container at planting so normal root development and landscape establishment occurs. In this respect, FCs+ are a disadvantage compared to traditional fiber containers, which are plantable.

Plumbago was more responsive to container design than *Coreopsis*. While *Coreopsis* grown in FCs had smaller growth indices compared to those grown in BPCs, this was an advantage since plants in the FCs were more compact with the same shoot dry weight, and thus increased salability. Root : shoot ratio of *Plumbago* increased for plants in FCs+ due to an increase in root dry weight. Prevention of root circling is an added benefit when using FCs+ . Results of this research indicate that FCs treated with $Cu(OH)_2$ have the potential to produce higher-quality plants with improved root systems when used on short-term crops such as perennials.

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Weed Mapping as a Component of Integrated Pest Management in Cranberry Production

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Summary. **A system of mapping weed infestations in cranberries (*Vaccinium macrocarpon* Ait.) was developed that enables growers to incorporate integrated pest management practices into their weed control program. This system provides growers with information on the location of weeds and the area of weed patches, but differs from other weed mapping systems in that information on control priorities is included on the maps. Weed management efforts can then be directed to the most economically damaging weeds first. The mapping system also provides growers with a permanent record that can be used to communicate with staff and to evaluate weed management strategies.**

Widespread infestations of many weed species cause significant losses to cranberry growers (Dana et al., 1982; Devlin and Demoranville, 1971). A recent survey in Massachusetts indicated that an average of 30% of the cranberry production area was covered with weeds (F.L. Caruso, unpublished data). The most serious weed species, dewberries (*Rubus* spp.) and dodder (*Cuscuta gronovii*), cause annual yield losses of 15% to 20%. More than 70 weed species have been identified on Massachusetts cranberry bogs (Demoranville, 1984, 1986), with 24 of these considered to be common and yield-threatening (Sandler and Else, 1995).

With few exceptions (notably dodder), economically important weed species are native perennials that propagate vegetatively. The weeds spread aggressively, eventually replacing cranberry vines as the primary plant species on the bog. Resulting yield declines necessitate replanting the bog at a cost of $10,000 to 15,000/acre for materials and labor (M.J. Else, unpublished data). This estimate does not include losses resulting from lowered crop production during reestablishment of the cranberry vines (usually 2 to 4 years). Alternative control strategies include hand digging weeds or carefully hand wiping applications of glyphosate solutions. Several years of these expensive, labor-intensive treatments may be needed to bring large weed patches under control. Yield losses due to these weeds are low in the initial years of invasion, and control costs exceed these losses. However, control costs increase rapidly as weed patches spread. For this reason, the most invasive and yield-damaging weed species can have economic thresholds that are functionally zero.

When integrated pest management (IPM) was formally introduced to the cranberry industry in 1983, the emphasis was primarily focused on managing insect pests (Lasota, 1990; Sandler, 1993), with minimal attention given to weeds and diseases. Increased awareness of the losses due to weeds has underscored the need to establish and promote a weed IPM program for the cranberry industry.

Weed mapping and scouting systems are key parts of a weed IPM program (Mutch and Michalak, 1985). Weed maps may serve a number of purposes, which include communication from scout to grower and among the grower's staff, location of weed problems, quantification of weed popu-

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lations, and assessment of the effectiveness of weed management measures. Pest management or scouting services may include weed management recommendations with maps and scouting reports.

In cranberry production, weed mapping can serve an additional purpose. Many cranberry bogs are infested with weed species, such as dewberries (*Rubus hispidus* and *R. flagellaris*) and greenbriers (*Smilax glauca* and *S. rotundifolia*), that damage yields and are very difficult to control. Other species present on the bog, while having an impact on yield, may be less serious. For most growers, controlling all weed species present on a bog is not possible in a single year. A weed mapping system for cranberries could therefore serve the additional purpose of prioritization of weed problems. Weed categories have been used in other crops in which weeds vary in impact or density (Kempen, 1993).

A mapping system that designates weed patches by control priority rather than solely by species was initiated. Criteria for prioritizing weeds were developed based on weed impact. A system for accurately recording weed locations was also developed. Bogs of eight participating growers in a state-sponsored IPM program were mapped. The mapping system was then presented to participating growers and members of the private scouting industry for evaluation and revision. Their suggestions were incorporated into the mapping system.

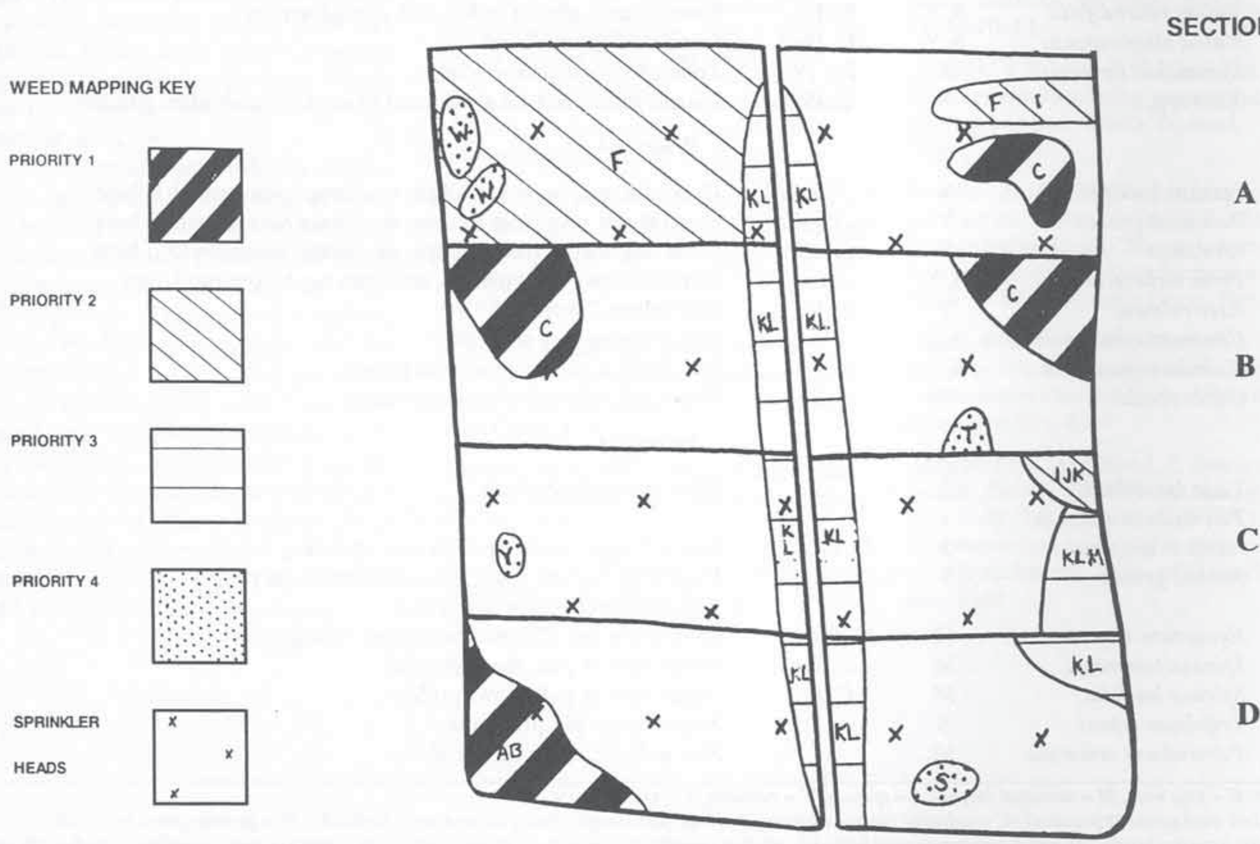
Material and methods

Bog outline. Many growers had precise drawings depicting the shape and acreage of their bog property obtained from aerial photography. These drawings were used as the base diagram for the weed map (Fig. 1). When a map was not available, one could be drawn from ground or aerial inspection. To enhance the accuracy of the map, the approximate locations of the main and lateral ditches of the bog and permanent sprinkler heads, were designated. Weed distribution was noted relative to these markers.

Coding system. Weeds were coded by species and management priority. Each priority group was assigned a specific pattern on the map to facilitate quick visual recognition of problem areas (Fig. 1). If weeds of more than one priority group occurred in a particular area, the highest priority code was chosen to represent that location.

The weed mapping system placed weeds into four priority management groups based on three factors: 1) potential to cause crop losses, 2) rate of spread, and 3) difficulty of control. Priority group 1 weeds (zero threshold) cause severe losses, spread rapidly, and are difficult to control (Table 1). Weeds in this group are extremely damaging to cranberry yields and may kill vines. Weeds in Priority group 2 are of serious concern. They are less damaging to yields than those in priority 1, but they are still aggressive and difficult to control. Weeds of less importance were grouped in priority 3. Weeds in this group may reduce yields, but yield impact is low. Spread or growth of these weeds is relatively slow. Control is not as difficult to achieve as in priority groups 1 and 2. The lowest-concern weeds were grouped in priority 4. These plant species are primarily found in bare spots, areas of poor cranberry vine growth, or at bog edges. Most are relatively easy to control.

Fig. 1. *Hypothetical weed map of a typical cranberry bog showing management priorities (shading) and weed species identified by letters.*



Weed mapping. Mapping was done when weed growth was complete, usually from the middle to latter part of July through August. This timing was selected for several reasons. Mapping weeds in cranberry production facilitates the planning of management strategies for the following year. Mapping done in the current season will not aid in control for that same season. In addition, weed mapping must be completed before the effects of postemergence herbicide applications hamper plant identification.

Individual sections of the bog were identified and labeled. A coding system, which can be modified to fit a grower's needs or preferences, was developed. In this identification system, cranberry bog weeds were codified in an alphabetical fashion (Table 1). Each weed was assigned a letter or symbol that identified the weed to species (Fig. 1, Table 2). Alternatively, growers could use abbreviations taken from the common or scientific names of the weeds (i.e., NL for narrow-leaved goldenrod, or RH for *Rubus hispidus*). As weeds were identified within a particular section on the bog, their corresponding letter or symbol was marked on the map. The approximate area covered by the weed was designated on the map. Significant bare patches and prominent problem areas were also noted on the map.

Results and discussion

A practical system of mapping weeds on cranberry bogs was developed. This system could provide the foundation for incorporating integrated weed management techniques in cranberry culture. This system can be used either by IPM consultants or by growers to locate weeds and develop management recommendations. Management recommendations include weed management priorities on the map and a generalized list of best management practices for each weed on the map key (Table 1). Further recommendations for weed management and herbicide use are published in a cranberry man-

Table 1. ***Priority management groups for common weeds on cranberry bogs.***

Code	Weeds	Impact[z]	BMP[y]	Comments
				Priority 1
A	*Rubus flagellaris* and *R. hispidus*	K, S	C, Po	Dig or pull while young, wipe[x] or spot renovate established patches.
B	*Cuscuta gronovii*	Y	C, Pr	Hand pull early, prevent seed production.
C	*Smilax glauca*	S, Y	C, Po	Wipe or spot renovate, don't allow to spread.
D	*Apios americana*	K, S, Y	Po, Pr	Provide structure for beans to climb on, may make wiping easier.
E	*Rhus radicans*	S, Y	C, Po	Easy to kill by wiping on small patches.
				Priority 2
F	*Solidago tenuifolia*	S, Y	Po, Pr	May take several years to control, herbicides most effective on small spots.
G	*Smilax rotundifolia*	S, Y	C, Po	Easier than *S. glauca* to kill with careful wiping.
H	*Rubus allegheniensis*	S, Y	C, Po	Good wiping candidate.
I	*Lysimachia terrestris*	S	Po, Pr	Treat patches before too large.
J	*Aster* spp.	S	C, Po	Usually found in bare areas, hard to control established patches.
				Priority 3
K	Perennial sedges	V	C, Po, Pr	Hand dig or spot treat clumps, encourage vine growth if bare.
L	Perennial grasses	V	C, Po, Pr	Hand dig or spot treat clumps, encourage vine growth if bare.
M	All rushes	V	C, Po, Pr	Hand dig or spot treat clumps, encourage vine growth if bare.
N	*Pyrus melanocarpa*	S, Y	Po	Hard to wipe (short plants), treat patches before too large.
O	*Acer rubrum*	Y	C, Po	Pull before 2 years old.
P	*Chamaedaphne calyculata*	S, Y	Po	Hand wiping very effective.
Q	*Kalmia angustifolia*	S, Y	C, Po	Hand pull saplings, wipe large plants.
R	Other shrubs	V	C, Po	Hand pull saplings, wipe large plants.
				Priority 4
S	*Viola lanceolata*	S	C	Fill in by fertilizing bog.
T	*Potentilla canadensis* and *P. simplex*	S	C, Po, Pr	May indicate a problem with vine growth.
U	Annual grasses	V	C, Po, Pr	Hand pull on new bogs, easy to control with pre- and postemergence herbicides.
V	*Equisetum arvense*	M	C, Po, Pr	Spot treatment effective, encourage vine growth.
W	*Spiraea tomentosa*	M	C, Po	Hand wipe or pull, slow spreader.
Y	*Spiraea latifolia*	M	C, Po	Hand wipe or pull, slow spreader.
Z	*Trifolium repens*	S	C	May indicate pH problems.
Δ	*Polytrichum commune*	M	C	May indicate damp or wet spot.

[z]*Impact: K = kills vine, M = minimal impact, S = spreads, V = variable, Y = reduces yield.*
[y]*BMP (best management practice): C = cultural control (digging, pulling, fertilizing), Po = postemergence herbicide, Pr = preemergence herbicide.*
[x]*Wiping is a control practice in which a postemergence herbicide solution (usually a glyphosate) is applied to the weed by hand or with specially designed applicators.*

agement guide, which is revised annually (Sandler et al., 1995).

Due to the perennial nature of cranberries and many of the most serious weeds, maps produced in one year provided an accurate predication of weed location for the following year. This makes spot treatment of large weed patches with preemergence herbicides possible, resulting in large decreases in herbicide use. In addition, maps form a permanent record and can be used for long-term evaluations of management strategies. Weed mapping can serve as a basis for adopting information-intensive management strategies, minimizing herbicide use and improving weed control.

The prioritized mapping system developed for cranberries may have implications for other crops as well. A prioritized approach may be useful in crop systems where long-term weed management considerations are important. This would be particularly true in perennial crops, such as tree crops and small fruits, where not all weeds cause economic impacts and control is expensive and labor-intensive. This system also has implications for annual crops. Weeds invading such crops should be considered to have high priority for elimination if they impact yield and are difficult to control in at least one crop in the grower's rotation. When long-term economic impacts are considered, these weeds may have thresholds at or near zero (Berti et al., 1992).

Geographical information systems (GIS) and global positioning systems may be used to improve the accuracy of weed maps (Lass and Callihan, 1993). A weed map could be used as a layer in a GIS approach (Prather and Callihan, 1993). Herbicide use could also be incorporated as a layer over the weed map. Weed mapping could be integrated with mapping systems in other crop and pest management systems. Combining the relative low cost of GIS technologies with the widespread use of computers, growers could develop a comprehensive farm plan with weed IPM as an important component.

Table 2. *List of weeds on hypothetical weed map.*

Patch label	Weeds	Priority
Section A		
AB	Dodder on *Rubus* spp.	1
KL	Sedges and grasses	3
S	White violets	4
Section B		
IJK	Loosestrife, asters, and sedges	2
KLM	Sedges, grasses, and rushes	3
KL	Sedges and grasses	3
Y	Meadowsweet	4
Section C		
C	*Smilax glauca*	1
KL	Sedges and grasses	3
T	Cinquefoil	4
Section D		
C	*Smilax glauca*	1
F	Narrow-leaved goldenrod	2
KL	Sedges and grasses	3
W	Hardhack	4

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