine the current ability of experts to identify unknown grasses particularly when they are in a juvenile or vegetative state of growth. Various programs have been developed for the identification of plant species by matching user selected values with similarity coefficients (Pankhurst, 1975; Ross, 1975). While these systems have generally reported similarity values of 60 to 90% (±5%) the success rate of identifying unknown species with the systems was not reported.

When using the identification key performance was generally better from the group with plant science training, however, the frequency analysis did not indicate a significant dependence on either participant group. This difference in performance, however, was not found when the same group used WEEDER, which generally benefited either group equally. It is important to note that a significant gain in the ability of all participants to correctly identify a grass specimen was found with WEEDER over the diagnostic key after rules were modified to maximize the support of consistently chosen correct values of variables to identify the specimens examined. While the modification of a rule generally provided for the identification of specimens which were previously not identified, it also removed some specimen identifications from the group initially considered correct. Further testing of WEEDER is required to determine if the modified rules are consistent with additional grass sample and user populations.

This study brings out one important aspect to the use of expert or advisory systems. While the use of knowledge is central to all advisory systems, the skills associated with recognizing the value of prompted variables is paramount in plant species identification. These recognition skills were probably lacking in the test population. It is necessary, therefore, to develop techniques to enhance recognition skills to further increase the effectiveness of WEEDER (Michalski, 1986).

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References

Atkinson, W.D., and A. Gammerman. 1987. An application of expert system technology to biological identification. Taxon. 36:705–714.

Fermanian, T.W., R.S. Michalski, B. Katz, and J. Kelly. 1988. AGASSISTANT: An artificial intelligence system for discovering patterns in agricultural knowledge and creating diagnostic advisory systems. Agron. J. 81:306–312.

Katz, B., T.W. Fermanian, and R.S. Michalski. 1987. AGASSISTANT: An experimental expert system building for agricultural applications ISG 87-16, UIUCDCS-F-87-978, Dep. of Comp. Sci., Univ of Illinois, Urbana, IL.

Michalski, R.S. 1986. Understanding the nature of learning. p. 3–25. *In* R.S. Michalski, J.G. Carbonell, and T.M. Mitchell, (Ed.) Machine learning: an artificial intelligence approach, Vol. 2. Morgan-Kaufmann, Los Altos, CA.

Morse, L.E. 1971. Specimen identification and key construction with time-sharing computers. Taxon. 20:269–282.

Pankhurst, R.J. 1975. Identification by matching. p. 79–91. *In* R.J. Pankhurst (ed.) Biological Identification with Computers. Academic Press, London & New York.

Pankhurst, R.J. 1978. Biological identification. Univ Park Press, Baltimore, MD.

Payne, R.W., and D.A. Preece. 1980. Identification keys and diagnostic tables: A review. J. Royal. Stat. Soc., Series A. 143:253–292.

Ross, G.J.S. 1975. Rapid techniques for automatic identification. p. 93–102. *In* R.J. Pankhurst (ed.) Biological identification with computers. Academic Press, London & New York.

Shurtleff, M.C., T.W. Fermanian, and R. Randall. 1987. Controlling turfgrass pests. Prentice-Hall, Inc. Englewood Cliffs, NJ.