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Differences in vegetation cover resulting from various methods of site preparation for pine plantations in South Africa

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Summary — Species composition, height, cover, and biomass of vegetation were examined in response to forest regeneration methods applied in exotic tree plantations of *Pinus radiata* in South Africa. The experimental treatments involved 4 soil cultivation techniques (pitting, augering, ripping and disking) and 2 levels of weed control (standard and intensive). Both species cover and composition were significantly affected by the experimental treatments. However, the most important weed species remained common irrespective of the site preparation technique applied. More research is needed to find methods for selective control of weed species.

tree plantations / biodiversity / competing vegetation / weed control / soil cultivation

Résumé — Effet des méthodes de préparation de site sur la couverture végétale dans les plantations de pin en Afrique du Sud. *La diversité des espèces, la hauteur, la couverture et la biomasse végétale des plantations exotiques de* Pinus radiata *ont été examinées en fonction des méthodes de régénération de forêt en Afrique du Sud. Les traitements expérimentaux comprennent 4 méthodes de préparation du sol, et 2 niveaux de contrôle des mauvaises herbes (standard et intensif). Les traitements expérimentaux ont un effet sur la couverture et la diversité des espèces. Pourtant, les espèces adventices les plus importantes restent présentes quelle que soit la technique utilisé pour préparer le site. Des recherches supplémentaires sont requises pour trouver des méthodes de contrôle sélectif des espèces adventices.*

plantations forestières / diversité biologique / compétition végétale / contrôle des mauvaises herbes / préparation du sol

INTRODUCTION

There are about 7 000 species of plants, of which more than half are endemic, in the Cape Province of South Africa. Endemic families include: Bruniaceae (12 genera, 75 species), Geisolomataceae (1 species), Grubbiaceae (2 genera, 5 species), Penaeceae (5 genera, 25 species), Retziaceae (5 genera, 12 species). The other characteristic families are, Ericaceae (*c* 650 endemic species), Proteaceae (*c* 320 endemic species), Restionaceae (*c* 180 endemic species), Rutaceae-Diosmeae (*c* 150 endemic species) (White, 1983). The prevalent vegetation in the Cape region is fynbos, occurring in the form of 1–3 m tall sclerophyllous shrubland. Apart from some extreme habitats, stands of fynbos contain a mixture of species. Taylor (1972) recorded 121 species of flowering plants from a single 100 m^2 homogenous stand. Grasses are uncommon and usually occur in disturbed areas, but were much more abundant before European settlement (Ackocks, 1971). It is now believed that fynbos evolved in the presence of recurrent fires. In the absence of fire, many fynbos species become moribund and die. Therefore, some species became almost extinct due to protection against fire, and today, controlled fires are applied to preserve fynbos. There are also large patches of indigenous forests preserved in this region. Plateau forest is a high, evergreen and mixed forest, composed of dominant tree species such as *Olea capensis* subsp *macrocarpa*, *Podocarpus latifolius* and *P falcatus*, *Platylophys trifoliatus*, and *Apodytes dimidiata*. *Trichocladus crinitus*, *Rhumora adiantiformis*, and *Blechnum punctulatum* are the major understory species. In the moist forest type, the most common species are *Cunonia capensis* and *Platylophys trifoliatus*.

The indigenous forest was heavily exploited in the past, especially for *Ocotea bullata* and *Podocarpus* spp timber, but timber production from indigenous forests was not sufficient to satisfy the demand. Establishment of exotic tree plantations during the last century resulted in suppression of natural vegetation ("weeds") on extensive areas. Large areas of fynbos have been invaded by aliens introduced for land reclamation or timber production, but most disturbance occurred at afforestation when indigenous vegetation was burnt and the land ploughed. Not only did it take longer for the vegetation to re-establish itself, but also a single society returned on the ploughed ground compared to at least 6 societies after spot hoeing ("pitting") (Donald and Schönau, 1963). Species diversity of indigenous vegetation was further reduced once exotic tree species formed a closed canopy (Cowling *et al*, 1976; Richardson and van Wilgen, 1986). Other silvicultural treatments, such as controlled burning under the canopy of mature trees, altered the composition and spread of the vegetation (Vlok and de Ronde, 1989).

However, after harvesting, re-establishment of exotic plantations is usually impeded by rapid regeneration of competing vegetation. Immediate timber production goals can be achieved by vegetation control ("weeding"), but continued suppression of native plant species can have a harmful ecological impact on long-term site quality and productivity (Rapp, 1983; Versveld and van Wilgen, 1986). Usually, large amounts of water and nutrients are released after harvesting timber. These resources are utilized efficiently by the species that invade first in a succession. Such species are usually characterized by rapid growth rates and high rates of nutrient absorption, thus minimizing nutrient losses from the ecosystem (Chapin, 1993). These species are short-lived and are eventually replaced by woody plants. Very few, if any, dominant species are able to utilize all the resources of any area or preserve those that they do not use for themselves (Grubb, 1977). Preservation of the resources by the vegetation is enhanced by succession (Odum, 1969; Vitousek and Reiners, 1975) and diversity (Auclair, 1983). Therefore, it seems important to minimize the impact of silvicultural treatments on the composition and cover of the natural vegetation while reducing competition to levels that allow adequate timber production at the same time.

This article examines changes in species composition, height, area cover and biomass of competing vegetation in response to forest regeneration methods applied after harvesting the first rotation of trees. The objectives are limited to the major species and potential competitors. It is suspected that more intensive silvicultural treatments reduce diversity and abundancy of the vegetation cover while aggravating the potential for spread of noxious weeds. The effect of reduced competition on tree survival and growth is provided by Zwolinksi *et al* (1994).

STUDY AREA AND METHODS

The study was located on the Tsitsikamma plateau in the southern Cape Province (34° 01'S, 24° 01'E, 200 masl). In the 1950s, almost 2 000 ha of indigenous vegetation were cleared and most sites were planted with pines. From the north, this plantation is surrounded with fynbos preserved on extensive areas in the Outeniqua and Tsitsikamma Mountains while its southern border is formed by indigenous forest growing on the cliffs of the Tsitsikamma National Park. Soils of the experimental area are relatively uniform, moderately deep and are classified with the South African Binomial Classification as a Kroonstad-Oakleaf intergrate (MacVicar, 1990) which is equivalent to ochric Planosol of the FAO classification (MacVicar *et al,* 1977). The topsoils are very fine textured loam or silt loam. There is an abrupt transition to a gleyed yellow clay at a depth of 0.8 m. The soils are hydromorphic and perched water tables occur due to gently undulating topography and the presence of an impervious clay subsoil. In the experimental block, the previous crop was *Pinus pinaster* established in 1951. In 1989, *P radiata* was planted after the 1st rotation had been harvested, producing at felling 245 m^3/ha of good quality timber. In this region, *P radiata* is preferred for timber production if fertilizer is applied on phosphorus deficient sites. It is anticipated that timber production will increase by 40% due to appropriate species choice, intensive silviculture, and fertilization.

A split-split-plot design was used in a factorial combination to compare 4 methods of soil cultivation (whole plots), 2 levels of weed control (subplots), and 2 size classes of planting stock (sub-subplots). For the purpose of this study, the seedling grade treatment was not taken into consideration because the impact of the seedling grade on vegetation regeneration and growth is minimal within the 1st year after planting. Soil cultivation treatments included pitting, augering, ripping (subsoiling), and ripping and disk-ploughing. Pitting is the standard site preparation procedure in the region and involves digging a pit (45 cm wide and 20 cm deep) with a hoe. Augering produced a planting pit (45 cm wide and 40 cm deep) with a 2-man mechanical soil auger (Sthil BT 308). Both treatments were applied in May 1989. Ripping (to 60 cm depth) on parallel planting lines (spaced at 2.7 m) was done with a D7 bulldozer equipped with a 1-tooth subsoiler. The most intensive treatment involved ripping on planting lines, disk-ploughing (to 25 cm depth on average) and disk-harrowing of the whole area. Ripping and ploughing were preceded by manual removal of slash and destumping with a Bellaco Destumper mounted on a tractor. Ripping and ploughing treatments were applied in July 1989. Weeds were controlled either with the standard method (slashing of weeds at planting and 1 year later to prevent overtopping of the planted trees) or with intensive ("total") weed control which involved hoeing and pulling of the vegetation and application of herbicides. Chemical weed control included broadcast applications of glyphosate at 2 kg ae/ha 3 and 1 months before planting, and a broadcast application of hexazinone at 2 kg ai/ha 7 months after planting. In each of the 64 experimental units, 100 trees were planted at 2.7 m spacing and fertilized with 208 g/tree of superphosphate (10.5% P) in September 1989. The size of the whole-plot and the subplot was 0.2916 and 0.1458 ha, respectively. In total, 4 replications of this experiment were established on 4.6656 ha area.

A pilot survey of forest floor vegetation was conducted before and after harvesting of the previous crop, by laying a transect in the compartment and identifying plants that occurred along it. In the experimental plots, vegetation was surveyed before (28 April 1989) and after (1 February 1990) treatment application, and 1 year after planting (26 September 1990). During the post-harvesting surveys, 5, 1 m^2 circular sampling plots were established at random in every subplot. Total vegetation cover was estimated as percentage area covered with live vegetation. Height of the vegetation was recorded as the average height of the estimated major plant biomass component within the 1 m^2 plots. The major species, that is, the species which contributed at least 25% to the total plant biomass of each sample, were identified. Vegetation was harvested on a 0.25 m^2 circular area of each sample plot and bulked within a subplot. Dry biomass of each sample was recorded.

Species composition was classified using the 2-way indicator species analysis Twinspan (Hill, 1979). In a phytosociological context, the data matrix consisted of cross classification of subplots between the major species and soil cultivation combined with weed control treatments (samples). In this method, a classification of the samples is used to obtain a classification of the species according to their habitat preference. The 2 classifications are then used together to obtain a 2-way table that expresses the species' synecological relations. Within each survey, 2 groups of treatments were defined by 2 distinctive groups of species (a and c). The 3rd group of vegetation (group b) consisted of species common for both groups of treatments. The vegetation cover, height, and biomass were compared with analysis of variance. The means for specific treatment levels were tested with Tukey HSD test. Details regarding sampling procedure and statistical analysis are discussed by Zwolinksi (1992).

RESULTS AND DISCUSSION

The mature stands of the exotic tree species suppressed natural vegetation. However, the number of species recorded 6 months after harvesting increased by 72%, that is, from 46 under the stand conopy to 79 in the cleared field (table I). It is suggested that some of the species regenerated from seed stored in the soil (*eg*, Asteraceae) or rhizomes (*eg*, *Pteridium aquilinum*), while others invaded exposed soil from the surrounding openings (*eg*, *Taraxacum officinale*).

Frequencies of occurrence of the major species in the sample plots during the 3 post-harvesting surveys is shown in table II. In general, the number of species and occurrence frequency increased after site preparation. One year after planting, however, fewer species were recorded, but frequency of occurrences generally increased. Within the 1st year after treatment, the plant species reacted in various ways and could be divided into the following principal groups:

i) species which occurred more frequently after treatment application (*Rubus pinnatus*, *Pteridium aquilinum*, *Themeda triandra*, *Senecio* sp, *Psoralea ensifolia*, *Helichrysum petiolare*);

ii) species which were initially stimulated, but later became suppressed (*Taraxacum officinale*, *Centella coriacea*, *Helichrysum cymosum*, *Pentaschistis angustifolia*);

iii) species which were initially suppressed by the treatments, but later recovered (*Hypoxis villosa*, *Tetraria cuspidata*, *Pinus pinaster*, *Oxalis* sp, *Galopina circeoides*);

iv) species which declined after treatment application (*Andropogon appendiculare*, *Erharta calycina*, *Myrica serrata*, *Halleria lucida*, *Cymbopogon marginatus*).

A decrease in the number of species, but an increase in occurrence frequency may indicate domination of the communities by some of the species better adapted to the site conditions modified by the site preparation methods. Perennials such as *Rubus pinnatus*, *Pteridium aquilinum*, *Helichrysum* spp and grasses became dominant species because they can accumulate resources and suppress other species. These species can be controlled by a pre-harvesting burn (Vlok and de Ronde, 1989). Frequency of natural regeneration of *Pinus pinaster* was initially reduced by hand pulling, but new regeneration resulted from abundant seed reserves in the soil. Clearly, the major effort to control competing vegetation should concentrate on species of the groups (i) and

Table I. A list of species recorded in the experimental area at Blueliliesbush before and after clear-felling.

Before and after	*After only*
Acacia mearnsii *	*Alectra sessiliflora*
Acacia melanoxylon *	*Andropogon triandra*
Andropogon appendiculare	*Argyrolobium* sp
Arctotheca calendula	*Asclepias* sp
Berzelia intermedia	*Aspalathus* sp
Centella coriacea	*Blechnum* sp
Chrysanthemoides monilifera	*Bobartia orientalis*
Cliffortia burchellii	*Brachylaena glabra*
Conyza scabrida	*Caesia contorta*
Cymbapogon marginatus	*Eragrostis curvula*
Cynodon dactylon	*Erica* sp
Epischoenis sp	*Ficinia* sp
Erharta calycina	*Gnidia francisci*
Erica copiosa	*Helichrysum* sp
Eriospermum sp	*Indigofera flabellata*
Galopina circaeoides	*Lachenalia rosea*
Gnidia juniperifolia	*Lobelia neglecta*
Halleria lucida	*Merxmuellera cincta*
Helichrysum petiolare	*Metalasia muricata*
Helichrysum cymosum	*Monopsis unidentata*
Hypoxis villosa	*Pellaea viride*
Kniphofia uvaria	*Pentameris* sp
Leucadendron eucalyptifolium	*Podalyria* sp
Leucospermum cuneiforme	*Polygala* sp
Myrica serrata	*Restio* sp
Oxalis sp	*Rhodocoma gigantea*
Penaea cneorum	*Schizaea pectinata*
Pentaschistis angustifolia	*Sonchus* sp
Pinus pinaster *	*Solanum* sp
Podalyria burchellii	*Taraxacum officinale*
Priestleya hirsuta	*Tarchonantus camphoratus*
Psoralea ensifolia	*Ursinea anthemoides*
Pteridium aquilinum	*Vellarophytum* sp
Pterocelastrus tricuspidatus	
Restio triticeus	
Rhus lucida	
Rubus pinnatus	
Secamone alpini	
Senecio juniperinus	
Senecio lineatus	
Stenotaphrum secundatum	
Tetraria capillacea	
Tetraria cuspidata	
Themeda triandra	
Vernonia mespiliformis	
Watsonia knysnana	

* exotic species of trees.

Table II. Frequency of the major species recorded in 160 random sampling plots established in the experimental area before (28.04.89) or after (01.02.90) soil cultivation, and 1 year after planting (26.09.90).

Date of survey					
28.04.89		*01.02.90*		*26.09.90*	
Rubus pinnatus	18	*Rubus pinnatus*	38	*Rubus pinnatus*	33
Pinus pinaster	17	*Taraxacum officinale*	27	*Senecio* sp	31
Hypoxis villosa	13	*Pteridium aquilinum*	16	*Pteridium aquilinum*	21
Andropogon appendiculare	10	*Senecio juniperinus*	16	*Themeda triandra*	20
Pteridium aquilinum	9	*Helichrysum petiolare*	13	*Taraxacum officinale*	16
Erharta calycina	8	*Themeda tiandra*	13	*Tetraria cuspidata*	15
Myrica serrata	8	*Centella coriacea*	11	*Helichrysum petiolare*	12
Senecio lineatus	7	*Erharta calycina*	10	*Hypoxis villosa*	12
Helichrysum petiolare	6	*Psoralea ensifolia*	7	*Psoralea ensifolia*	12
Themeda cuspidata	6	*Helichrysum cymosum*	6	*Oxalis* sp	10
Centella coriacea	4	*Hypoxis villosa*	6	*Lobelia neglecta*	9
Galopina circeoides	3	*Pentaschistis angustifolia*	6	*Pinus pinaster*	8
Helleria lucida	3	*Monopsis unidentata*	4	*Centella coriacea*	7
Senecio juniperinus	3	*Myrica serrata*	4	*Galopina circaeoides*	7
Cymbapogon marginatus	2	*Pinus pinaster*	4	*Caesia contorta*	3
Pentaschistis angustifolia	2	*Ficinia* sp	3	*Erica calycina*	3
Themeda triandra	2	*Senecio lineatus*	3	*Helichrysum cymosum*	3
Acacia mearnsii	1	*Tetraria capillacea*	3	*Chrysanthemoides monalifera*	2
Leucospermum cuneiforme	1	*Tetraria cuspidata*	3	*Halleria lucida*	2
Oxalis sp	1	*Cymbapogon marginatus*	2	*Hellichrysum* sp	2
Psoralea ensifolia	1	*Helichrysum* sp	2	*Myrica serrata*	2
Secamone alpini	1	*Sonchus* sp	2	*Acacia mearnsii*	1
Cliffortia burchellii	1	*Asclepias* sp	1	*Epischoenis* sp	1
Cynodon dactylon	1	*Aspalathus* sp	1	*Erica* sp	1
Stenotaphrum secundatum	1	*Brachylaena glabra*	1	*Pentaschistis angustifolia*	1
Kniphofia uvaria	1	*Galopina circaeoides*	1	*Podalyria* sp	1
		Halleria lucida	1	*Rhus lucida*	1
		Indigofera flabellata	1	*Secamone alpini*	1
		Lobelia neglecta	1		
		Merxmuellera cincta	1		
		Pentameris sp	1		
		Rhus lucida	1		
		Solanum sp	1		
		Tarchonantus camphoratus	1		
		Vellaropythum sp	1		

(iii). *Rubus pinnatus*, *Senecio* sp, *Pteridium aquilinum*, *Tetraria cuspidata*, *Helichrysum petiolare*, *Pinus pinaster*, *Themeda triandra*, and *Psaralea ensifolia* are believed to be among the most competitive species retarding the establishment of commercial tree species in this region.

Grouping of the plant species for the treatment plots (table III) showed that the experimental area demarcated for ripping and augering combined with total weed control was covered with specific plant species (group c) which were only sporadically recorded in plots allocated to the other treat-

Table III. Grouping of species [1] according to their habitat [2] preference as expressed with treatment groups [3] before (28.04.89) or after (01.02.90) treatment application, and 1 year after planting (26.09.90).

28.04.89

Species	*Treatment: soil cultivation / weed control* ADDPP SSTST	 ARR TST	Group
C martinatus	--1-1	---	(a)
C dactylon	--1--	---	
E calycina	22-22	---	
G circaeoides	-1-11	---	
M serrata	11222	---	
Oxalis sp	1----	---	
S alpini	1----	---	
Senecio sp	1-11-	---	
S secundatum	---1-	---	
T cuspidata	12-11	--1	
H villosa	-2212	112	(b)
P angustifolia	1----	-1-	
P pinaster	22212	122	
P aquilinum	211--	121	
R pinnatus	12222	222	
S lineatus	-112-	111	
T triandra	----1	-1--	
A melanoxylon	----	--1	(c)
A appendiculare	--11-	122	
C coriacea	----1	1-2	
C burghellii	-----	1--	
H lucida	1----	11-	
H petiolare	1-1--	2-2	
K uvaria	-----	-1-	
L cuneiforme	-----	1--	
P ensifolia	-----	-1-	
Treatment split	XXXXX	YYY	

01.02.90

Species	*Treatment: soil cultivation / weed control* PRRADDP SSTTSTT	 A S	Group
Asclepias sp	--1----	-	(a)
C coriacea	-222-1	-	
C marginatus	2------	-	
Ficinia sp	1-1-1--	-	
G circaeoides	--1----	-	
H lucida	--1----	-	
Helichrysum sp	---11--	-	
H villosa	1121-1-	-	
M cincta	---1---	-	
M unidentata	---2-2-	-	
N neglecta	------1	-	
P angustifolia	2-1----	-	
P pinaster	11-1---	-	
P ensifolia	2--111-	-	
R lucida	1------	-	
S lineatus	-21----	-	
Solanum sp	-----1-	-	
Sonchus sp	-1-----	-	
T camphoratus	1------	-	
Vellarophitum sp	----1--	-	
E calycina	----11-	1	(b)
H cymosum	1111-1	1	
H petiolare	2-11---	2	
M serrata	1------	2	
P aquilinum	-21--11	2	
R pinnatus	2222222	2	
Senecio sp	1221212	2	
T officinale	2222222	1	
T cuspidata	1-1----	1	
T triandra	2212--2	1	
Aspalathus sp	-------	1	(c)
B glabra	-------	1	
I flabellata	-------	1	
Pentameris sp	-------	1	
T capillacea	-------	2	
Treatment split	XXXXXXX	Y	

26.09.90

Species	*Treatment: soil cultivation / weed control* APR SSS	 ADPRD TTTTS	Group
A mearnsii	--1	-----	(a)
C monalifera	2--	-----	
Épischoenis sp	--1	-----	
Erica sp	1--	-----	
H cymosum	111	-----	
Helichrysum sp	1-1	-----	
M serrata	11-	-----	
P angustifolia	1--	-----	
R lucida	-1-	-----	
E calycina	1-1	-1--1	(b)
H lucida	-1-	----1	
H petiolare	221	---12	
H villosa	111	2-22-	
L neglecta	1-2	-1112	
Oxalis sp	121	1-211	
P pinaster	12-	2-11-	
P ensifolia	221	1122-	
P aquilinum	2-2	21-2-	
R pinnatus	223	11211	
Senecio sp	222	2-222	
T cuspidata	122	11-2-	
T triandra	222	1-22-	
C contorta	---	-11-1	(c)
C coriacea	1--	2-121	
G circaeoides	1--	211--	
Podalyria sp	---	----1	
S alpini	---	---1-	
T officinale	---	21212	
Treatment split	XXX	YYYYY	

[1] Grouping of species according to their habitat preference: (a) habitat X preferred, (b) no preference in habitat X or Y, and (c) habitat *Y* preferred. [2] Treatment split into habitats: X or Y. [3] Treatments: augering (A), disking (D), pitting (P), ripping (R), standard weed control (S), total weed control (T). Numbers represent frequency of subplots in which a corresponding species was found.

ments. The differences in species composition were reduced by treatment application. Five months after the treatments had been applied, only augering combined with standard weed control was represented by a specific vegetation group. One year after planting, augering, pitting and ripping, each combined with standard weed control, were covered with uniform vegetation (group a). A 2nd group, consisting of all the soil cultivation treatments combined with total weed control, had significantly reduced cover. Disking combined with standard weed control resulted in almost total control of vegetation, and weed control treatment was irrelevant. Species considered as the strongest competitors – *Rubus pinnatus*, *Senecio* sp, *Pteridium aquilinum*, *Tetraria cuspidata*, *Helichrysum petiolare*, *Psoralea ensifolia*, *Pinus pinaster* and *Themeda triandra* – were recorded frequently throughout the survey period, forming a vegetation group (group b) not related to any specific treatment.

Vegetation height, cover and dry biomass are shown in table IV for each of the surveys. The vegetation cover was best controlled in disked plots. Disking combined with total weed control reduced the vegetation to 2.9% in cover, 0.1% in height, and 1.1% in biomass compared to the pre-treatment values. Disking results in existing vegetation and humic soil horizons being covered with mineral soil from deeper horizons. This prevents immediate re-colonization of the sites by the vegetation. Despite a relatively low mean vegetation cover and height, however, individual trees could be subjected to severe competition where *Senecio* spp

Table IV. Vegetation abundance in the experimental area assessed before (28.04.89) or after (29.09.89) site preparation, and 1 year after planting (26.09.90).

Treatment	*Cover (%)*			*Height (m)*			*Biomass (kg ha^{-1})*		
	28.04	*29.09*	*26.09*	*28.04*	*29.09*	*26.09*	*28.04*	*29.09*	*26.09*
Soil cultivation:									
augering	9.7	8.2^{B}	23.4^{B}	0.25	0.18^{B}	0.56^{B}	322.1	132.0^{B}	1407.8^{B}
disking	9.5	0.4^{A}	7.3^{A}	0.19	0.01^{A}	0.25^{A}	281.9	7.9^{A}	279.6^{A}
pitting	11.0	8.7^{B}	25.5^{B}	0.24	0.15^{B}	0.47^{B}	353.2	109.9^{B}	1069.0^{B}
ripping	10.6	4.2^{AB}	19.1^{AB}	0.22	0.08^{AB}	0.57^{B}	404.0	63.9^{AB}	915.3^{B}
Weed control:									
standard	10.0	6.7^{B}	27.1^{B}	0.21	0.17^{B}	0.66^{B}	320.4	66.4	1658.8^{B}
total	10.4	4.1^{A}	106^{A}	0.24	0.05^{A}	0.27^{A}	360.3	90.5	177.1^{A}
Interactions									
augering*standard	8.3	11.6^{C}	36.0^{CD}	0.19	0.33^{B}	0.80	246.0	109.2	2641.2^{C}
augering*total	11.0	4.8^{B}	10.8^{AB}	0.31	0.04^{A}	0.32	398.2	154.8	174.7^{AB}
disking*standard	8.8	0.5^{A}	10.3^{AB}	0.20	0.01^{A}	0.40	297.6	3.4	503.0^{AB}
disking*total	10.2	0.3^{A}	4.3^{AB}	0.18	0.00^{A}	0.10	266.2	12.4	56.2^{AB}
pitting*standard	12.5	11.5^{C}	39.0^{CD}	0.21	0.27^{B}	0.72	356.8	70.4	1970.4^{C}
pitting*total	9.6	6.0^{B}	12.0^{AB}	0.26	0.04^{A}	0.23	349.6	149.4	167.6^{AB}
ripping*standard	10.5	3.1^{AB}	23.0^{BC}	0.22	0.06^{A}	0.72	381.0	82.6	1520.4^{BC}
ripping*total	10.8	5.3^{B}	15.1^{AB}	0.21	0.11^{AB}	0.42	427.0	45.2	310.2^{AB}

$^{A-D}$ Means with different letter indexes differ significantly ($P < 0.05$) within sampling dates.

is regenerated on the exposed mineral soil. *Senecio* spp spread quickly on bare ground and grew rapidly, overtopped the trees and caused occasional mechanical damage through wind buffeting.

The amount of vegetation increased after augering or pitting combined with standard weed control. One year after planting, augering and standard weed control produced 2 641 kg ha^{-1} of vegetation, that is, 47 times more than the combination of disking and total weed control. The standard method of site preparation in the region (*ie,* pitting and standard weed control) yielded the 2nd largest amount of vegetation not differing significantly from augering and standard weed control. Frequently, pits were invaded by grasses taking advantage of the fertilizer applied on the soil surface around the planted trees. The average reduction of vegetation biomass by 90% through "total weed control" was achieved by repetitive mechanical and chemical measures.

CONCLUSIONS

i) Natural vegetation regenerates rapidly and colonizes bare ground when released from tree competition after timber harvesting. Its natural successional development, however, is disturbed by site preparation for tree planting and rapid natural regeneration of exotic trees. The impact of this repetitive disturbance on regeneration potential of the native species and their continued presence on the sites is unknown.

ii) The cover of competing vegetation is significantly reduced by intensive soil cultivation and weed control. However, the most important weed species in tree plantations remain common irrespective of the site preparation method applied.

iii) It is recommended that the time between harvesting and re-establishment be reduced to decrease competition from natural vegetation and to reduce costs of weed control. More research is needed to find better control measures against the important weeds.

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