Herbicides and forest vegetation management: A review of possible alternatives

Nick Mc Carthy[a] and Claire Mc Carthy

Abstract

A major component of forest management programmes is the suppression or elimination of weeds. This is essential during seedling establishment, as the more vigorous the growth of non-crop vegetation, the more the competition with desired plants for space, light, water and nutrients.

Much of the research into forest vegetation management has been on developing technology to control unwanted species with the main focus being on herbicides. In this paper, four alternative methods of weed control: (1) mowing, (2) cultivation, (3) mulching, and (4) ground cover species, are reviewed and their advantages and disadvantages discussed. Recently, certification initiatives and increasing public and industry awareness of the importance of environmental protection have led to concerns over the continued use of herbicides. It is therefore important to examine some potential alternatives for the Irish forestry situation.

Keywords: Vegetation management, alternatives, mowing, cultivation, mulching, ground cover species.

Introduction

In forestry, control of competing vegetation is essential during seedling establishment. Weeds, particularly grasses are fast-growing and compete aggressively with newly planted trees for moisture and nutrients. Generally, the more vigorous the growth of vegetation on a site, the more the competition with trees for the moisture and nutrients. It is widely acknowledged that a reduction in available moisture and nutrients due to weed competition on a site leads to reduced tree growth and survival (Davies 1987). In effect, weed competition reduces growth and vigour of young seedlings and often results in mortality. Thus, in order to establish a tree crop effectively, the rooting area of seedlings must be freed from competition until rooting is extensive and deep enough for the seedling to compete with weed vegetation. Maximum tree growth is obtained under weed-free conditions (Beaton and Hislop 2000), a contention supported by almost all the literature on the subject. However, maintaining weed-free conditions over the full site is prohibitively expensive. Furthermore, such an approach provides no cover for wildlife and the result is often andunsightly.

In practice weed control is carried out for the first two to three growing seasons after planting (Beaton and Hislop 2000, Lund-Høie 1984). Poorer sites and slower growing trees require a longer establishment time (Atchison and Ricke 1996) and hence competing vegetation may need to be controlled for a longer period. In Ireland,

[a] Chemical and Life Sciences Department, Waterford Institute of Technology, Cork Road, Waterford. (nmccarthy@wit.ie).

since the 1960s the operation has been predominately carried out using herbicides. Recently, however, certification initiatives and increasing public and industry awareness of the importance of environmental protection have led to concerns over the continued use of herbicides. It is therefore important to examine some potential alternatives for the Irish forestry situation.

Wagner and Zasada (1991) defined forest vegetation management, as the management of non-crop vegetation to achieve silvicultural objectives, using a variety of methods that are environmentally sound, economical, and socially acceptable. Although the ability to control unwanted vegetation has been the principal criterion for selecting particular vegetation management treatments, these are only silviculturally effective if they enhance the survival and growth of treated stands (Wagner 1993). On purely economic grounds, vegetation management can only be justified if the value gained from a treatment is greater than its discounted cost (Row 1987, Brodie and Walstead 1987).

Optimising vegetation management in young forest plantations entails finding the most effective time to reduce competing vegetation around the seedling (Wagner et al. 1996). This critical period is the time after planting when herbaceous vegetation must be controlled to avoid significant growth loss. Swanton and Weise (1991) identified this as an important component of integrated weed management for agriculture.

Wagner et al. (1996) also indicated that both timing and duration of herbaceous vegetation control are important to the growth of northern conifers. Weed infestation curves show that herbaceous vegetation can substantially decrease seedling diameter growth in the first year after growth. A study with Norway spruce (*Picea abies* L.) found that the greatest growth occurred when vegetation was controlled during site preparation, with substantial growth decreases occurring as the interval between planting and competition release increased (Lund-Høie 1984). Lauer et al (1993) found that herbaceous vegetation control applied in the first and second year after planting nearly doubled wood volume gains in loblolly pine (*Pinus taeda* L.) at age nine, relative to trees that had received vegetation control in the first year only.

Developing technology to control unwanted vegetation has been the focus of most research in forest vegetation management, with nearly all the work being done on herbicides (Wagner 1993). Their attraction is that they generally kill both sprouting and non-sprouting plants and are therefore effective in controlling many plant communities. They also give the best vegetation control relative to cost (McDonald and Fiddler 1993). In suppressing the undesirable plants, soil moisture and nutrients are made available to the roots of new tree seedlings.

Most new woodlands require weed control to enable trees to establish successfully and although research continues into alternatives, the use of herbicides is currently the only cost effective option in many situations (Willoughby and Claridge 2000).

In new plantations, treating competing vegetation when it is small, not yet fully established and still recovering from any damage incurred in site preparation is fundamental to a successful vegetation control programme (McDonald and Fiddler

1996). When carried out early, weed control treatments are also cost effective. However, one treatment per year all most budgets can afford, and in these circumstances competing plants take advantage and may reduce seedling growth (McDonald and Fiddler 1996).

Over the past few decades, the use of herbicides to manage forest vegetation has generated considerable public debate across North America (Wagner 1994). In one research paper Thomas et al. (2001) stated that in British Columbia there is a growing reluctance on the part of many land-owners and farmers to use herbicides because of the associated permits and training that are required before they can be applied. The recent certification initiative in Britain has confirmed this trend (Willoughby 1999). The Forest Stewardship Council has stated in its principles and criteria, that the aim of forest managers of certified forests, whether they be plantations or natural forest, should be to control disease, pest insects and animals, or unwanted, competing plants only when necessary and without the use of chemical pesticides such as fungicides, insecticides or herbicides (Upton and Bass 1996).

Potential alternatives to herbicides

Mowing

On sites where erosion is a problem, mowing may be an option between tree rows but it does little to reduce the competition for moisture and nutrients. According to Davies (1987), mowing of grass is positively detrimental to tree growth. He also found that in some un-mown grass swards the weeds often die back thereby creating a self-mulching effect in winter that gave the trees a good start the following season.

Mowing does reduce fuel build-up, rodent cover and makes the plantation more accessible for other management activities (Atchison and Ricke 1996) but it is primarily cosmetic.

Weed plant species compete with each another as well as newly-planted trees. Mowing can change the natural balance between weed species in favour of detrimental perennial grasses, which are resistant to cutting. However Willoughby and McDonald (1999) found that maintaining a 1 m wide weed-free strip around the trees, combined with mowing the inter-row to minimize weed seeding, was a cost-effective method of weed control. In their study on vegetation control for the establishment of ash (*Fraxinus excelsior*), Culleton et al. (1995) found that leaving an un-mown strip of grass between lines of ash was of benefit. They speculated that the trees, while profiting from the weed-free zone around them, were sheltered from the wind by the grass.

The conclusion is that mowing on its own is ineffective but combining it with another weed control method could have potential.

Cultivation

Cultivation is the tilling of the soil to provide a favourable environment for tree establishment and growth of plants or regeneration; and, where appropriate, to improve root anchorage for better wind-firmness. Methods include bedding, discing, moling, mounding, peat tunnelling, ploughing, ripping, scalping, scarifying and subsoiling (Paterson and Mason 1999). During the operation weeds are often cut below ground level, uprooted and left to desiccate, or they may be buried.

Cultivation can be vital in ensuring successful and cost-effective establishment. Ploughing before planting is relatively cheap and as well as providing initial weed control, it also improves the ease and quality of planting (Davies 1987). Mounding, used extensively in Ireland, provides the same function.

Cultivation is quite effective in the control of annual weeds, especially at the seeding stage. However this method may bring weed seeds to the surface where they can germinate so it is a better weed control method in countries with a Mediterranean climate where there is little or no summer rainfall. Seeds brought to the surface in summer will not germinate and uprooted weeds and rhizomes soon wither (Davies 1987). Otherwise, shallow cultivation is used to reduce the number of dormant seeds brought to the surface. During the growing season repeated tillage passes may be required as new weeds emerge. Shallow cultivation, not deeper than 7 or 8 cm, also avoids damaging small feeder roots near the surface.

Schuette et al. (1996) suggest that a combination of cultivation to remove the between-row vegetation and herbicide to maintain a weed-free band around the trees is a good way of controlling weeds. Cultivation as a means of controlling weeds is more effective on less fertile sites (Willoughby and Moffat 1996).

Mulching

Mulching (the spreading of material around desired trees to control competing vegetation) is used in agriculture and forestry throughout the world (Gupta 1991, McDonald and Helgerson 1990). It has been used in the western United States for the last thirty years. It provides a means to passively control vegetation and thereby reduce the need for mechanical and chemical weed control (Haywood 1999). Where labour for continual weeding is scarce, machines cannot operate, or the use of herbicides is restricted or not desirable, mulching may be an attractive alternative which can help to conserve soil moisture, improve water infiltration and reduce sedimentation (Walker and McLaughlin 1989, Gupta 1991).

In an agricultural context, mulching is one of the most environmentally benign strategies for weed control, reducing the need for tillage and herbicides, and avoiding associated problems (Feldman et al. 2000).

Although expensive in forestry applications, mulches have proven to be as biologically effective as other treatments (McDonald and Helgerson 1990). Willoughby (1999) estimated that in Britain plastic mulch installation would cost, on average, two and a half times as much per hectare than band spraying with herbicide.

Research has suggested that the use of mulch mats can reduce grass and herbaceous competition for water and improve the initial survival and growth of conifer seedlings. The mats are best applied in spring, soon after planting, before competing vegetation has had an opportunity to develop.

Waggoner et al. (1960) conducted an extensive study on the principles and benefits of polyethylene films. Their results indicated that black films had the least modifying effect on soil energy budgets and had a high ability to conserve soil moisture. The black film, by reducing light transmission, also exerted good control over unwanted vegetation compared to translucent plastic.

Parfitt and Stott (1984) compared the effect of black polyethylene and straw mulch covers with herbicides (which maintained bare ground conditions) on the establishment, growth and nutrition of poplar and willow cuttings. The polyethylene mulch significantly increased the number of shoots per cutting and the length of the longest willow shoot, when compared with straw mulch and herbicide treatments.

Temperature and moisture content under the mulches were higher than for the other treatments. In a previous study Bowersox and Ward (1970) also examined black polyethylene mulch as an alternative to mechanical cultivation in hybrid poplar establishment from dormant cuttings. They concluded that establishment success using black polyethylene mulch could equal or exceed that of mechanical cultivation. Similarly Blain (1984) set up an experiment to study the response of Salix and Populus cuttings to mulching with black polyethylene. The mulch improved shoot extension growth and suppressed weed growth, though occasional weeds appeared where the polyethylene had become torn around the base of the cuttings.

In a study in Canada (VMAP 1994), results indicated that hardwood seedlings treated with brush blanket mulches grew as well as seedlings treated annually with Vision or Simazine herbicide sprays and better than seedlings that received no vegetation control.

Harper et al. (1998) established a trial to compare the effectiveness of the herbicides glyphosate and hexazinone with plastic mulch mat treatments in reducing grass competition and improving Douglas fir seedling performance. They found that pre-plant herbicide application was effective for at least three growing seasons for perennial grasses and that Douglas fir seedling growth and survival improved. Post-planting spot application resulted in a high (65%) seedling mortality rate during the first year even when seedlings were protected. Mat sizes of 1.2 x 1.2 m were found to reduce competing vegetation ground cover for five years.

McDonald and Fiddler (1996) demonstrated that a vigorously sprouting shrub species could be killed with a sheet-type mulch. They tested large and small mulch mats and their efficacy in suppressing non-crop vegetation and enhancing conifer growth. Conclusions reached were that mulching showed promise for application in almost all plant communities, including those with plants that originate from sprouts and rhizomes, with larger mats being especially effective. A durable mulch that persists for several years has obvious benefits for seedling growth. In areas having a high density of widely spaced seedlings surrounded by dense, tall competition, having a visible mulch would be beneficial for evaluating seedling growth and survival. McDonald and Fiddler (1996) also concluded that pore structure is of the mulch important, and ideally it should allow water to percolate downwards but restricting upward movement. This was borne out by Feldman et al. (2000) in their experiment in an agricultural situation where landscape fabric, which is permeable to water, was preferable to polyethylene film.

Although the microclimatic effects of various mulch materials on soil, air temperature and soil moisture have been investigated (McDonald and Helgerson 1990), there is a limited understanding of the relation between mulch area and the growth and survival responses of trees. Increasing growth appears to require a larger diameter mulch than for survival. Thomas et al. (2001) found that 60x60 cm mats only increase tree growth during the first year with no measurable effects in successive years. They concluded that the result was most likely due to the small mat size and postulated that perhaps a larger mat may have prolonged the growth response. Willoughby (1999) included 1x1 m mulch mats in his investigation into reducing herbicide inputs in British forestry and drew the same conclusions with respect to the mat size.

Many types of mulch are marketed but few may actually meet enough of the criteria outlined to be useful. According to McDonald and Helgerson (1990) the ideal silvicultural mulch mat should be opaque, dark, permit water infiltration, retard evaporative water loss, supportive of favourable soil temperatures, sufficiently strong and durable to last until seedlings are established, low in cost and lightweight, non-toxic and of a colour that blends into the landscape. Other factors could include biodegradability and unattractiveness to animals. The authors also indicate that understanding: 1. site conditions, 2. vegetation type, 3. mulch material and 4. combinations of these factors, as the important features of refining mulch technology. Technological advancements in mulch material that increase effectiveness, durability and size while decreasing weight and application costs will improve the attractiveness of this method.

Haywood and Youngquist (1991) investigated plant fibre and plant fibre-polyester mats placed round the root collar of newly planted loblolly pine seedlings and over a cover of grasses, forbs and blackberries. The small sample sizes precluded the detection of any positive response to the mats but it was concluded that the negative effects of the mats on the seedlings were minimal.

Haywood (1999) established two studies to determine the ability of a large selection of mulches to remain intact and in place under field conditions (durability), control weeds, and influence the growth of loblolly pine (*Pinus taeda*) seedlings. Among the mulches tested were jute, pine straw, cellulose, polypropylene and polyethylene. As weather can influence the durability of a mulch, meteorological data were collected. Note was taken of installation difficulties for the various mats as this could be a serious obstacle to their continued use. Pine seedling measurements and weed cover estimations were carried out and mulch durability estimated visually over three growing seasons. In most cases mulches eliminated the established cover and germinants and vegetation did not readily re-establish after the deterioration of a mulch. After three growing seasons, the loblolly pine seedlings grew better where mulches were used.

Adams et al. (1997) examined three alternative weed control strategies in blue oak (*Quercus douglasii*) seedling plantations in California. The effect of herbicides, porous plastic mats and impervious plastic mats were compared. No one strategy was superior, though all resulted in greater seedling survival compared with no weed control. The use of herbicides proved to be the most cost effective.

In a later paper Adams (2000) states that the use of synthetic mulch mats may be competitive with cheaper chemical sprays for weed control where use of natural resources is intensive rather than extensive. Intensive use imparts greater value and the protection, and enhancement of this value often warrants investment that could not be justified under extensive management where value per unit area is low. In addition, environmental and social considerations have a higher priority in areas of intensive use and they may be more easily accommodated. It was also estimated that as the primary benefit of landscape fabric is its durability, thus producing less solid waste, the higher initial expense of fabric compared to black plastic may be offset. Initial labour costs for the fabric mulch were higher than for a bare ground control and organic mulch but this was reversed in the following two years of the trial.

Fertilisers are sometimes necessary to improve tree growth, mostly because of nitrogen deficiency. Various formulations are used such as nitram, urea or the slow release compound Osmocote. When mulch mats are used for weed control, such top dressings may be difficult to apply. Appleton et al. (1990) stated that a feature of mulch mats is that they encourage rooting near the soil surface and that these surface roots, and therefore the trees, become damaged if soluble fertilisers are used beneath the mats. Armstrong and Moffat (1996) began an investigation into the benefits of slow release nitrogen fertiliser compared with conventional formulations on recently planted trees. They examined the effect of mulch mats on fertiliser response and the effect of weed control method on ammonia release from applied urea. They concluded that mulch mats presented few problems for fertiliser applied during the dormant season, but issues such as lifting and replacing the mats during application needed to be considered. No evidence was found that release of ammonia from urea applied at recommended rates reduced tree growth. In fact mulch mats appeared to reduce the loss of nitrogen by volatilisation where urea was applied.

Organic mulches, especially those derived from waste products may in economic, environmental and aesthetic terms be a more favourable option than inorganic products. Froment et al. (2000) reported results of an experiment in which the effectiveness of four organic mulches (farmyard manure, compost, chopped straw and wood chips) applied at two depths was compared with a herbicide treated control. Results showed that all mulch treatments resulted in greater height and stem diameter increment compared with the herbicide treated control. Persistence of the mulches was assessed by comparing mulch depth at the start and end of the growing season. Farmyard manure was the least, and compost the most persistent. Straw and woodchip mulches gave the best weed control but height and stem diameter increments were less than for farmyard manure and household compost.

Smith et al. (2000) used a wood chip mulch (obtained from cleared right of ways) on pecan (*Carya illinoinensis*) seedlings. The chips were stockpiled for three months prior to being applied to a depth of 30 cm. Pecan harvesters sweep the ground so the mulch must deteriorate by the time the trees begin bearing nuts. The wood chipmulch treatments were in factorial combination with two rates of nitrogen, applied as either a single application at budbreak or again three weeks later. Foliar nitrogen concentration during the third year was positively related to mulch width as were stem diameter and tree height.

Lo et al. (2000) carried out a mulching trial in a hybrid poplar plantation using waste fibre from a paper mill. Analysis of the residue showed them to be mainly waste fibre and lime with few contaminants that could pose hazardous to the environment. Weed biomass data showed that weed cover was in the range 9-19%, which represented 80-90% weed suppression, compared with controls. The data also showed that the mulch was largely mineralised and lost its effectiveness as a weed suppressant after the fourth growing season.

Iles and Dosmann (1999) evaluated and compared the effects of five mineral (crushed red brick, pea-gravel, lava rock, carmel rock and river rock) and three organic mulches (finely screened pine bark, pine wood chips and shredded hardwood bark) on soil properties and on the growth of red maple (*Acer rubrum*). The authors concluded that the mineral mulches used in the trial did not create growth-limiting soil environments.

Pickering and Shepherd (2000) undertook a study to investigate nutrient content and nutrient release characteristics of six organic landscape mulches (cocoa shells, coarse conifer bark chips, wood chips, garden compost, horse manure and finely ground conifer bark). Comparisons were made with black polythene mulch and a bare ground control. The mulches were put in place and left for a twelve month period, after which they were removed and the plots sown with agricultural mustard (*Sinapsis alba*). Soil analysis was carried out at the beginning and end of the experiment, fresh and dry masses of the mustard crop were determined and their nutrient contents assessed. It was found that horse manure, garden compost and cocoa shell mulches with low C:N ratios and high potassium content resulted in significant increases in soil nutrients and supported the highest yields. After twelve months there was no evidence of nitrogen immobilisation or growth suppression under wood or bark-based mulches.

Samyn and De Vos (2002) published results of a trial in Flanders, Belgium where the use of mulch sheets made from 100% recycled waste (Ecopla sheets comprised of paper mill sludge 45%, compost (fruit, vegetable and garden waste) 45% and recycled paper or textile fibres 10%) was investigated. along with a number of other treatments. Results showed that the sheet mulches increased the relative growth rate of all species planted in pasture.

A number of experiments have shown that tree growth response often lags suppression of competing vegetation by one or more years. Lanini and Radosevich (1986) attributed the delayed response in conifers to the cyclic nature of their growth, where the current season's growth is partially dependent on carbohydrate produced the year before. It appears that the lag period between resource increase and concomitant increase in growth is species dependant. Flint and Childs (1986) also found that first year growth data did not show statistical differences among treatments and attributed it to a combination of nursery conditions and transplanting stresses on first year out-planted seedlings. This factor would have to be considered in any studies undertaken.

From the literature, it can be seen, that the interaction of factors involved in the response of trees to mulches is extremely complex. These considerations should be taken into account when choosing a mulch. However the variety and choice of materials available, means that growers can choose a mulch most suited to their circumstances while taking into account the material and maintenance cost.

Ground-cover plants

Establishment of ground-cover plants to prevent noxious weed invasion and provide only minimal competition with the tree crop has been suggested as a potential method of controlling weeds in young plantations. During tree establishment perennial broadleaved ground-cover plants are possible alternatives to mulch, provided the cover can be maintained. Clover (*Trifolium* spp.) and lucerne (*Medicago sativa*) are plants that may be used effectively under certain conditions. (Beaton and Hislop 2000).

Experiments in the United Kingdom on ex-agricultural land have shown the value of sowing ground-cover at planting (Williamson 1992, Williamson et al. 1992, Willoughby and McDonald 1999). The sown ground-cover out- competes and suppresses the growth of invasive weeds and thus confines herbicide use to maintaining a 1 m wide, weed-free band along the planting lines.

It is generally acknowledged that the control of weeds in forestry need not extend over the total site area for trees to survive and grow. Maintaining either a 1 m^2 spot round the base of each seedling or a 1 m wide strip along the row will often be adequate (Williamson 1992, Davies 1987, Willoughby and Dewar 1995). The 1 m^2 spot can be maintained with a hand-held, ground based applicator. Strip weeding allows mechanisation with the adaptation of agricultural spraying equipment. there is an open area of ground where weeds would proliferate if left unmanaged.

Williamson (1992) suggests two approaches to maintain good weed control to promote rapid tree establishment and managing the ground flora in the inter-row.

1. The vegetation round the planted trees is controlled and the vegetation naturally develops on the area between the weed-free areas. This then should be mowed regularly in order to prevent it seeding and becoming a problem.
2. Weed control around the planted trees is imposed as before and a ground cover crop is sown in the inter-row.

Williamson et al. (1992) reported the results of an experiment on the effect on tree growth of five inter-row management regimes on - Corsican pine (*Pinus nigra*) and Norway maple (*Acer platanoides*). After two growing seasons the strip-weed-and-mow combination was the cheapest and most practical option for establishing trees. Willoughby and McDonald (1999) reported on the same experiment at the end of four growing seasons and found the same result. One treatment, sowing kale (*Brassica oleracea* var. *viridis*) in the inter-row resulted in tree growth similar to strip-weed-and-mow, though tree growth was not as good as in the bare ground plots. The kale offered some competition but its main period of growth is in June, whereas the trees began their growth in May, before the kale plots had begun to grow. Once sown, kale requires very little management and is provides food and cover for game birds for about three years. It forms a tall, dense canopy and effectively prevents most weeds from establishing.

Coates et al. (1993) studied the efficacy of various grass/legume mixtures in controlling competing vegetation and their effect on survival and growth of Sitka spruce (*Picea sitchensis*) seedlings on a coastal alluvial site in northwestern British Columbia. Legume or grass seeding reduced two out of four major competitors compared to the unseeded control, even though some grasses may provide more severe early competition than native species. It was felt however that the long-term competition effects of one of the native species were likely to be the greatest threat to Sitka spruce performance.

Seeding of clover (*Trifolium repens*) ground-cover was one of number of weed control methods employed by Ferm et al. (1994) to aid in the establishment of a birch plantation. However, vole damage and bark necrosis were associated with a high percentage of clover ground-cover. They found also that the clover did not reduce root competition as effectively as the best herbicides.

Hanninen (1998) compared seven clover species with cultivation and grass sod to determine their influence on birch growth in a nursery field. Contrary to Ferm et al. (1994) damage by voles and other pests was not a problem. It was concluded that annual clovers could have potential as ground-cover. They suppress weed growth during the summer without seeming to compete too much with the trees. During the winter they form a paper-like mat on the ground and delay weed germination in early summer. The one disadvantage was having to sow annually. However herbicide use could be minimised.

Several criteria should be considered when choosing legumes such as clover for ground-cover in young plantations (Ponder 1994). Those that are used must grow well with minimal site preparation. Early benefits of leguminous ground-cover may decline later on because it will normally be shaded-out as the forest develops. However, enough seed may be stored in the soil to allow the legumes to re-establish themselves when the stand is thinned or harvested.

In Britain there has been some research carried out on the practicality of establishing ground-cover through which the trees could be planted directly, without the need for weed-free strips to be maintained. Whereas Hanninen (1998) deemed clovers as non-competitive, Davies (1987) regarded them as highly competitive under UK conditions. Willoughby (1999) published the results of two experiments which investigated the use of nineteen alternative ground cover and silvicultural treatments for newly planted ash (*Fraxinus excelsior*) and Douglas fir (*Pseudotsuga menziesii*) established on fertile ex-agricultural land. He found that most ground-cover was difficult to establish and was more competitive to the trees than naturally occurring vegetation. White clover did show some potential for suppressing weed competition without reducing tree growth.

Conclusion

Although vegetation management is most often directed at reducing competition by removing or suppressing forest weeds, it is important to consider the potential role of non-crop vegetation in the forest ecosystem. Walstad et al. (1987) identified the beneficial aspects of non-crop vegetation that should be considered in arriving at vegetation management prescriptions for conifers:

1. preventing soil erosion on disturbed or unstable sites,
2. uptake, storage and recycling of nutrients that might otherwise be lost from the ecosystem,
3. improvement of soil physical and chemical properties through the addition of organic matter and nutrients,
4. improvement of excessively hot, dry, or cold microclimatic conditions through shade or mulching effects,
5. protection of tree seedlings from browsing animals,
6. reduction or elimination of disease.

These benefits probably apply equally as well in the case of broadleaves.

Good vegetation management seeks to optimise the balance between the positive and negative effects of non-crop vegetation within the context of silvicultural objectives. Broadcast elimination of all vegetation (bare ground) for extended periods of time is rarely desirable or affordable in most situations (Wagner and Zasada 1991).

If the use of herbicides is not sustainable then alternatives must be sought. Research needs to begin well before they are phased-out otherwise it will have little value. If the research is has not been done and feasible alternatives demonstrated then forest scientists have failed to meet their client's needs (Wagner 1993).

Unfortunately, feasible alternatives to herbicides do not currently exist for forest establishment in Ireland. Abrupt reductions in herbicide use, without the knowledge or technology to implement alternatives, will severely threaten our ability to protect the new forest and meet further wood supply demands (Mc Carthy 2001).

The systems outlined may constitute some viable alternatives to the use of herbicides in Ireland. In the final analysis however, the material and and maintenance costs of these alternatives will most probably dictate which will be used. It this regard is of the utmost importance to clearly define the objectives and constraints in establishing new forests. Taking these into account the most appropriate vegetation management approach can be chosen options will be possible.

References

Adams, T.E. Sands, P.B. and McHenry, W.B. 1997. Weed control improves survival of transplanted blue oak. *California Agriculture* 51(5): 26-30.

Adams, T.E. 2000. *Competition control strategies for the artificial regeneration of California Blue Oak.* University of California Integrated Hardwood Range Management Programme.

Appleton, B.L., Derr, J.F. and Ross, B.B. 1990. The effect of various weed control measures on soil moisture, temperature and tree growth. *Journal of Arboriculture* 16:264-268.

Armstrong, A.T. and Moffat, A.J. 1996. How compatible are different weed control methods with the application of nitrogen fertilisers during tree establishment? *Arboricultural Journal* 20(4): 411-423.

Atchison, R.L. and Ricke, L.B. 1996. *Weed control options in tree plantings.* Kansas State University Agricultural Experiment Station & Cooperative Extension Service MF-2216.

Beaton, A. and Hislop, M. 2000. Trees in Agroforestry Systems. In *Agroforestry in the U.K.* Eds. Hislop, M. and Claridge, J., pp. 31-38. Forestry Commission Bull. No. 122. Forestry Commission, Edinburgh.

Blain, A.Q.M. 1984. Black polyethylene mulches as an aid in field propagation of hardwood cuttings. I*nternational Plant Propagators' Society* 34:281-286.

Bowersox, T.W. and Ward, W.W. 1970. Black polyethylene mulch - an alternative to mechanical cultivation for establishing hybrid poplars. *Tree Planters Notes* 21(1): 21-24.

Brodie, J.D. and Walstad, J.D. 1987. Douglas-fir growth and yield response to vegetation management. In *Forest vegetation management for conifer production,* pp 273-294. Eds. Walstad J.D. and Kuch P.J. John Wiley and Sons Inc. New York.

Coates, K.D., Douglas, M.J., Schwab, J.W. and Bergerund, W.A. 1993. Grass and legume seeding on a scarified coastal alluvial site in northwestern British Columbia: response of native non-crop vegetation and planted Sitka Spruce seedlings. *New Forests* 7(3): 193-211.

Culleton, N., Murphy, W.E., and Hicks, R.R. 1995. Competition control for establishment of Ash (Fraxinus excelsior L) on lowland soil in Ireland. *Irish Forestry* 52(1-2): 88-94.

Davies, R.J. 1987. *Trees and weeds*. For. Comm. Handbook No. 2. HMSO, London.

Feldman, R.S., Holmes, C.E. and Blomgren, T.A. 2000. Use of fabric mulches for vegetable production in a low tillage, permanent bed system: effects on crop yield and labour. American *Journal of Alternative Agriculture*. 15 (4): 146-153.

Ferm, A., Hytonen, J., Lilja, A. and Jylha, P. 1994. Effects of weed control on the early growth of Betula pendula seedlings established on an agricultural field. *Scand. J. For. Res*. 9: 347-359.

Flint, L.E. and Childs, S.W. 1987. Effect of shading, mulching and vegetation control on Douglas fir seedling growth and water supply. *For. Ecol. and Man*. 18: 139-203.

Froment, M.A., Britt, C.P. and Doney, J. 2000. Farm woodland control: Mulches as an alternative to herbicides around newly planted *Quercus robur* transplants. *Aspects of Applied Biology* 58: 81-86.

Gupta, W.J. 1991. Effects of mulching and fertiliser applications on initial development of some tree species. *For. Ecol. and Man*. 44: 211-221.

Hanninen, K.S. 1998. Effects of clovers as vegetative ground cover on the growth of red birch in nursery field production. *J. Hortic. Sci. Biotechnol*. 73: 393-398.

Harper, G.H., Comeau, P.G., Biring B.S., Reid, W.J. and Fielder P. 1998. *A comparison of mulch mat and herbicide treatments for reducing grass competition in the IDFww,* pp1-7. Extension Note, British Colombia Ministry of Forestry Research Programme.

Haywood, J.D. 1999. Durability of selected mulches, their ability to control weeds, and influence growth of loblolly pine seedlings. *New Forests* 18: 263-276.

Haywood, J.D. and Youngquist, J.A. 1991. Mulching effects of plant fiber and plant fiber-polyester mats combined with fertiliser on loblolly pine seedlings. *Tree Planters Notes* 42(3): 32-35.

Iles, J.K. and Dosmann, M.S. 1999. Effect of organic and mineral mulches on soil properties and growth of Fairview Flame R red maple trees. *Journal of Arboriculture* 25(3): 163-167.

Lanini, W.T. and Radosevich, S.R. 1986. Response of three conifer species to site preparation and shrub control. *Forest Science* 32: 61-67.

Lauer, D.K., Glover, G.R. and Gjerstad, D.H. 1993. Comparison of duration and method of herbaceous weed control on loblolly pine response through mid-rotation. *Canadian Journal of Forest Research* 23: 2116-2125.

Lo, A., Velema, G. and Liard, A. 2000. Use of primary clarifier fibre as a mulch in forestry plantations: 4 year study. *Pulp and Paper Canada* 101(7): 24-27.

Lund-Høie, K. 1984. Growth responses of Norway Spruce (*P. abies* L.) to different vegetation management programmes – preliminary results. *Aspects of Applied Biology* 5:127-133.

Mc Carthy, N. 2001. Research proposal. COFORD, Dublin.

McDonald, P.M. and Fiddler, G.O. 1993. Feasibility of alternatives to herbicides in young conifer plantations in California. *Can. J. For. Res.* 23:2015-2022.

McDonald, P.M. and G.O. Fiddler. 1996. Mulching: A persistent technique for weed suppression. In *Integrated forest vegetation management: Options and Applications*, Proceedings of the fifth B.C. Forest Vegetation Management workshop November 29-30th 1993 Richmond B.C. pp 51-57.

Mc Donald, P.M. and Helgerson, O.T. 1990. Mulches aid in regenerating California and Oregon forests: past, present and future. *US Dept. Agric. For. Serv., Pac SW. Res. Sta. Gen. Tech. Rep. Psw* 123.

Parfitt, R.I. and Stott, K.G. 1984. Effects of mulch covers and herbicides on the establishment, growth and nutrition of poplar and willow cuttings. *Aspects of Appl. Biol.* 5: 305-313.

Paterson, D.B. and Mason, W.L. 1999. *Cultivation of soils for forestry.* Forestry Commission Bulletin 119. Forestry Commission, Edinburgh.

Pickering, J.S. and Shepherd, A. 2000. Evaluation of organic landscape mulches: composition and nutrient characteristics. *Arboricultural Journal* 24(2-3): 175-187.

Ponder, F. Jr. 1994. *Leguminous ground covers could reduce herbicide use in forestry.* Research paper, North Central Forest Experimental Station. USDA Forest Service NC 316.

Row, C. 1987. Using costs and values in forest vegetation management analyses. In *Forest vegetation management for conifer production*, pp 327-364. Eds. Walstad, J.D. and Kuch P.J. John Wiley and Sons Inc.

Samyn, J. and De Vos, B. 2002. The assessment of mulch sheets to inhibit competitive vegetation in tree plantations in urban and natural environment. *Urban For. Urban Green.* 1: 25-37.

Schuette, B., and Kaiser, C. 1996. Weed control strategies for SRIC hybrid poplar plantations: farmer's perspective. Paper presented at the *First Conference of the Short Rotation Woody Crops Operations Working Group*, Paducah, Ky, September 23-25, 1996.

Smith, M.W., Carroll, B.L. and Cheary, B.S. 2000. Mulch improves pecan tree growth during orchard establishment. *Hortscience* 35(2): 192-195.

Swanton, C.J. and Weise, S.F. 1991. Integrated weed management: The rationale and approach. *Weed Technology* 5: 657-663.

Thomas, K.D., Reid, W.J. and Comeau, P.G. 2001. Vegetation management using polythene mulch mats and glyphosate herbicide in a coastal British Columbia hybrid Poplar plantation: 4-year growth response. *West. J. Appl. For.* 16(1): 26-30.

Upton, C. and Bass, S. 1996. *The Forest Certification Handbook.* Earthscan, London.

VMAP.1993/1994. *Vegetation Management Alternatives Programme*, pp 25-27. Annual Report. Ontario Ministry of Natural Resources, Canada.

Waggoner, P.E., Miller, P.M., and De Roo, H.C. 1960. *Plastic mulching – principles and benefits.* Bull. 634, New Haven: Connecticut Agric. Expt. Stn.

Wagner, R.G. and Zasada, J.C. 1991. Integrating plant autecology and silvicultural activities to prevent forest vegetation management problems. *Forestry Chronicle* 67: 506-513.

Wagner R.G. 1993. Research directives to advance vegetation management in N. America. *Can. J. For. Res.* 23: 2317-2327.

Wagner, R.G. 1994. Toward integrated forest vegetation management. *Journal of Forestry* 92(11): 26-30.

Wagner, R.G., Noland, T.L. and Mohammed, G.H. 1996. Timing and duration of herbaceous vegetation control around four northern coniferous species. *NZ Journal of Forestry Science* 26(1/2): 39-52.

Walker, R.F. and McLaughlin, S.B. 1989. Black polyethylene mulch improves growth of plantation-grown loblolly pine and yellow poplar. *New Forests* 3: (265-274).

Walstad, J.D., Newton, M. and Boyd, R.J. Jr. 1987. Forest vegetation problems in the Northwest. In *Forest vegetation management for conifer production*, pp 15-53. Eds. Walstad, J.D. and Kuch P.J. John Wiley and Sons Inc.

Williamson, D.R. 1992. *Establishing farm woodlands*. Forestry Commission Handbook No 8. HMSO, London.

Williamson, D.R., McDonald, W.G. and Nowakowski, M.R. 1992. Vegetation management during the establishment of farm woodlands. *Aspects Appl. Biol.* 29: 203-210.

Willoughby, I. 1999. Future alternatives to the use of herbicides in British Forestry. *Can. J. For. Res.* 29: 866-874.

Willoughby, I., and Dewar, J. 1995. *The use of herbicides in the forest.* Forestry Commission Field Book 8. HMSO, London.

Willoughby, I. and Moffat, A. 1996. *Cultivation of lowland sites for new woodland establishment.* Forestry Commission Research Information Note 288. Forestry Commission, Edinburgh.

Willoughby, I. and McDonald, H.G. 1999. Vegetation management in farm forestry – a comparison of alternative methods of inter row management. *Forestry* 72 (2): 199-221.

Willoughby, I. and Claridge, J. 2000. Trees and weeds. An update on herbicides. *Forestry and British Timber* 29(2): 31.

Zollinger, R. and Quam, V. 1997. *Weed control in tree plantings.* North Dakota State University Extension Service W-1097.