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THE UNIVERSITY OF ALBERTA

THE EFFECT OF COMPANION CROPPING AND HERBICIDE ON GROWTH OF THREE CULTIVATED GRASS SPECIES

BY

THOMAS ANDREW ODDIE ©

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF **MASTER OF SCIENCE**

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled THE EFFECT OF COMPANION CROPPING AND HERBICIDE ON GROWTH OF THREE CULTIVATED GRASS SPECIES submitted by THOMAS ANDREW ODDIE in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

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ABSTRACT

Annual companion crops are frequently planted with perennial forages to provide an economic return during the establishment year. However, competition for resources between crops can impede forage establishment and reduce yields. The study objectives were to: 1) assess growth of smooth bromegrass (Bromus inermis Leyss.), meadow bromegrass (Bromus biebersteinii Roem & Schult.) and orchardgrass (Dactylis glomerata L.) during the establishment year; 2) monitor grass species productivity in the second growing season; 3) evaluate the feasability of establishing grasses with an oat (Avena sativa L.) companion crop, removed as greenfeed or grain, compared to establishment alone with or without a herbicide application; and 4) determine the effects of each agronomic practice on subsequent forage productivity. Measurements of growth characteristics, light penetration and soil water content were taken over a two year period during two separate trials near Highvale, Alberta.

The results from Trial A indicated that smooth bromegrass had higher yields, tiller height, leaf area index and crop growth rate than orchardgrass and meadow bromegrass during the establishment year. Orchardgrass had the highest tiller numbers. There was no significant difference in growth between species during Trial B. Early tiller growth and leaf area development appeared to promote grass establishment. During the second growing season, smooth bromegrass was more productive than meadow bromegrass and orchardgrass least productive.

Growth of the three grass species decreased under an oat companion crop and increased following a herbicide treatment. Competition for light was considered a major factor limiting growth, since the companion crop reduced light penetration to underseeded grasses by about 50%. Competition for soil water may have been a limiting factor, but facilities were not available to adequately assess differences. The companion crop reduced weed yields, but herbicide was more effective in suppressing weed growth. Early companion crop removal (greenfeed) did not improve grass establishment compared to late removal (grain). A cost/benefit analysis indicated an economic return from the oat companion crop, but use of herbicide was more profitable in terms of forage production. Therefore, use of companion crops during grass establishment is not recommended in this region unless required for soil conservation purposes or herbicide is not readily available.

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PART I - INTRODUCTION

1.1 BACKGROUND

Perennial forage grasses and legumes play an important role in diversifying Alberta's agricultural economy. They are the mainstay of the ruminant livestock industry, representing between 70 and 80% of livestock rations (Alberta Agriculture, 1986c). Forage crops occupy approximately 1.6 million hectares of tame hay and pasture farmland in Alberta. At present, Alberta forage production contributes about one-quarter of the Canadian total of tame hay.

Forage grasses and legumes also help maintain the productivity of soils. Fibrous grass root systems and nitrogen fixing legumes are important for enhancing soil and water conservation, increasing soil fertility and improving soil structure and tilth. Crop rotations that include perennial forages can also help control disease and pest outbreaks commonly associated with continuous cropping of annual cereals.

Despite the obvious importance of forage crops, their management presently requires closer attention than has been provided in the past. For instance, forage crops on many farms are grown on the least productive soils, haying operations are given a low priority and/or pastures are overgrazed and deterioration results (Agriculture Canada, 1974). Improved establishment techniques which promote healthy, vigorous forage growth are necessary to discourage invasion of weedy, less nutritious and unproductive plant species. The selection of suitable forage species is also necessary to ensure optimum quality and productivity. Therefore, improved management procedures for range, tame pasture and hay farmland presently in use are necessary to maintain forage productivity and quality, as well as expand with Alberta's growing livestock industry and secure future export markets.

Management of forage crop farmland in the central and northern parts of the prairie provinces has typically involved the establishment of cultivated grass species. Yet the establishment of most perennial species can be a slow process and costly if no marketable product is produced during the establishment year. Smooth bromegrass (Bromus inermis Leyss.) is often established because it is adaptable to various soil and moisture conditions. Cleared and broken forest land, or broken native grassland, are frequently seeded to smooth bromegrass or smooth bromegrass-legume mixtures because the productivity can be several times that of native grassland or bush-pasture (Looman, 1976). Other grass species, such as orchardgrass (Dactylis glomerata L.) and meadow bromegrass (Bromus biebersteinii Roem. & Schult.), are established less frequently, yet they offer good quality feed, quick recovery after defoliation and are adaptable to similar environmental conditions (Alberta Agriculture, 1981).

One of the more common management practices utilized to provide a financial return in the establishment year has been to seed the perennial forage crop with an annual "companion" crop (Agriculture Canada, 1974). A companion crop, also known as a "nurse" or "cover" crop, can be defined as an annual crop grown in association with a perennial forage crop during the forage establishment year, forming a mixed cropping management system. In Alberta, companion crops often include plant species such as oats (Avena sativa L.), barley (Hordeum vulgare L.), wheat (Triticum aestivum L.), rye (Secale cereale L.), flax (Linum usitatissimum L.) or rapeseed (Brassica campestris and B. napus L.) (Alberta Agriculture, 1981).

To a grower, the primary benefit of a companion crop is to maintain income during the establishment year when forage yields are low. Other benefits that have been suggested from the use of companion crops include suppression of weed growth, reduction of soil erosion, decreased surface crusting in poorly structured soils, and protection of the slow growing forage seedlings from wind, strong sunlight and high temperatures (Kelly, 1972; Scott et al., 1987; Walton, 1983). With these benefits in mind, companion crops have been recommended for use on summerfallow farmland, newly broken land, high rainfall areas, and areas prone to soil erosion (Alberta Agriculture, 1975).

Companion crops, however, also compete directly with the forage crop for resources such as light, water and nutrients. They reduce the vigor and increase the mortality of forage seedlings. Use of a companion crop assumes that: 1) all of the light is not exploited by the cereal crop; 2) water and nutrients are not limiting; and 3) the slow growing forages will have little effect on the cereal crop (Stoskopf, 1981). Due to the competitive nature of companion crops, therefore, they are not generally recommended for use on stubble farmland, land free of weeds and soil erosion, areas with low rainfall, or when soil moisture conditions are below normal (Alberta Agriculture, 1975).

The objectives of the present study were to: (i) assess the relative growth of smooth bromegrass, meadow bromegrass and orchardgrass in the Highvale region of central Alberta during the establishment year; (ii) monitor the productivity of each grass species during the second growing season; (iii) evaluate the feasability of establishing grass species with an oat companion crop removed as greenfeed or grain compared to establishment alone with or without a herbicide application; and (iv) determine the effect of the companion crop and herbicide application on subsequent forage productivity in the second growing season.

1.2 LITERATURE REVIEW

1.21 The Effect of Companion Crops on the Forage Crop Environment

.1 Light

Companion crops intercept light, thereby shading the underseeded forage crop and influencing its growth and development. Cooper and Ferguson (1964) reported a 25 to 50% reduction in mid-day light penetration to alfalfa (*Medicago sativa* L.), birdsfoot trefoil (*Lotus corniculatus* L.) and orchardgrass crops when seeded with a barley companion crop. Such a decrease in light intensity reduced the growth rate and root/shoot ratio of alfalfa and birdsfoot trefoil (Cooper, 1967). Pritchett and Nelson (1951) found that the dry weight of alfalfa and smooth bromegrass decreased as the shading effect of an oat companion crop increased, provided that soil water and fertility conditions were adequate. Light penetration to underseeded alfalfa and red clover (*Trifolium pratense* L.) seedlings has been reduced 70 to 80% when seeded with an oat companion crop at rates of 21 to 128 kg/ha (Bula et al., 1954). The authors stated that more light penetration occured at low companion crop seed rates, but that weed encroachment eventually caused light penetration to decrease. Center et al. (1984) suggested that the major factor influencing competition between mixtures of annual ryegrass (*Lolium multiflorum* Lam.) and soft chess (*Bromus mollis* L.) was light, and that fertility level was not important. It would appear, therefore, that competition for light has a major effect on the establishment of forage grasses when seeded with companion crops.

.2 Soil Water

The companion crop also competes directly with the underseeded forage crop for soil water, thereby adversely affecting germination and growth of forage seedlings. Smith et al. (1954) stated that competition for soil water appeared to be the major factor influencing the establishment of alfalfa and red clover when seeded with an oat companion crop on sandy soils. It has also been suggested by Santhirasegarem and Black (1968) that reductions in clover establishment under a wheat companion crop were caused by competition for soil water rather than competition for light. Genest and Steppler (1973) found that soil water content was lower and light penetration to alfalfa, birdsfoot trefoil, timothy (*Phleum pratense* L.) and smooth bromegrass was reduced when established with an oat, barley and wheat companion crop. The authors indicated that forage yields were enhanced more by increased soil water content than increased light intensity during establishment. McGowan and Williams (1971) reported that establishment of subterranean clover (*Trifolium subterraneum* L.) with a barley companion crop was less successful when soil water was limiting during spring growth. The literature suggests that soil water can become limiting when establishing forages with a companion crop, but the level of effect can be compounded by environmental factors such as soil texture and annual rainfall.

1.22 Weed Suppression by Companion Crops and Herbicides

Several researchers have investigated the effect of herbicides and companion crops on weed growth during forage crop establishment. Maillette (1986) showed that wheat canopy development was not generally affected by the presence of weed species, but the shading effect of wheat was reported to decrease weed leaf area, yield, leaf number and leaf distribution. It has been stated that forage establishment of an alfalfa, smooth bromegrass, timothy and orchardgrass mixture using a 2,4-DB herbicide was a feasible alternative to establishment with a companion crop (Hume et al., 1969). Temme et al. (1979) showed that animal intake and digestibility of alfalfa hay improved when established with EPTC plus 2,4-DB or benefin herbicide treatments compared to establishment with an oat companion crop or alone without chemical weed control. It has been reported that orchardgrass yields increased by 20% when 2,4-D herbicide was used to control dandelion (*Taraxacum officinale* Web.) growth (Moyer, 1984). In contrast, Haggar (1979) found that companion crops of annual ryegrass and white clover (*Trifolium repens* L.) were not successful in controlling weed growth in perennial ryegrass (*Lolium perenne* L.) stands compared to 2,4-D or benazolin herbicide application. It can be concluded from the literature, therefore, that companion crops may suppress weed growth to some extent during forage establishment, but herbicides are considered more effective.

1.23 Competition and Companion Crops

Several strategies have been utilized to minimize competition between companion crops and underseeded forage crops. Neighboring plants in a field crop may compete with each other in several ways: roots may compete for mineral nutrients or soil water; shoots may shade each other and so decrease photosynthesis; plants may compete for atmospheric carbon dioxide and oxygen; by influencing air movement they may alter temperature and humidity within the plant, which can influence the exchange of CO_2 with the outside air; or roots may excrete substances inhibitory to growth (Watson and French, 1971). Santhirasegaram and Black (1965) suggested that competition between forages and companion crops could be reduced by: decreasing companion crop seed rates; increasing seeded row spacings, using cross-seeding or alternate row seeding techniques; cutting the companion crop at an immature stage of growth; and selecting less competitive companion crops and more competitive forage species.

.1 Companion Crop Seed Rates

A decrease in companion crop seed rates has generally been effective in reducing competition with forage seedlings, but this is not always the case. Tossell and Fulkerson (1960) found that a reduction in the seeding rate of an oat companion crop increased seedling vigor of underseeded alfalfa, red clover, timothy, orchardgrass and smooth bromegrass without large decreases in oat yield. The authors also indicated an increase in forage crop seedling vigor when the oat companion crop row spacing was doubled from 17 to 35 cm. Pelton (1969) reported that high seeding rates in wheat quickly depleted soil water content, while low seeding rates maintained soil water levels for longer periods of time. Reductions in the seed rate of a rapeseed companion crop was shown to increase yield of sweetclover by Malik and Waddington (1988). In contrast to these results, Scott (1974) demonstrated that the establishment of undersown white clover (Trifolium repens L.) was not improved by decreases in seed rate of a wheat companion crop. Although somewhat inconclusive, the literature generally suggests that forage establishment success may be improved by a reduction in companion crop seed rate.

Reductions in annual crop seeding rates may have an effect on crop yield, as indicated when no forage crop has been grown. Finlay et al. (1971) demonstrated that a decrease in seeding rate in barley from 151 to 54 kg/ha did not decrease grain yield. Changes in seed rate and row spacing in barley did not generally lead to increased grain yield due to adjustments in tillering capacity (Simmons et al., 1982). In contrast, Briggs (1975) found that higher seeding rates and narrower row spacings of spring wheat cultivars generally resulted in higher yield and earlier maturity. Higher seed rates for eight spring wheat cultivars have also been shown to result in higher grain yields (Baker, 1982). The contrasting views identified in the literature indicate a quadratic relationship between crop yield and seed rate. Initially yields increase as seed rate increases, until seedling competition causes a gradual decrease in crop yield. Therefore, the effect of lower seed rates on crop yield will depend on the nature of the quadratic relationship.

.2 Companion Crop Row Spacings

Wide companion crop row spacing has usually, but not always, been shown to reduce competition with underseeded forage seedlings. Depuis (1983) found that alfalfa yields were reduced by only 14% in the second year when seeded with an oat companion crop at 54 cm row spacings, compared to a 30% reduction in alfalfa yields when seeded with oats at 18 cm row spacings. It has also been shown that legume seedling survival increased when the row spacing of oat, barley, wheat and rye companion crops were increased from 17 to 35 cm, but that the positive impact of wider seed rows was less evident when soil water was not a limiting factor (Harper, 1946). Similarily, Pendleton and Dungan (1953) reported that forage yield, height and cover of red clover increased proportionally with increases in oat companion crop row spacing during a dry year, but did not increase under conditions of normal rainfall. Kilcher and Heinrichs (1960) have shown that wheat, oats, barley and rye companion crops reduced forage yield, cover and vigor compared to establishment alone, but that the negative effects of the companion crop were reduced if seeded at wide row spacings and at right angles to the seeded forage rows. It has been reported that alfalfa seed yields were lower for two years after seeding with a Polish rapeseed companion crop, but that alfalfa plant numbers were positively influenced by increases in row spacing (Waddington and Malik, 1987). Darwent et al. (1987) studied the effect of row spacing on forage seed production and hay yield for eleven Alberta grass species and found that row spacing had its greatest effect during the first year after establishment, and was less evident thereafter. In contrast to these results, Lawrence (1970) stated that row spacings and row arrangements of a wheat companion crop did not affect the establishment of underseeded crested wheatgrass (Agropyron cristatum (L.) Gaertn.). In general, it appears from the literature that forage establishment can be improved by seeding the companion crop at wide row spacings.

.3 Companion Crop Harvest Dates

The effect of companion crop harvest date on forage establishment has shown variable results. Roberts (1964) stated that forage yield of orchardgrass was increased by seeding the oat companion crop at a reduced rate and removing it as silage rather than mature grain. Similarily, Brink and Martin (1986a, 1986b) found that alfalfa yield was reduced when established with an oat or barley companion crop, but the negative effects of the companion crop could be reduced if the companion crop was removed at an immature stage of growth. In contrast to these results, Kilcher and Heinrichs (1960) reported that establishment of a smooth bromegrass, alfalfa and crested wheatgrass forage mixture was improved by harvesting a wheat, oats, barley or rye companion crop at a height of 20 cm or more as mature grain, rather than harvesting the immature crop at a height of 5 cm for grain hay/silage. The literature presents contrasting views regarding the most suitable harvest date for companion crops, likely because the positive effects of reduced competition for resources after companion crop removal can be offset by the negative effects of competition encountered prior to companion crop removal.

.4 Competitive Nature of Companion Crop Species

The selection of less competitive companion crop species has also been recommended as a means of improving forage crop establishment success. Klebesadel and Smith (1959) stated that winter wheat and rye companion crops were the strongest competitors for light and soil water with underseeded alfalfa and red clover, while flax was the least competitive. The authors indicated that oats, barley and spring wheat were all about equally competitive for plant resources, although barley was more competitive for light and oats more competitive for soil water. Berkenkamp and Meeres (1987a, 1987b) reported that oat forage crops harvested as hay, silage or pasture were more productive than barley, wheat, and triticale (Triticosecale Wittmack) when grown alone or intercropped with peas (Pisum sativum sp. arvense), beans (Phaseolus vulgare) and sunflower (Helianthus annuus) on Gray-Wooded soils. The authors suggested that barley was more competitive than oats, while wheat and triticale were least competitive. Buxton and Wedin (1970) demonstrated that an oat companion crop cultivar with a less-dense canopy had greater penetration of incident solar radiation than an oat companion crop cultivar with a more-dense canopy, but that there was no difference between the two when weed competition was heavy. Therefore, the literature indicates that the selection of a less competitive companion crop can have a positive effect on grass establishment. The suitability and adaptability of a companion crop species to a particular growing region will be important in its selection.

.5 Competitive Nature of Forage Grass Species

The aggressive nature and competitive ability of the underseeded forage species will also influence seedling survival and growth. Frasier et al. (1985) indicated that growth of grass species following plantings can be related to the number of seedlings which develop sufficient vigor to survive undesireable changes in the environment, as well as the number of ungerminated, but viable, seeds which remain until environmental conditions improve. It has been reported that grass species such as annual ryegrass, perennial ryegrass and intermediate wheatgrass (Agropyron intermedium (Host) Beauvois) are most aggressive; orchardgrass, tall fescue (Festuca arundinacea (Schreb.) Wimm.), meadow fescue (Festuca elatior L.), and smooth bromegrass are moderately aggressive; and reed canarygrass (Phalaris arundinacea L.), meadow foxtail (Alopecurus pratensis L.), timothy, red fescue (Festuca rubra L.), redtop (Agrostis stolonifera L.), and bluegrass (Poa pratensis L.) are non-aggressive species in terms of competitive ability with other plant species (Blaser et al., 1956). Sheaffer et al. (1981) found that orchardgrass seedlings were generally more competive than tall fescue and reed canarygrass. Orchardgrass was also demonstrated as more competive than perennial ryegrass, especially when no nitrogen fertilizer was added and shoot defoliation was infrequent (Remison and Snaydon, 1978; 1980). Tossell and Fulkerson (1960) showed that red clover and timothy were most sensitive, alfalfa and orchardgrass were moderately sensitive and smooth bromegrass was least sensitive to competition when seeded with an oat companion crop. It has been stated that meadow bromegrass was less aggressive than smooth bromegrass and thus, retains better balance with alfalfa in grass-alfalfa mixtures (Alberta Agriculture, 1980). The literature indicates that a competitive forage species would provide improved forage growth when seeded with a companion crop, largely due to its ability to aggressively compete for resources.

PART II - MATERIALS AND METHODS

2.1 PLOT ESTABLISHMENT

2.11 Background

The study was conducted from 1986 to 1988 using plots established on cultivated farmland near Lake Wabamun in central Alberta (Sec 7 - Twp 52 - Rge 4 - W5). Environment Canada (1982) records show that the area has a sub-humid to humid climate, averaging 504 mm of precipitation and 2.1°C temperatures annually, a 104 frost free day growing season (May 29 to September 11), 1340 degree days above 5°C (departure of mean daily temperature from base temperature), and an 11.3 km/hr northwest prevailing wind. Environment Canada (1987) records from the Highvale Meteorological Station (Table 1) show that annual precipitaticn totalled 585 mm in 1986, 431 mm in 1987 and 496 mm in 1988. The mean daily temperature from 1978 to 1987 was 3.6°C.

The field site was selected 22 July, 1985 on a well-drained, south facing slope. At that time, the site supported an oat companion crop underseeded with alfalfa (*Medicago sativa* L.). The study site consists of a clay loam soil (Dark Gray Luvisol) developed over weathered residual bedrock (Canada Soil Survey Committee, 1978).

2.12 Experimental Design

The experimental design for plots established in 1986

TABLE 1. HIGHVALE METEOROLOGICAL DATA - 1978 to 1988

MONTH	TOTAL PRECIPITATION (mm)				MEAN TEMPERATURE (°C)
	1986	1987	1988	1978-87 AVERAGE	1978-87 AVERAGE
JANUARY	12.5*	3.5	8.5	21.4	-10.0
FEBRUARY	13.7	5.6	20.0	13.0	-9.7
MARCH	27.4	23.5	6.0	27.6	-2.6
APRIL	41.3	14.7	11.0	25.5	4.9
MAY	44.4	88.8	32.2	57.3	10.8
JUNE	59.4	48.3	103.0	76.4	14.6
JULY	219.2	97.5	192.3	129.1	16.8
AUGUST	19.0	118.7	71.1	61.9	15.6
SEPTEMBER	94.8	5.5	41.1	64.1	10.4
OCTOBER	27.6	5.3	1.6	26.6	6.0
NOVEMBER	22.0	2.0	7.0	14.5	-5.0
DECEMBER	4.0	17.9	2.0	20.5	-9.0
TOTAL	585.3	431.3	495.8	538.0	AVG 3.6

* Environment Canada, Highvale Meteorological Station

(Trial A) and 1987 (Trial B) was a split-plot factorial with three crop species randomized in main plots and four agronomic practices randomized in sub-plots. Each trial was conducted for two consecutive years (Trial A - 1986 to 1987; Trial B - 1987 to 1988) to monitor the effects of agronomic practices on forage crop establishment during the first year, as well as subsequent forage productivity in the second year. Trials A and B were replicated in eight and five randomized complete blocks, respectively (Appendix A, Figures A-1 and A-2). The number of blocks or replicates that could be established in Trial B was limited by available space and uniform topography. A third trial (Trial C) was established in 1988, but was discontinued due to weed invasion by quackgrass (*Agropyron repens* L.).

Individual replicates were divided into three main plots, each measuring 12 m wide by 6 m long. Main plots were subdivided further into four sub-plots, 3 m wide by 6 m long. The outer 1 m wide boundary of each sub-plot was used for destructive sampling during the first year, while the inner 1 m wide portion was reserved for forage productivity sampling in the second year. Each replicate was separated by a 3 m buffer zone.

2.13 Plant Species and Cultivars

Crop species seeded to individual main plots included: meadow bromegrass (*Bromus biebersteinii* Roem & Schult. c.v. Regar); smooth bromegrass (*Bromus inermis* Leyss. c.v. Carlton); or orchardgrass (*Dactylis glomerata* L.

c.v. Kay). Agronomic practices utilized on sub-plots included: a grass-only control (no companion crop or herbicide); grass-only (no companion crop) with a chemical herbicide application for weed control; grass with an oat (Avena sativa c.v. Athabasca) companion crop removed as greenfeed (August harvest); and grass with an oat companion crop removed as mature grain (September harvest). The same plant species and cultivars were used in both trials (A and B). Certified seed was obtained from the Alberta Wheat Pool.

2.14 Site Preparation

Glyphosate [N-(phosphonomethyl) glycine] herbicide was applied for complete vegetation control on 25 July, 1985 at a rate of 3.5 litres/hectare. Glyphosate (Roundup) is a non-selective chemical herbicide with no lingering soil residue. Glyphosate was also applied on 6 May, 1986 and 30 April, 1987 at a rate of 2.0 litres/hectare for weed and volunteer vegetation control on the Trial A and B areas, respectively. Herbicide applications were made with a McKee White Model L80 boom sprayer at 275 kPa pressure using TeeJet 8002 flat spray tips. Dead vegetation was incorporated into the soil approximately 7 to 10 days after herbicide application using a tractor-mounted offset disk.

Soil fertility samples were collected prior to the establishment of each trial to assess soil nutrient deficiencies (Alberta Agriculture, 1984). A composite soil sample was collected from six random locations across each trial area using a Dutch Model J-880 soil auger (Alberta Agriculture, 1988b). Separate composite samples from depths of 0-15, 15-30 and 30-60 cm were placed in plastic bags, frozen and delivered to Monenco Analytical Laboratories for analysis of available nitrogen, phosphorus, potassium and sulphur (McKeague, 1978).

Fertilizer applications were based on information and recommendations provided by the Alberta Soil and Feed Testing Laboratory (personnal communication with J. Carsen, Soil Specialist, 27 January, 1986). Fertilizer was applied to both the Trial A and B areas on 8 May, 1986 at a rate of 85 kg N/ha, 19 kg P/ha, 35 kg K/ha and 40 kg S/ha (source 46-0-0, 22-11-11-11 and 0-0-52). A supplemental fertilizer application was made to the Trial B area on 11 May, 1987 at a rate of 50 kg N/ha (source 46-0-0). Fertilizer applications were made with a tractor-mounted Cyclone Model S3B power spreader and incorporated to a depth of approximately 15 cm with a offset disk. The seedbed was packed after cultivation with a parallel bar harrow.

2.15 Establishment of Crop Species

The oat companion crop was seeded to selected sub-plots in each trial with a double disk Kincaid Model 70 plot grain drill on 20 May, 1986 and 25 May, 1987. Seed was applied at a rate of 38 kg/ha using 36 cm row spacings. The seed rate was half the recommended rate of 76 kg/ha (Alberta Agriculture, 1986a; 1986b; 1986d). The row spacing was twice the standard spacing of 18 cm (Alberta Agriculture, 1986c). The seeder required 2 passes to cover each 3 m wide sub-plot.

Smooth bromegrass, meadow bromegrass and orchardgrass were seeded later the same day into individual main plots in each trial with a Brillion Model SST-1201 grass seeder at rates of 11, 15 and 9 kg/ha, respectively. The seed rates were the same as those recommended for the surrounding area (Alberta Agriculture, 1981a; 1986c). Germination test results for each seed lot showed that 84% of smooth bromegrass, 98% of meadow bromegrass and 82% of orchardgrass was viable (personal communication with Mr. Hardy, Seed Division, Alberta Wheat Pool, 16 September, 1986). The seeder was cleaned throughly prior to seeding each new crop species. Three passes were required to cover each 12 m wide main plot. After the seeding program was complete, all plot boundary markers (wire flags) were replaced with wooden stakes.

2.16 Initiation of Agronomic Practices

One of the agronomic practices included the application of bromoxynil [octanoic acid] + MCPA ester [methlyl chloro phenoxy acetic acid] to selected sub-plots in each trial for broadleaf weed control on 7 July, 1986 and 2 July, 1987. Bromoxynil + MCPA ester (Buctryl M) is a commonly used chemical herbicide for control of broadleaf weeds in seedling grasses. Herbicide was applied with a portable backpack sprayer and flat fan spray nozzle at a rate of 1.0 litre/hectare.

The remaining agronomic practices included the removal of the oat companion crop as greenfeed (mid-August) or mature grain (mid-September) by clipping with a sickle bar mower at a height of 25 cm. The mid-August and mid-September harvest dates were selected to correspond with local greenfeed and grain harvest dates. A 25 cm harvest height was selected so that the companion crop could be harvested without excessive clipping of underseeded forage grass seedlings. Clipped vegetation was raked off each plot and discarded. Measurements of companion crop dry matter yield during the first year of Trial A and B were taken prior to the removal of the companion crop during a separate plot monitoring program.

The greenfeed and grain companion crop harvests took place on schedule in Trial A. The greenfeed companion crop was harvested in mid-August as planned in Trial B, but the grain companion crop was not allowed to mature. The grain companion crop was harvested in mid-August (same time as the greenfeed companion crop harvest), due to excessive weed growth. The early harvest was regarded as essential for weed control, since weeds appeared to be choking out the underseeded grass seedlings. In addition, weed seeds produced during the establishment year could have contributed to considerable weed growth in the second growing season if allowed to mature. Therefore, plot vegetation was mowed and discarded, leaving no mature grain companion crop for harvest in September during Trial B.

2.2 OBSERVATIONS OF CROP GROWTH CHARACTERISTICS DURING THE ESTABLISHMENT YEAR

Crop growth characteristics (dry matter yield, tiller number, tiller height, leaf area) of grasses and oats were observed at approximately 30 day intervals (15 July, 15 August, 15 September) during the first growing season of Trial A and B to assess crop growth. Observations of leaf area were made during the first growing season of Trial A only, due to time constraints during Trial B. All observations of crop growth characteristics taken in mid-August and mid-September preceeded the removal of the oat companion crop, so as to reflect the stage of crop growth prior to harvest disturbance. Observations were taken from 0.25 X 0.50 m sample areas randomly selected within the outer 1 m boundary of each sub-plot. Two undisturbed sample areas were selected within individual sub-plots during each monthly sampling date. The central 1 m wide portion of each sub-plot was not sampled so that the productivity of undisturbed forage growth could be measured during the second growing season.

Crop growth rate was calculated for increases in grass dry matter yield from the July to August and August to September sampling dates during the establishment year of each trial. An example of the calculation is as follows:

$$\text{Crop Growth Rate (CGR) for dry matter yield (kg/ha/month)} = \frac{\text{Weight 2} - \text{Weight 1}}{\text{Time 2} - \text{Time 1}} \times \frac{1}{\text{Area}}$$

2.21 Dry Matter Yield

Dry matter yield for above-ground vegetation within each 0.25 X 0.50 m sample area was determined by hand clipping the grass, oat and weed components at a height of 5 cm, placing each vegetation component into a separate paper bag and oven-drying for at least 48 hours at 65°C. Dried plant material was weighed to the nearest 0.1 g. Dry matter yield for the oat companion crop included a combined yield of grain and straw. All observations of dry matter yield are reported in kilograms per hectare.

2.22 Tiller Number

Tiller number was observed by counting the total number of grass and oat tillers within each sample area. A tiller, composed of leaf blades, leaf sheaths and an apical meristem, was defined as a shoot originating from a basal node of a single plant. Observations of tiller number are reported as tillers per square meter.

2.23 Tiller Height

Tiller height was observed by measuring the height of five grass and oat tillers randomly selected along a transect within each sample area. Tiller height was measured by tape measure from ground level to the tip of the uppermost extended leaf. Observations of tiller height are reported in centimeters.

2.24 Leaf Area

Leaf area was measured by collecting a small grab sample of the grass and cereal component from each bulk sample, separating each vegetative component into paper bags and immediately freezing the samples to maintain leaf shape. Leaf area observations were only taken during the July, August and September sampling dates of Trial A due to time constraints in Trial B. Each grab sample was thawed at room temperature and separated into green leaves, senescent leaves and stems (including leaf sheaths and inflorescence). Oat leaf area was not observed during the September sampling date due to complete leaf senescence in the annual crop. Leaf area measurements were attempted for weed leaves during Trial A, but efforts were abandonded due to leaf tissue destruction upon freezing and thawing. The surface area of green leaves were measured on a Li-Cor Model LI 3300 leaf area meter fitted with a pressure device to keep leaves flat while passing through the sensor. The entire grab sample was then oven-dried for 48 hours at 65^{o}C and weighed to the nearest 0.01 g on an analytical balance. The relationship between leaf area and dry weight for the small grab sample was used to estimate the leaf area for the larger bulk sample area as follows:

$$\text{Leaf Area for Bulk Sample (ie. per } 0.125\ m^2\text{)} = \frac{\text{Leaf Area for Grab Sample} \times \text{Dry Matter Yield for Bulk Sample}}{\text{Dry Matter Yield for Grab Sample}}$$

Observations of leaf area are reported as leaf area per ground area or leaf area index (LAI). Leaf area measurements were used to calculate specific leaf weight (leaf weight/leaf area) for each grass species.

2.3 MEASUREMENTS OF THE CROP GROWTH ENVIRONMENT DURING THE ESTABLISHMENT YEAR

Measurements of the crop growth environment (ie. light penetration, soil water content) were recorded during the first growing season of Trial A and B to assess the impact of the oat companion crop during grass establishment. Light penetration was recorded on approximately 30 day intervals (15 July, 15 August, 15 September) immediately after observations of crop growth characteristics were completed. Light measurements were recorded after removal of the companion crop during mid-August and mid-September to assess any positive impacts of improved light penetration on grass growth, should they occur. Light penetration was not recorded in July of Trial B due to a malfunction in the light sensor. Soil water content was measured in the fall after the mid-September companion crop harvest during both trials (15-30 September).

2.31 Light Penetration

Light penetration through the crop canopy was recorded within each sub-plot by using a Li-Cor Model LI-188B light meter and 1.0 m line quantum sensor (1986) or point quantum sensor (1987). Measurements of light penetration were recorded within the crop canopy at ground level and above grass level and compared to light reception above the oat canopy. Photosynthetic photon flux density (400 to 700 nm) was measured in micromoles per square meter per second using a 30 second scan rate. A light reading was taken above the oat canopy to determine the total level of incoming radiation. The sensor was then placed at ground level and above grass level across each sub-plot. The sampling procedure was repeated twice for each sub-plot and averaged. All readings were collected on cloudless days near solar noon (1000 to 1400 h). Percentage of light penetration through the crop canopy to ground level and grass level was determined by dividing the amount of light striking each level by the total level of incoming radiation.

$$\text{Light Penetration To Ground Level (\%)} = \frac{\text{PPFD (uM/m}^2\text{/s) Received At Ground Level}}{\text{PPFD (uM/m}^2\text{/s) Received Above the Oat Canopy}} \times 100$$

$$\text{Light Penetration To Grass Level (\%)} = \frac{\text{PPFD (uM/m}^2\text{/s) Received Above Grass Level}}{\text{PPFD (uM/m}^2\text{/s) Received Above the Oat Canopy}} \times 100$$

2.32 Fall Soil Water Content

Soil water content was determined gravimetrically from samples collected in the fall after the first growing season of both trials. The soil profile was sampled with a Dutch soil auger at a depth of 0-15 and 15-30 cm from one randomly located sample point within each sub-plot. Each soil sample was placed in a moisture tin, sealed with tape and the wet weight determined to the nearest gram. Each sample was then opened and oven-dried for at least 48 hours at 100°C. The dry weight of the soil sample and empty tin was then measured. Gravimetric soil water content was calculated as follows:

$$\text{Soil Water Content (\% by weight)} = \frac{\text{Wet Weight} - \text{Oven Dry Weight}}{\text{Oven Dry Weight}} \times 100$$

2.4 FORAGE PRODUCTION IN THE SECOND GROWING SEASON

All plant litter remaining from the establishment year was removed in April of the second growing season by clipping with a tractor rear-mount rotary mower at a height of 10 cm. Forage yield (combined weight of grass and weed material) was measured in the second growing season on 15 June and 30 August, 1987 (Trial A) and 28 June and 25 August, 1988 (Trial B) to assess the effect of each agronomic practice on subsequent forage productivity. Harvest dates were selected to correspond with local hay harvest practices. Forage yields were measured at each harvest date by clipping a 0.64 X 4.00 m sample area from the central portion of each sub-plot using a Mott Forage Plot Harvester. The harvestor was set to clip vegetation at a height of 5 cm from ground level. Each clip sample was placed in a cotton sack, oven dried for at least 48 hrs at 65°C and weighed to the nearest gram. After each harvest date, all remaining plot vegetation was clipped and removed. Measurements of dry matter yield are reported in kilograms per hectare.

2.5 COST/BENEFIT ANALYSIS

The economic feasibility of establishing forage grasses with an oat companion crop or herbicide application was assessed by estimating costs and benefits associated with each agronomic practice over the two year growing period. In order to complete a cost/benefit analysis using market conditions existing during the present experiment, a number of assumptions were made. First, it was assumed that the oat companion crop and grass species were planted at the same time, thereby eliminating the extra cost and time required for two separate seeding operations. Second, it was assumed that fertilizer application rates were the same for grasses seeded with or without the companion crop. Third, it was assumed that each agronomic practice involved one harvest during the first growing season, such that the companion crop was removed as greenfeed or grain and the grasses seeded alone were removed in the fall as hay, and each agronomic practice was harvested as hay twice during the second growing season. Finally, it was assumed that variable costs such as fuel, lubrication, repairs and maintenance would change relative to the agronomic practice, but fixed costs such as depreciation, interest on investment, taxes, insurance and housing would stay the same for the purposes of this comparison.

The approximate costs (1988 dollars) associated with each agronomic practice were obtained from custom rate charts published by Alberta Agriculture (1988a), discussions with a local District Agriculturalist (personal communication with B. Drysdale, Department of Agriculture, Calgary, 12 January, 1989), and information from seed and chemical company representatives. These costs have been summarized as follows:

$10.65/ha to purchase herbicide (bromoxynil + MCPA).
$2.50/ha to spray herbicide;
$12.40/ha to purchase seed oats (37 kg/ha seed rate);
$15.00/ha to swath grain;
$32.00/ha to combine grain;
$22.00/ha to cut and condition hay or greenfeed;
$5.00 to bale each 545 kg large round bale;

The average economic return for hay and greenfeed crops was estimated by the District Agriculturalist, while the return for grain oats was published in the Calgary Herald (17 January, 1989 edition). The economic returns have been summarized as follows:

$71.65/1000 kg for hay;

$49.60/1000 kg for greenfeed oats; and

$155.00/1000 kg for grain oats.

2.6 STATISTICAL ANALYSIS

Statistical analyses was completed on mainframe computer using a split-split plot analysis of variance (ANOVA) procedure over both trials and a split plot analysis of variance procedure for individual trials (LeClerg et al., 1962; Steel and Torrie, 1980). Where the F test was significant (P = 0.05), a Duncan's multiple range test was used to identify significant main effects for trial, crop species, and agronomic practice, as well as their interactions (GLM procedure; SAS Institute, 1985). Due to consistent differences in measured variables between Trial A and B, data and analyses were presented separately for each trial. Results of the analysis of variance procedure and Duncan's multiple range test for each trial shows data from across all crop species or agronomic practices, unless otherwise specified. Where appropriate, a Pearson correlation coefficient (r) was calculated to show the intensity of association between paired variables (CORR procedure; SAS Institute, 1985). Correlation coefficients were determined from two data sub-sets: 1) grass characteristics were analyzed using data from agronomic practices without the companion crop (grass-only control and grass-only plus herbicide); and 2) oat characteristics were analyzed using data from agronomic practices with the companion crop (greenfeed oats and grain oats).

PART III - RESULTS

3.1 ANALYSIS OF VARIANCE OVER BOTH TRIALS

3.11 Growth of Grasses During the Establishment Year

Analysis of variance (ANOVA) for grass dry matter yield, tiller height and tiller number over the two trials (Trial A and B) indicated significant (P = 0.05) main effects due to trial, crop species and agronomic practice during the three sampling dates (Tables 2, 3 and 4). Therefore, data and analyses are presented by trial. Analysis of variance also indicated significant interaction effects for trial X crop species, trial X agronomic practice, crop species X agronomic practice and trial X crop species X agronomic practice during one or more sampling dates.

Grass yields were significantly higher in Trial A than B during the August (1578 and 192 kg/ha, respectively) and September (2324 and 1110 kg/ha, respectively) sampling dates (Table 5). Grass tiller heights were greater in Trial B than A during the July (20.1 and 14.6 cm, respectively) sampling date, but greater in Trial A than B during the August (56.4 and 24.7 cm, respectively) and September (57.7 and 36.7 cm, respectively) sampling dates. Grass tiller numbers were also higher in Trial A than B during the July (206 and 107 #/m^2, respectively) sampling date. Differences in grass dry matter yield, tiller height and tiller number between the two trials can be partly attributed to lower precipitation (Table 1) and

TABLE 2. ANALYSIS OF VARIANCE FOR GRASS DRY MATTER YIELD (kg/ha) OVER TRIAL A (1986) AND B (1987)

SOURCE OF VARIATION	DF	MEAN SQUARE (X 100)		
		JULY HARVEST	AUGUST HARVEST	SEPTEMBER HARVEST
Trial (T)	1	307 ns	709730 *	789179 *
Error a (Rep(T))	11	156	4197	14918
Crop (C)	2	126 *	91271 *	142778 *
Crop x Trial	2	127 *	87190 *	101381 *
Error b (C x Rep(T))	22	269	4159	1094
Practice (P)	3	6 ns	145342 *	723510 *
Practice x Trial	3(2)	29 ns	89533 *	237423 *
Practice x Crop	6	16 ns	9327 ns	32708 *
Practice x Trial x Crop	6(4)	6 ns	8733 ns	24670 ns
Residual Error c	99(87)	25	41820	13159
Total	155(140)			

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom (September harvest in brackets).

TABLE 3. ANALYSIS OF VARIANCE FOR GRASS TILLER HEIGHT (cm) OVER TRIAL A (1986) AND B (1987)

SOURCE OF VARIATION	DF	MEAN SQUARE		
		JULY HARVEST	AUGUST HARVEST	SEPTEMBER HARVEST
Trial (T)	1	1100 *	37123 *	10905 *
Error a (Rep(T))	11	167	277	252
Crop (C)	2	566 *	1801 *	519 *
Crop x Trial	2	195 *	1725 *	337 *
Error b (C x Rep(T))	22	48	127	72
Practice (P)	3	209 *	724 *	4824 *
Practice x Trial	3(2)	25 ns	672 *	3689 *
Practice x Crop	6	29 ns	50 ns	318 *
Practice x Trial x Crop	6(4)	15 ns	74 ns	289 *
Residual Error c	99(87)	21	93	68
Total	155(140)			

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom (September harvest in brackets).

TABLE 4. ANALYSIS OF VARIANCE FOR GRASS TILLER NUMBER ($\#/m^2$) OVER TRIAL A (1986) AND B (1987)

SOURCE OF VARIATION	DF	MEAN SQUARE (X 100)		
		JULY HARVEST	AUGUST HARVEST	SEPTEMBER HARVEST
Trial (T)	1	3647 *	320 ns	2 ns
Error a (Rep(T))	11	175	322	773
Crop (C)	2	900 *	4628 *	1729 *
Crop x Trial	2	1344 *	402 ns	274 ns
Error b (C x Rep(T))	22	90	248	304
Practice (P)	3	52 ns	9580 *	15969 *
Practice x Trial	3(2)	122 ns	1354 *	1083 *
Practice x Crop	6	33 ns	364 ns	578 *
Practice x Trial x Crop	6(4)	34 ns	385 *	229 ns
Residual Error c	99(87)	60	174	217
Total	155(140)			

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom (September harvest in brackets).

TABLE 5. GRASS DRY MATTER YIELD, TILLER HEIGHT AND TILLER NUMBER IN RELATION TO TRIAL A AND B

TRIAL	GRASS CHARACTERISTICS		
	JULY	AUGUST	SEPTEMBER
	GRASS DRY MATTER YIELD (kg/ha)		
A	61 a*	1578 a	2324 a
B	32 a	192 b	1110 b
MEAN	50	1045	1937
S.E.	16	84	182
	GRASS TILLER HEIGHT (cm)		
A	14.6 b	56.4 a	57.7 a
B	20.1 a	24.7 b	36.7 b
MEAN	16.7	44.2	51.0
S.E.	1.7	2.1	2.4
	GRASS TILLER NUMBER ($\#/m^2$)		
A	206 a	356 a	420 a
B	107 b	327 a	485 a
MEAN	168	345	441
S.E.	54	23	41

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

higher weed yields during the establishment year of Trial B (see 3.13).

3.12 Growth of Oats During the Establishment Year

Analysis of variance for oat dry matter yield, tiller height and tiller number over the two trials indicated significant ($P = 0.05$) main effects due to trial during the July and August sampling dates, while effects of crop species and agronomic practice were not significant (Tables 6, 7 and 8). Therefore, data and analyses are presented by trial. Analysis of variance also indicated that trial X crop species, trial X agronomic practice, crop species X agronomic practice and trial X crop species X agronomic practice interaction effects were not significant.

Oat yields were significantly higher in Trial A than B during the July (2884 and 766 kg/ha, respectively) and August (13843 and 5779 kg/ha, respectively) sampling dates (Table 9). Oat tiller heights were also greater in Trial A than B during the July (69.5 and 55.1 cm, respectively) and August (101.2 and 79.9 cm, respectively) sampling dates. In addition, oat tiller numbers were higher in Trial A than B during the July (311 and 113 $\#/m^2$, respectively) and August (492 and 289 $\#/m^2$, respectively) sampling dates. Differences in oat dry matter yield, tiller height and tiller number between the two trials can be partly attributed to lower precipitation (Table 1) and

TABLE 6. ANALYSIS OF VARIANCE FOR OAT DRY MATTER YIELD (kg/ha) OVER TRIAL A (1986) AND B (1987)

SOURCE OF VARIATION	DF	MEAN SQUARE (X 10000)	
		JULY HARVEST	AUGUST HARVEST
Trial (T)	1	8282 *	120062 *
Error a (Rep(T))	11	330	1044
Crop (C)	2	40 ns	736 ns
Crop x Trial	2	11 ns	1367 ns
Error b (C x Rep(T))	22	89	673
Practice (P)	1	25 ns	496 ns
Practice x Trial	1	81 ns	652 ns
Practice x Crop	2	55 ns	277 ns
Practice x Trial x Crop	2	6 ns	136 ns
Residual Error c	33	51	1073
Total	77		

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom.

No September harvest for Trial B.

TABLE 7. ANALYSIS OF VARIANCE FOR OAT TILLER HEIGHT (cm) OVER TRIAL A (1986) AND B (1987)

SOURCE OF VARIATION	DF	MEAN SQUARE	
		JULY HARVEST	AUGUST HARVEST
Trial (T)	1	3817 *	8382 *
Error a (Rep(T))	11	179	219
Crop (C)	2	65 ns	71 ns
Crop x Trial	2	90 ns	45 ns
Error b (C x Rep(T))	22	153	47
Practice (P)	1	29 ns	3 ns
Practice x Trial	1	12 ns	14 ns
Practice x Crop	2	5 ns	1 ns
Practice x Trial x Crop	2	6 ns	10 ns
Residual Error c	33	56	23
Total	77		

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom.

No September harvest for Trial B.

TABLE 8. ANALYSIS OF VARIANCE FOR OAT TILLER NUMBER ($\#/m^2$) OVER TRIAL A (1986) AND B (1987)

SOURCE OF VARIATION	DF	MEAN SQUARE (X 100)	
		JULY HARVEST	AUGUST HARVEST
Trial (T)	1	7254 *	7594 *
Error a (Rep(T))	11	127	85
Crop (C)	2	61 ns	143 ns
Crop x Trial	2	9 ns	404 ns
Error b (C x Rep(T))	22	74	129
Practice (P)	1	26 ns	335 ns
Practice x Trial	1	58 ns	186 ns
Practice x Crop	2	80 ns	129 ns
Practice x Trial x Crop	2	1 ns	11 ns
Residual Error c	33	32	161
Total	77		

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom.

No September harvest for Trial B.

TABLE 9. OAT DRY MATTER YIELD, TILLER HEIGHT AND TILLER NUMBER IN RELATION TO TRIAL A AND B

TRIAL	OAT CHARACTERISTICS		
	JULY	AUGUST	SEPTEMBER
	OAT DRY MATTER YIELD (kg/ha)		
A	2884 a*	13843 a	14869
B	766 b	5779 b	-
MEAN	2069	10742	-
S.E.	332	590	-
	OAT TILLER HEIGHT (cm)		
A	69.5 a	101.2 a	105.7
B	55.1 b	79.9 b	-
MEAN	63.9	93.0	-
S.E.	2.4	2.7	-
	OAT TILLER NUMBER (#/m^2)		
A	311 a	492 a	555
B	113 b	289 b	-
MEAN	235	414	-
S.E.	21	17	-

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

higher weed yields during the establishment year of Trial B (see 3.13).

3.13 Growth of Weeds During the Establishment Year

Analysis of variance for weed dry matter yield over the two trials indicated significant (P = 0.05) main effects for trial and agronomic practice during most sampling dates, while effects of crop species were not significant (Table 10). Therefore, data and analyses are presented by trial. Analysis of variance also indicated significant interaction effects for trial X agronomic practice, while trial X crop species, crop species X agronomic practice and trial X crop species X agronomic practice interaction effects were not significant.

Weed yields were significantly lower in Trial A than B during the July (207 and 1403 kg/ha, respectively) and August (798 and 1808 kg/ha, respectively) sampling dates (Table 11). Differences in weed dry matter yield between the two trials can be partly attributed to an ineffective weed control program on the Trial B area prior to plot establishment.

3.14 Light Penetration During the Establishment Year

Analysis of variance for light penetration to ground and grass level over the two trials indicated significant (P = 0.05) main effects for trial and agronomic practice during at least one sampling date, while effects for crop species

TABLE 10. ANALYSIS OF VARIANCE FOR WEED DRY MATTER YIELD (kg/ha) OVER TRIAL A (1986) AND B (1987)

SOURCE OF VARIATION	DF	MEAN SQUARE (X 100) JULY HARVEST	AUGUST HARVEST	SEPTEMBER HARVEST
Trial (T)	1	528093 *	376759 *	58645 ns
Error a (Rep(T))	11	1464	4540	25445
Crop (C)	2	301 ns	2681 ns	4647 ns
Crop x Trial	2	871 ns	5920 ns	27160 ns
Error b (C x Rep(T))	22	4097	10612	11472
Practice (P)	3	77297 *	276425 *	617210 *
Practice x Trial	3(2)	79275 *	75241 *	1364 ns
Practice x Crop	6	881 ns	2617 ns	13147 ns
Practice x Trial x Crop	6(4)	468 ns	1198 ns	6604 ns
Residual Error c	99(87)	1308	8920	17085
Total	155(140)			

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom (September harvest in brackets).

TABLE 11. WEED DRY MATTER YIELD IN RELATION TO TRIAL A AND B

TRIAL	WEED DRY MATTER YIELD (kg/ha)		
	JULY	AUGUST	SEPTEMBER
A	207 b*	798 b	886 a
B	1403 a	1808 a	1432 a
MEAN	667	1187	1060
S.E.	49	87	238

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

were not significant (Table 12 and 13). Therefore, data and analyses are presented by trial. Analysis of variance also indicated significant interaction effects for trial X agronomic practice, while trial X crop species, crop species X agronomic practice, and trial X crop species X agronomic practice interaction effects were not significant.

Light penetration to ground level was significantly higher in Trial A than B during the August (214 and 83 $uM/m^2/s$, respectively) sampling date (Table 14). The difference in light penetration to ground level can be partly attributed to increased weed growth during 1987 of Trial B (see 3.13). The analysis of variance over both trials for light reception above the oat canopy has been shown in Appendix B to illustrate consistency of light reception across all plots during each sampling date (Table B-1).

3.15 Soil Water Content During the Establishment Year

Analysis of variance for fall soil water content over the two trials indicated significant (P = 0.05) main effects for trial at both sample depths, while effects for crop species and agronomic practice were not significant (Table 15). Therefore, data and analyses are presented by trial. Analysis of variance also indicated significant interaction effects for trial X crop species, while trial X agronomic practice, crop species X agronomic practice, and trial X crop species X agronomic practice interaction effects were not significant.

TABLE 12. ANALYSIS OF VARIANCE FOR LIGHT PENETRATION ($uM/m^2/s$) TO GROUND LEVEL OVER TRIAL A (1986) AND B (1987)

SOURCE OF VARIATION	DF	MEAN SQUARE (X 100)	
		AUGUST HARVEST	SEPTEMBER HARVEST
Trial (T)	1	32 ns	2418 *
Error a (Rep(T))	11	223	284
Crop (C)	2	277 ns	117 ns
Crop x Trial	2	376 ns	68 ns
Error b (C x Rep(T))	22	229	60
Practice (P)	3	25695 *	7982 *
Practice x Trial	3(2)	3022 *	3364 *
Practice x Crop	6	76 ns	28 ns
Practice x Trial x Crop	6(4)	330 ns	14 ns
Residual Error	99(87)	179	129
Total	155(140)		

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom (September harvest in brackets).

No July measurements in Trial B.

TABLE 13. ANALYSIS OF VARIANCE FOR LIGHT PENETRATION ($uM/m^2/s$) TO GRASS LEVEL OVER TRIAL A (1986) AND B (1987)

SOURCE OF VARIATION	DF	MEAN SQUARE (X 100) AUGUST HARVEST	MEAN SQUARE (X 100) SEPTEMBER HARVEST
Trial (T)	1	52 ns	1 ns
Error a (Rep(T))	11	773	2902
Crop (C)	2	199 ns	233 ns
Crop x Trial	2	71 ns	162 ns
Error b (C x Rep(T))	22	121	147
Practice (P)	3	67568 *	16462 *
Practice x Trial	3(2)	16834 *	14407 *
Practice x Crop	6	163 ns	37 ns
Practice x Trial x Crop	6(4)	130 ns	80 ns
Residual Error c	99(87)	130	82
Total	155(140)		

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom (September harvest in brackets).

No July measurements in Trial B.

TABLE 14. LIGHT RECEPTION AT GROUND AND GRASS LEVEL IN RELATION TO TRIAL A AND B

TRIAL	PHOTOSYNTHETIC PHOTON FLUX DENSITY ($uM/m^2/s$)		
	JULY	AUGUST	SEPTEMBER
	---------LIGHT RECEPTION AT GROUND LEVEL---------		
A	576 (46%)	274 a*(23%)	214 a (24%)
B	-	283 a (18%)	83 b (7%)
MEAN	-	278 (21%)	173 (18%)
S.E.	-	19	25
	---------LIGHT RECEPTION AT GRASS LEVEL---------		
A	851 (68%)	981 a (82%)	798 a (91%)
B	-	969 a (63%)	788 a (68%)
MEAN	-	977 (73%)	795 (82%)
S.E.		36	80

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

Percentage of total incoming radiation shown in brackets.

TABLE 15. ANALYSIS OF VARIANCE FOR FALL SOIL WATER CONTENT (%) OVER TRIAL A (1986) AND B (1987)

SOURCE OF VARIATION	DF	MEAN SQUARE 0-15 cm DEPTH	MEAN SQUARE 15-30 cm DEPTH
Trial (T)	1	13403 *	3787 *
Error a (Rep(T))	11	11	16
Crop (C)	2	34 ns	9 ns
Crop x Trial	2	17 ns	22 *
Error b (C x Rep(T))	22	17	6
Practice (P)	3	7 ns	5 ns
Practice x Trial	2	4 ns	6 ns
Practice x Crop	6	3 ns	1 ns
Practice x Trial x Crop	4	6 ns	6 ns
Residual Error c	87	5	5
Total	140		

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom.

Trial B has only 3 practices.

Fall soil water content was significantly higher in Trial A than B at the 0-15 cm (32.7 and 10.6%, respectively) and 15-30 cm (24.1 and 12.5%, respectively) sampling depths (Table 16). Differences in soil water content between trials can be partly attributed to lower precipitation (Table 1) and increased weed growth during 1987 (Trial B).

3.16 Forage Dry Matter Yield During the Second Year

Analysis of variance for second year forage dry matter yield over the two trials indicated significant (P = 0.05) main effects for trial, crop species and agronomic practice during the individual and/or combined harvests (Table 17). Therefore, data and analyses are presented by trial. Analysis of variance also indicated significant interaction effects for trial X agronomic practice, while trial X crop species, crop species X agronomic practice, and trial X crop species X agronomic practice interaction effects were not significant.

Forage yields in the second year were significantly higher in Trial A than B during the July harvest (4910 and 2982 kg/ha, respectively) and combined harvest total (7380 and 5317 kg/ha, respectively) (Table 18). Differences in forage yield during the second year can be partly attributed to improved establishment and growth of grasses in 1987 of Trial A.

TABLE 16. FALL SOIL WATER CONTENT
IN RELATION TO TRIAL A AND B

TRIAL	SOIL WATER CONTENT (%)	
	0-15 cm DEPTH	15-30 cm DEPTH
A	32.7 a*	24.1 a
B	10.6 b	12.5 b
MEAN	25.6	20.4
S.E.	0.5	0.6

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE 17. ANALYSIS OF VARIANCE FOR SECOND YEAR FORAGE PRODUCTIVITY (kg/ha) OVER TRIAL A (1987) AND B (1988)

SOURCE OF VARIATION	DF	MEAN SQUARE (x 10000)		
		JUNE HARVEST	AUGUST HARVEST	COMBINED TOTAL
Trial (T)	1	14846 *	87 ns	17196 *
Error a (Rep(T))	11	407	316	1232
Crop (C)	2	1221 *	147 ns	1860 ns
Crop x Trial	2	126 ns	86 ns	101 ns
Error b (C x Rep(T))	22	169	174	587
Practice (P)	3	4049 *	354 *	6468 *
Practice x Trial	2	805 *	98 ns	1189 *
Practice x Crop	6	94 ns	99 ns	364 ns
Practice x Trial x Crop	4	134 ns	43 ns	265 ns
Residual Error c	87	70	62	179
Total	140			

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom.

Trial B has only 3 practices.

TABLE 18. FORAGE YIELD IN THE SECOND YEAR IN RELATION TO TRIAL A AND B

TRIAL	FORAGE DRY MATTER YIELD (kg/ha)		
	JULY HARVEST	AUGUST HARVEST	COMBINED TOTAL
A	4910 a*	2470 a	7380 a
B	2982 b	2335 a	5317 b
MEAN	4295	2426	6721
S.E.	301	265	523

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

3.2 ANALYSIS OF VARIANCE FOR INDIVIDUAL TRIALS

A separate analysis of variance (ANOVA) was completed on each of the two trials (Trial A and B) for grass and oat characteristics (dry matter yield, tiller height, tiller number and leaf area index), weed dry matter yield, light reception (above ground level, above grass level), soil water content, and forage yield in the second year. The analyses indicated significant ($P = 0.05$) main effects within each of the two trials due to crop species and agronomic practice during the three sampling dates. Therefore, differences in measured parameters among crop species or agronomic practices are presented separately. Differences among crop species or agronomic practices for the analysis of variance over both trials are also presented.

For Trial A, analysis of variance indicated significant crop species X agronomic practice interaction effects for grass yield, tiller number and leaf area index, light penetration to ground level, and light penetration to grass level during the August sampling date; as well as grass yield, height, and leaf area index during the September sampling date.

For Trial B, analysis of variance indicated no significant crop species X agronomic practice interaction effects during any sampling date, except for grass height during September.

3.21 THE THREE CROP SPECIES

.1 Growth of Grasses During the Establishment Year

For Trial A, emergence of grass tillers was first observed on 18 June, 1986. The results from Trial A showed that smooth bromegrass had consistently higher yields and greater tiller heights than meadow bromegrass and orchardgrass during the July, August and September sampling dates of the establishment year (Table 19 and 20). Orchardgrass (1928 kg/ha) and meadow bromegrass (1553 kg/ha) yields were 45% and 55% lower, respectively, than smooth bromegrass yield (3492 kg/ha) at the September sampling date. The July to August crop growth rate (grass dry matter yield) was 2346 kg/ha/month for smooth bromegrass, 1475 kg/ha/month for orchardgrass and 731 kg/ha/month for meadow bromegrass during the establishment year (Figure 1). The August to September crop growth rate was 1051 kg/ha/month for smooth bromegrass, 784 kg/ha/month for meadow bromegrass and 404 kg/ha/month for orchardgrass (Figure 1). Yields and tiller heights were not significantly different between meadow bromegrass and orchardgrass at the three sampling dates, except in August when the yield of orchardgrass (1524 kg/ha) was higher than meadow bromegrass (769 kg/ha). Orchardgrass also had consistently higher tiller numbers than smooth bromegrass and meadow bromegrass during the July and August sampling dates of the 1986 establishment year (Table 21). By August, orchardgrass had 29% more tillers (489 $\#/m^2$) than

TABLE 19. GRASS DRY MATTER YIELD IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	GRASS DRY MATTER YIELD (kg/ha)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
MEADOW BROME	38 b*	769 c	1553 b
SMOOTH BROME	95 a	2441 a	3492 a
ORCHARD GRASS	49 b	1524 b	1928 b
MEAN	61	1578	2324
S.E.	11	139	219
	TRIAL B (1987)		
MEADOW BROME	40 a	211 a	855 a
SMOOTH BROME	33 a	201 a	1237 a
ORCHARD GRASS	23 a	163 a	1238 a
MEAN	32	192	1110
S.E.	6	54	149

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE 20. GRASS TILLER HEIGHT IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	GRASS TILLER HEIGHT (cm)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
MEADOW BROME	13.8 b*	48.5 b	55.0 b
SMOOTH BROME	18.2 a	69.6 a	64.6 a
ORCHARD GRASS	12.0 b	51.0 b	53.5 b
MEAN	14.6	56.4	57.7
S.E.	1.1	2.3	1.6
	TRIAL B (1987)		
MEADOW BROME	23.8 a	27.0 a	38.7 a
SMOOTH BROME	21.5 a	24.9 a	36.0 a
ORCHARD GRASS	15.0 b	22.2 a	35.4 a
MEAN	20.1	24.7	36.7
S.E.	1.8	1.4	2.0

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

FIGURE 1 - CROP GROWTH RATE OF GRASS DRY MATTER YIELD DURING TRIAL A (1986)

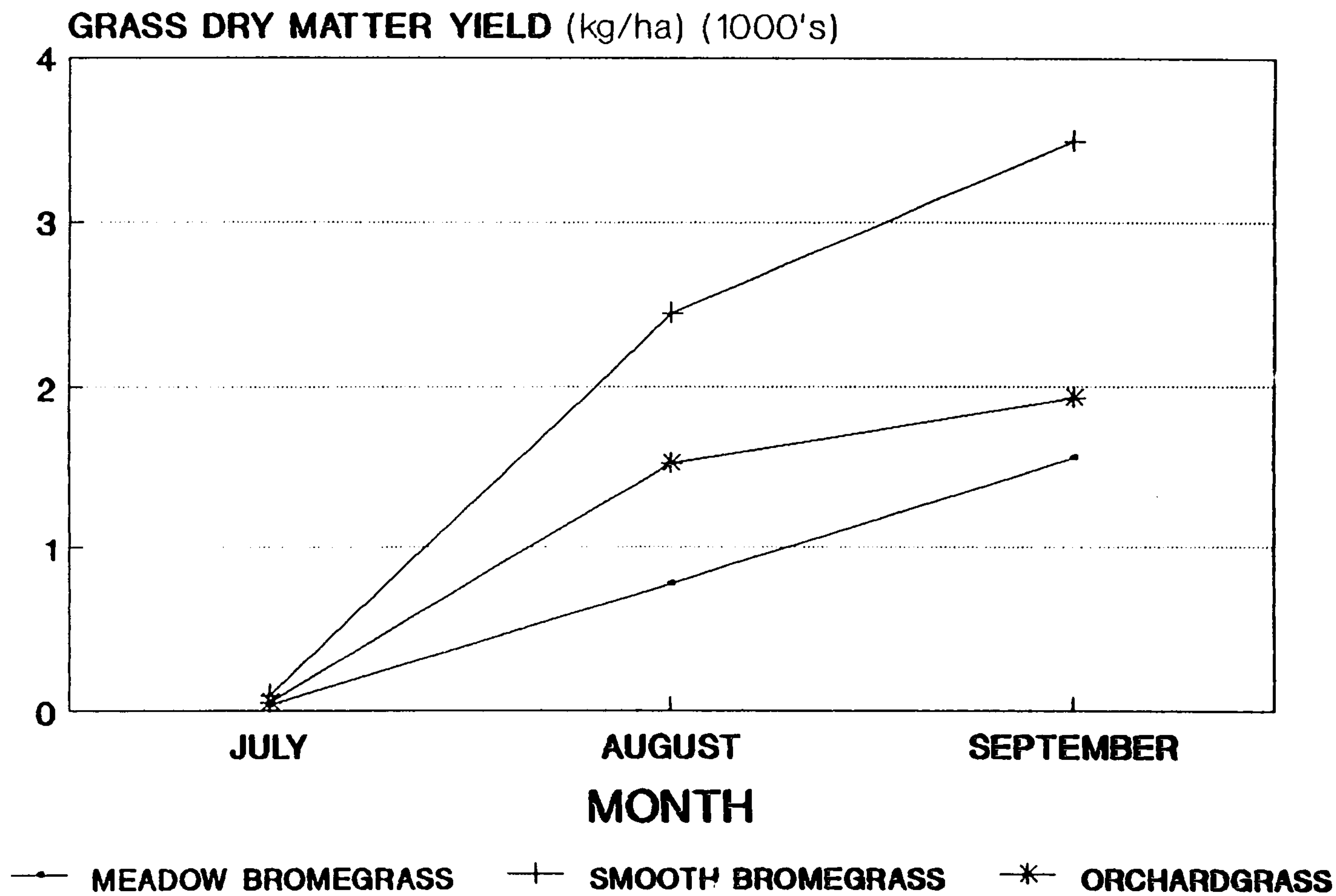


TABLE 21. GRASS TILLER NUMBER IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	GRASS TILLER NUMBER (#/m^2)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
MEADOW BROME	138 b*	296 b	430 a
SMOOTH BROME	169 b	285 b	374 a
ORCHARD GRASS	312 a	489 a	457 a
MEAN	206	356	420
S.E.	18	20	26
	TRIAL B (1987)		
MEADOW BROME	123 a	329 a	470 a
SMOOTH BROME	102 a	243 a	400 a
ORCHARD GRASS	96 a	409 a	586 a
MEAN	107	327	485
S.E.	18	47	56

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

meadow bromegrass (296 #/m^2) and 32% more than smooth bromegrass (285 #/m^2).

Results for the 1986 establishment year of Trial A also showed that meadow bromegrass had a lower leaf area index than smooth bromegrass at all three sampling dates, and a lower leaf area index than orchardgrass in August and September (Table 22). During September, the leaf area index for smooth bromegrass and orchardgrass was 2.18 and 1.88, respectively compared to 0.93 for meadow bromegrass. Leaf area index was not significantly different between orchardgrass and smooth bromegrass during the three sampling dates. Specific leaf weight (leaf weight/leaf area) was significantly higher for meadow bromegrass (11.84 mg/cm^2) than orchardgrass (7.14 mg/cm^2) and smooth bromegrass (5.51 mg/cm^2) during the August sampling date (S.E. = 0.32 ; P = 0.05).

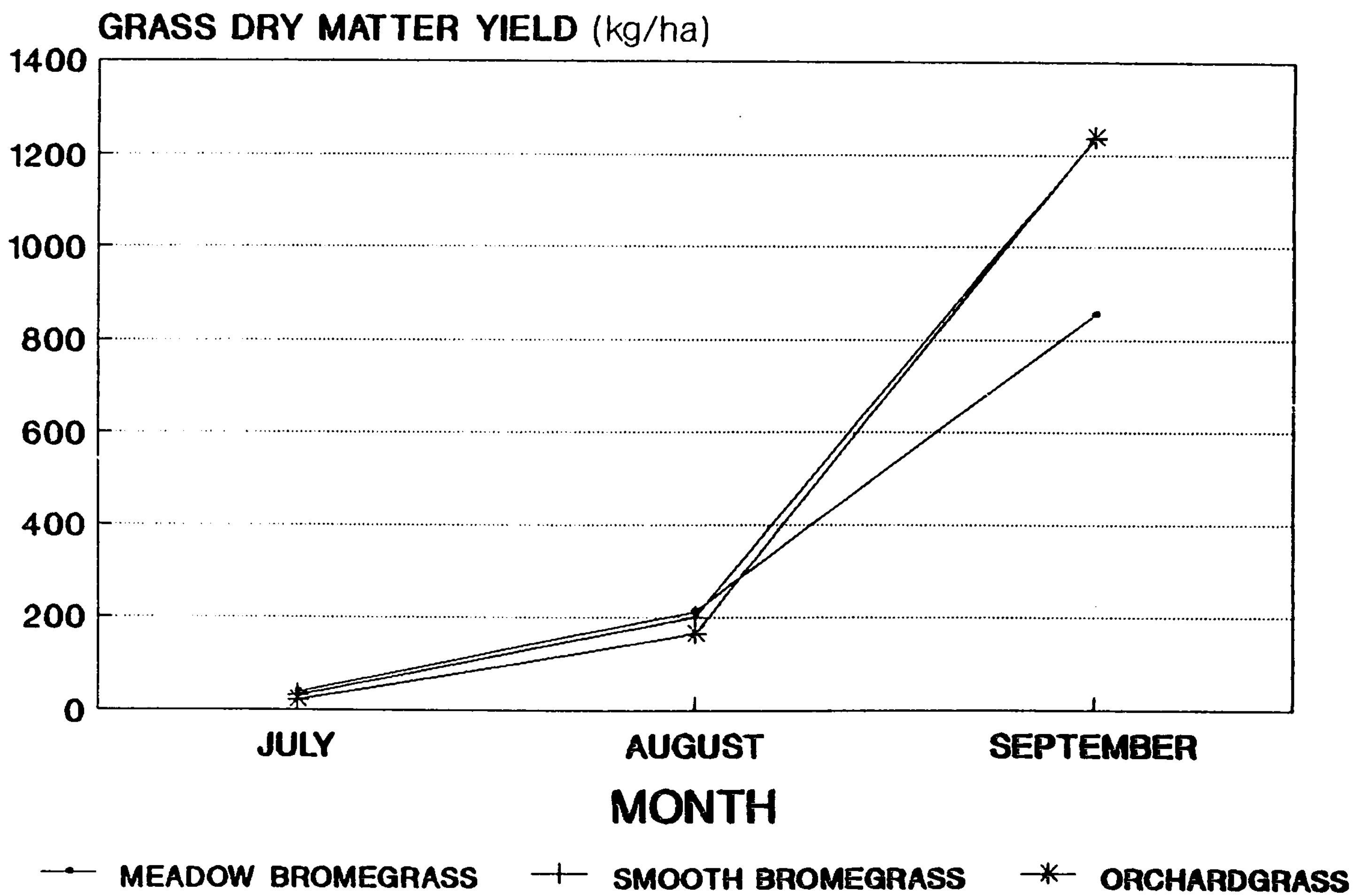
For Trial B, emergence of grass tillers was first observed on 11 June, 1987. The results from Trial B showed that there was no significant difference in grass yield, tiller height and number among the three crop species at any sampling date, except in July when tiller height was lower for orchardgrass (15.0 cm) than meadow bromegrass (23.8 cm) and smooth bromegrass (21.5 cm) (Table 19, 20 and 21). The July to August crop growth rate (grass dry matter yield) was 168 kg/ha/month for smooth bromegrass, 140 kg/ha/month for orchardgrass and 171 kg/ha/month for meadow bromegrass during the establishment year (Figure 2). The August to September crop growth rate was 1075

TABLE 22. GRASS LEAF AREA INDEX IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	GRASS LEAF AREA INDEX (leaf area/ground area)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
MEADOW BROME	0.04 b*	0.66 b	0.93 b
SMOOTH BROME	0.16 a	1.85 a	2.18 a
ORCHARD GRASS	0.09 ab	2.07 a	1.88 a
MEAN	0.10	1.53	1.66
S.E.	0.022	0.147	0.180

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

FIGURE 2 - CROP GROWTH RATE OF GRASS DRY MATTER YIELD DURING TRIAL B (1987)



kg/ha/month for orchardgrass, 1036 kg/ha/month for smooth bromegrass and 644 kg/ha/month for meadow bromegrass (Figure 2).

Over both trials (Table 2), analysis of grass yield measurements at the end of the first growing season showed that smooth bromegrass (2772 kg/ha) was significantly more productive during the establishment year than both orchardgrass (1708 kg/ha) and meadow bromegrass (1331 kg/ha) (S.E. = 153 ; P = 0.05). Grass height (Table 3) was also significantly greater for smooth bromegrass (55.5 cm) compared to both meadow bromegrass (50.0 cm) and orchardgrass (47.7 cm) (S.E. = 1.2 ; P = 0.05). Grass tiller number (Table 4) was significantly higher for orchardgrass (498 #/m^2) than smooth bromegrass (382 #/m^2), but not significantly higher than meadow bromegrass (443 #/m^2) (S.E. = 25 ; P = 0.05).

.2 Growth of Oats During the Establishment Year

For Trial A, emergence of oat tillers was first observed on 10 June, 1986. The crop reached flag leaf stage by 4 July, 1986. Growth characteristics of oats during the 1986 establishment year of Trial A were not significantly different among the three crop species at all sampling dates, except in August when oat tiller number was higher when underseeded with orchardgrass than smooth bromegrass (Table 23, 24 and 25). However, there was no significant difference in oat tiller number when seeded with meadow bromegrass compared to the other two grasses in August.

TABLE 23. OAT DRY MATTER YIELD IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	OAT DRY MATTER YIELD (kg/ha)		
	JULY	AUGUST	SEPTEMBER
		TRIAL A (1986)	
MEADOW BROME	2987 a*	13749 a	14898 a
SMOOTH BROME	2684 a	12652 a	14746 a
ORCHARD GRASS	2981 a	15129 a	14963 a
MEAN	2884	13843	14869
S.E.	269	691	1255
		TRIAL B (1987)	
MEADOW BROME	886 a	5471 a	-
SMOOTH BROME	691 a	6173 a	-
ORCHARD GRASS	720 a	5693 a	-
MEAN	766	5779	-
S.E.	201	715	-

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE 24. OAT TILLER HEIGHT IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	OAT TILLER HEIGHT (cm)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
MEADOW BROME	69.5 a*	98.3 a	103.8 a
SMOOTH BROME	67.3 a	101.6 a	106.4 a
ORCHARD GRASS	71.6 a	103.8 a	106.9 a
MEAN	69.5	101.2	105.7
S.E.	1.6	1.9	1.6
	TRIAL B (1987)		
MEADOW BROME	58.3 a	79.0 a	-
SMOOTH BROME	54.0 a	81.3 a	-
ORCHARD GRASS	53.0 a	79.4 a	-
MEAN	55.1	79.9	-
S.E.	6.0	1.7	-

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE 25. OAT TILLER NUMBER IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	OAT TILLER NUMBER ($\#/m^2$) JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
MEADOW BROME	326 a*	505 ab	529 a
SMOOTH BROME	301 a	429 b	568 a
ORCHARD GRASS	305 a	542 a	568 a
MEAN	311	492	555
S.E.	24	28	48
	TRIAL B (1987)		
MEADOW BROME	133 a	256 a	-
SMOOTH BROME	112 a	319 a	-
ORCHARD GRASS	93 a	292 a	-
MEAN	113	289	-
S.E.	19	37	-

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

Oat leaf area index during the 1986 establishment year of Trial A was not significantly different among the three crop species at all sampling dates (Table 26).

For Trial B, emergence of oat tillers was first observed on 4 June, 1987. Growth characteristics of oats during the 1987 establishment year of Trial B were not significantly different among the three crop species at the July and August sampling dates (Table 23, 24 and 25).

Over both trials (Table 6, 7 and 8), there was no significant difference in oat dry matter yield, tiller height and number among crop species during any sampling date.

.3 Growth of Weeds During the Establishment Year

Weed yields during the 1986 establishment year of Trial A were not significantly different among the three crop species at all sampling dates (Table 27). Weed species observed during the establishment year included stinkweed (Thlaspi arvense L.), lamb's-quarters (Chenopodium album L.), field horsetail (Equisetum arvense L.), Canada thistle (Cirsium arvense (L.) Scop.), tartary buckwheat (Fagopyrum tataricum (L.) Gaertn.), ball mustard (Neslia paniculata (L.) Desv.), dandelion (Taraxacum officinale Web.), shepard's-purse (Capsella bursa-pastoris (L.) Medic.), night-flowering catchfly (Silene noctiflora), hemp-nettle (Galeopsis tetrahit L.), broad-leaved plantain (Plantago major L.), perennial sow-thistle (Sonchus

TABLE 26. OAT LEAF AREA INDEX IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	OAT LEAF AREA INDEX (leaf area/ground area)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
MEADOW BROME	1.35 a*	1.26 a	-
SMOOTH BROME	1.11 a	1.21 a	-
ORCHARD GRASS	1.25 a	1.22 a	-
MEAN	1.24	1.23	-
S.E.	0.100	0.102	-

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE 27. WEED DRY MATTER YIELD IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	WEED DRY MATTER YIELD (kg/ha)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
MEADOW BROME	157 a*	982 a	1256 a
SMOOTH BROME	200 a	769 a	743 a
ORCHARD GRASS	263 a	645 a	659 a
MEAN	207	798	886
S.E.	51	220	235
	TRIAL B (1987)		
MEADOW BROME	1398 a	1740 a	1272 b
SMOOTH BROME	1449 a	1882 a	1623 a
ORCHARD GRASS	1362 a	1803 a	1400 b
MEAN	1403	1808	1432
S.E.	221	103	62

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

arvensis L.), scentless camomile (Matricaria maritima L.), and narrow-leaved hawk's-beard (Crepis tectorum L.).

Similarily, weed yields during the 1987 establishment year of Trial B were not significantly different among the three crop species at the July and August sampling dates (Table 27). However, weed yields were higher in association with smooth bromegrass, which appeared to have a more open canopy, at the September sampling date. Weed species observed during the establishment year included stinkweed, lamb's-quarters, ball mustard, tartary buckwheat, broad-leaved plantain, shepard's-purse, bluebur (Lappula echinata Gilib.), chickweed (Stellaria media (L.) Cyrill.) and prostrate knotweed (Polygonum aviculare L.).

Over both trials (Table 10), there was no significant difference in weed dry matter yield among crop species during any sampling date.

.4 Light Penetration to Ground Level During the Establishment Year

Results from Trial A showed that light penetration (PPFD) to ground level was significantly higher in meadow bromegrass than smooth bromegrass and orchardgrass during the July, August and September sampling dates (Table 28). There was no significant difference in light penetration to ground level between smooth bromegrass and orchardgrass. During August, meadow bromegrass allowed 19% of the total incoming radiation to pass through to

TABLE 28. LIGHT PENETRATION TO GROUND LEVEL IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	PHOTOSYNTHETIC PHOTON FLUX DENSITY ($uM/m^2/s$)		
	JULY	AUGUST	SEPTEMBER
		TRIAL A (1986)	
MEADOW BROME	957 a*(77%)	227 a (19%)	56 a (6%)
SMOOTH BROME	724 b (58%)	76 b (6%)	19 b (2%)
ORCHARD GRASS	842ab (67%)	54 b (4%)	8 b (1%)
MEAN	841 (67%)	119 (10%)	28 (3%)
S.E.	60	37	7
		TRIAL B (1987)	
MEADOW BROME	-	222 a (14%)	43 a (4%)
SMOOTH BROME	-	254 a (17%)	33 a (3%)
ORCHARD GRASS	-	244 a (16%)	55 a (5%)
MEAN	-	240 (16%)	44 (4%)
S.E.	-	82	21

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

Percentage of total incoming radiation shown in brackets.

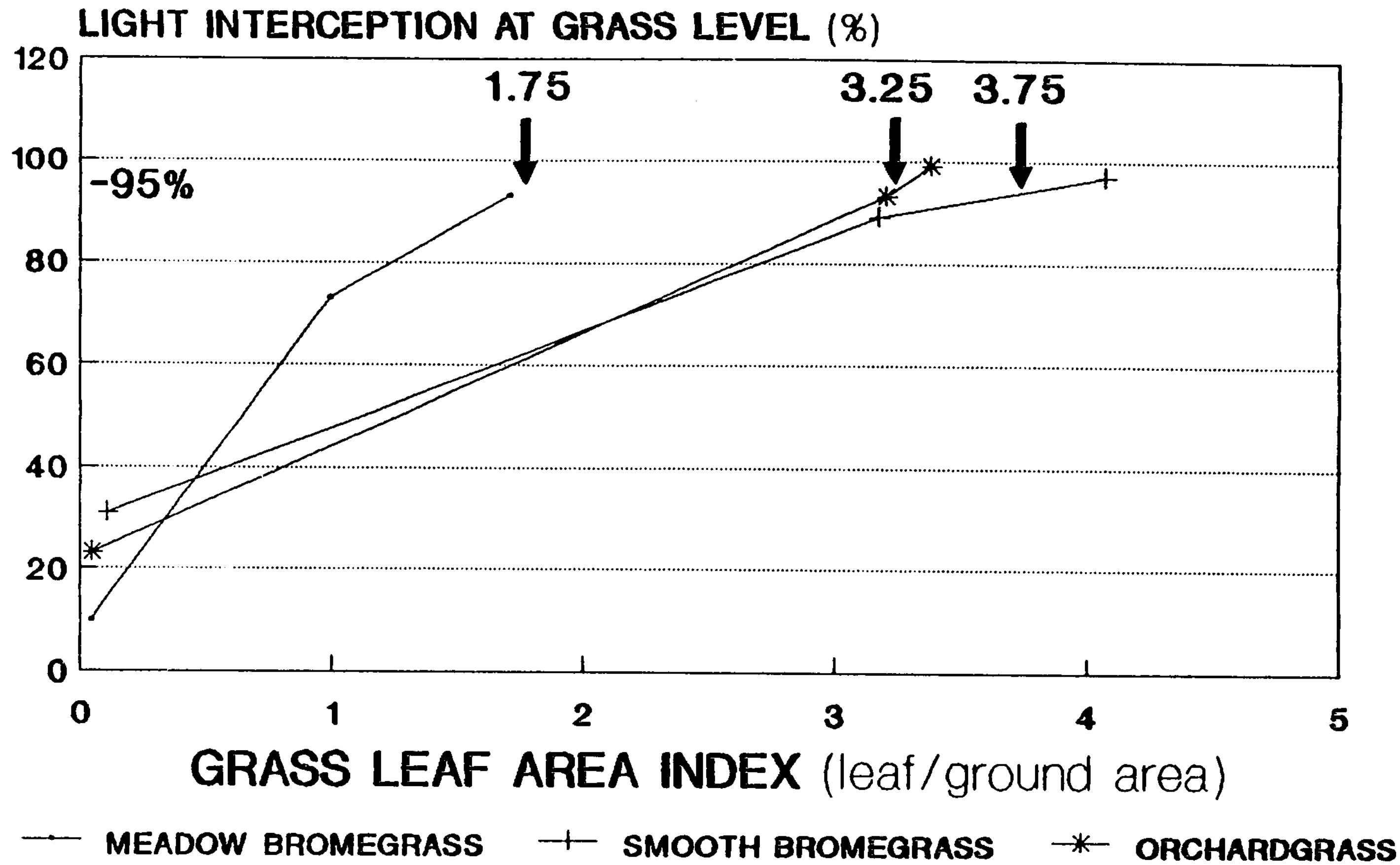
Data from plots without companion crop (grass-only).

ground level, compared to 6% for smooth bromegrass and 4% for orchardgrass. Light penetration ranged from 58 to 77% of total incoming radiation in July, then decreased to 4 to 19% in August and 1 to 6% in September as the grass canopy filled in. Total incoming radiation averaged 1246, 1201 and 879 $uM/m^2/s$ in July, August and September, respectively (Appendix B, Table B-2). Data from the grass-only plots were used in this analysis. The critical leaf area index (95% light interception by the crop canopy) for each grass species was determined to be approximately 1.75 for meadow bromegrass, 3.25 for orchardgrass and 3.75 for smooth bromegrass during Trial A, based on data from the grass plus herbicide plots (Figure 3).

Results from Trial B showed light penetration to ground level was not significantly different among the three crop species during the August and September sampling dates. Light penetration ranged from 14 to 17% of total incoming radiation in August and decreased to 3 to 5% in September as the grass canopy filled in. Total incoming radiation averaged 1535 and 1154 $uM/m^2/s$ in August and September, respectively (Appendix B, Table B-2).

Over both trials (Table 12), there was no significant difference in light penetration to ground level among crop species during any sampling date.

FIGURE 3 - ESTIMATION OF CRITICAL LEAF AREA INDEX FOR EACH GRASS SPECIES DURING TRIAL A (1986)



.5 Light Penetration to Grass Level During the Establishment Year

The results from Trial A showed that light penetration (PPFD) through the oat canopy to grass level was not significantly different among the three crop species at all sampling dates (Table 29). Light penetration to grass level ranged from 67 to 70% of total incoming radiation in July, then increased to 79 to 85% in August and 89 to 92% in September as oat leaves senesced and grasses grew taller. Total incoming radiation averaged 1246, 1201 and 879 uM/m^2/s in July, August and September, respectively (Appendix B, Table B-2).

The results from Trial B showed that light penetration (PPFD) through the oat canopy to grass level was not significantly different among grass species during the August and September sampling dates (Table 29). Light penetration to grass level ranged from 62 to 65% of total incoming radiation in August and 64 to 70% in September. Total incoming radiation averaged 1535 and 1154 uM/m^2/s in August and September, respectively (Appendix B, Table B-2).

Over both trials (Table 13), there was no significant difference in light penetration to grass level among crop species during any sampling date.

TABLE 29. LIGHT PENETRATION TO GRASS LEVEL IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	PHOTOSYNTHETIC PHOTON FLUX DENSITY ($uM/m^2/s$)		
	JULY	AUGUST	SEPTEMBER
		TRIAL A (1986)	
MEADOW BROME	837 a*(68%)	955 a (79%)	796 a (89%)
SMOOTH BROME	836 a (67%)	1009 a (85%)	788 a (92%)
ORCHARD GRASS	880 a (70%)	980 a (81%)	810 a (91%)
MEAN	851 (68%)	981 (82%)	798 (91%)
S.E.	31	21	17
		TRIAL B (1987)	
MEADOW BROME	-	970 a (63%)	729 a (64%)
SMOOTH BROME	-	987 a (65%)	816 a (70%)
ORCHARD GRASS	-	951 a (62%)	818 a (70%)
MEAN	-	969 (63%)	788 (68%)
S.E.	-	22	40

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

Percentage of total incoming radiation shown in brackets.

.6 Fall Soil Water Content During the Establishment Year

Measurements of fall soil water content during the establishment year of Trial A and B showed no significant difference among the three crop species at 0-15 and 15-30 cm sample depths (Table 30).

Over both trials (Table 15), there was no significant difference in soil water content among crop species at either sampling depth.

.7 Forage Growth During the Second Year

Results from Trial A showed that smooth bromegrass (5707 kg/ha) was significantly more productive in the second year than meadow bromegrass (4660 kg/ha) and orchardgrass (4365 kg/ha) for the first harvest (late-June) of 1987 (Table 31). There was no significant difference in second year forage yields among the three crop species for the second harvest (late-August) of 1987. Although not statistically significant, meadow bromegrass appeared to have the best regrowth after defoliation in the second year. The total combined yield for both harvests showed that smooth bromegrass (8179 kg/ha) was 20% more productive in the second year than orchardgrass (6515 kg/ha), but was not significantly more productive than meadow bromegrass (7446 kg/ha). There was no significant difference between the total combined yield for meadow bromegrass and orchardgrass, although meadow bromegrass yields appeared to be somewhat higher.

TABLE 30. FALL SOIL WATER CONTENT IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	SOIL WATER CONTENT (%)	
	0-15 cm	15-30 cm
	TRIAL A (1986)	
MEADOW BROME	32.7 a*	24.5 a
SMOOTH BROME	33.8 a	24.0 a
ORCHARD GRASS	31.6 a	23.6 a
MEAN	32.7	24.1
S.E.	0.8	0.4
	TRIAL B (1987)	
MEADOW BROME	9.4 a	11.4 a
SMOOTH BROME	11.6 a	13.7 a
ORCHARD GRASS	10.9 a	12.5 a
MEAN	10.6	12.5
S.E.	1.0	0.7

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE 31. SECOND YEAR FORAGE YIELDS IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	FORAGE DRY MATTER YIELD (kg/ha)		
	JUNE HARVEST	AUGUST HARVEST	COMBINED TOTAL
	TRIAL A (1987)		
MEADOW BROME	4660 b*	2786 a	7446 a
SMOOTH BROME	5707 a	2472 a	8179 a
ORCHARD GRASS	4365 b	2150 a	6515 a
MEAN	4910	2469	7380
S.E.	254	249	463
	TRIAL B (1988)		
MEADOW BROME	3086 a	2297 a	5383 a
SMOOTH BROME	3292 a	2436 a	5728 a
ORCHARD GRASS	2568 a	2271 a	4839 a
MEAN	2982	2335	5317
S.E.	261	296	526

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

The results from Trial B showed no significant differences in yield among the three crop species for the first harvest, second harvest or total combined yield in 1988 (Table 31).

Over both trials (Table 17), forage yield in the second year was significantly higher for smooth bromegrass (4936 kg/ha) than meadow bromegrass (4157 kg/ha) and orchardgrass (3791 kg/ha) during the July harvest (S.E. = 189 ; P = 0.05). However, analysis of the August harvest and combined forage yields showed no significant differences among crop species during the second growing season.

3.22 THE FOUR AGRONOMIC PRACTICES

.1 Growth of Grasses During the Establishment Year

The results from Trial A showed that grass yields and tiller numbers were not significantly different among the four agronomic practices during July of the 1986 establishment year (Table 32, 33 and 34). However, tiller height was greater for grasses seeded with a companion crop to be removed as greenfeed (16.1 cm) or grain (15.8 cm) than when seeded alone with (12.6 cm) or without (14.0 cm) herbicide. In August and September, grasses had the greatest tiller height when seeded alone and without a herbicide application. Grass species seeded alone and treated with herbicide had higher yields and tiller numbers during the August and September sampling dates of the establishment year than when seeded with an oat companion crop. By the end of the first growing season, grass yields were 76 and 91% lower when seeded with a companion crop removed as greenfeed (337 kg/ha) or grain (903 kg/ha), respectively, compared to the grass-only control without herbicide (3801 kg/ha), while grass yields were 11% higher than the control when seeded alone with herbicide (4257 kg/ha). The association between oats, underseeded grasses and weed growth during Trial A has been shown in Plate 1. Tiller height of grasses observed during September was lowest (34.0 cm) when the oat companion crop had been removed in August as greenfeed. Plate 2 shows reduced growth of grasses seeded with an oat companion crop harvested as greenfeed compared to growth

TABLE 32. GRASS DRY MATTER YIELD IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	GRASS DRY MATTER YIELD (kg/ha)		
	JULY	AUGUST	SEPTEMBER
		TRIAL A (1986)	
CONTROL (NO OATS)	71 a*	2444 a	3801 a
HERBICIDE (NO OATS)	45 a	2634 a	4257 a
GREENFEED (OATS)	65 a	579 b	337 b
GRAIN (OATS)	62 a	656 b	903 b
MEAN	61	1578	2324
S.E.	12	170	269
		TRIAL B (1987)	
CONTROL (NO OATS)	28 a	134 b	771 b
HERBICIDE (NO OATS)	39 a	470 a	2135 a
GREENFEED (OATS)	23 a	99 b	425 c
GRAIN (OATS)	39 a	65 b	-
MEAN	32	192	1110
S.E.	7	53	115

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE 33. GRASS TILLER HEIGHT IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	GRASS TILLER HEIGHT (cm)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
CONTROL (NO OATS)	14.0 bc*	67.6 a	74.8 a
HERBICIDE (NO OATS)	12.6 c	51.8 b	60.8 b
GREENFEED (OATS)	16.1 a	52.3 b	34.0 c
GRAIN (OATS)	15.8 ab	53.8 b	61.1 b
MEAN	14.6	56.4	57.7
S.E.	0.7	2.3	1.9
	TRIAL B (1987)		
CONTROL (NO OATS)	19.9 ab	25.6 b	32.0 b
HERBICIDE (NO OATS)	15.7 b	30.1 a	50.7 a
GREENFEED (OATS)	21.8 a	23.2 bc	27.5 c
GRAIN (OATS)	22.9 a	19.7 c	-
MEAN	20.1	24.7	36.7
S.E.	1.6	1.2	1.3

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test)

TABLE 34. GRASS TILLER NUMBER IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	GRASS TILLER NUMBER (#/m^2)		
	JULY	AUGUST	SEPTEMBER
		TRIAL A (1986)	
CONTROL (NO OATS)	223 a*	469 b	565 b
HERBICIDE (NO OATS)	200 a	590 a	678 a
GREENFEED (OATS)	205 a	167 c	216 c
GRAIN (OATS)	197 a	200 c	223 c
MEAN	206	356	420
S.E.	18	23	31
		TRIAL B (1987)	
CONTROL (NO OATS)	88 b	287 b	442 b
HERBICIDE (NO OATS)	145 a	520 a	713 a
GREENFEED (OATS)	82 b	248 b	301 c
GRAIN (OATS)	113 ab	254 b	-
MEAN	107	327	485
S.E.	14	41	36

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

PLATE 1. THE OAT COMPANION CROP (30 cm ROW SPACING) SIGNIFICANTLY REDUCED LIGHT PENETRATION TO UNDERSEEDED GRASSES AND WEEDS DURING THE ESTABLISHMENT YEAR

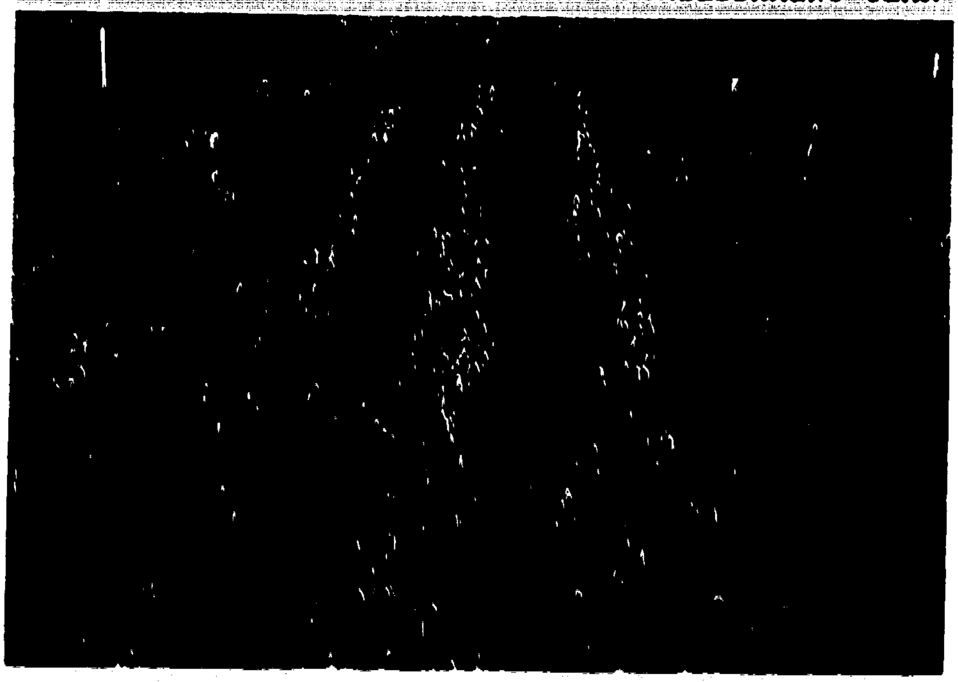
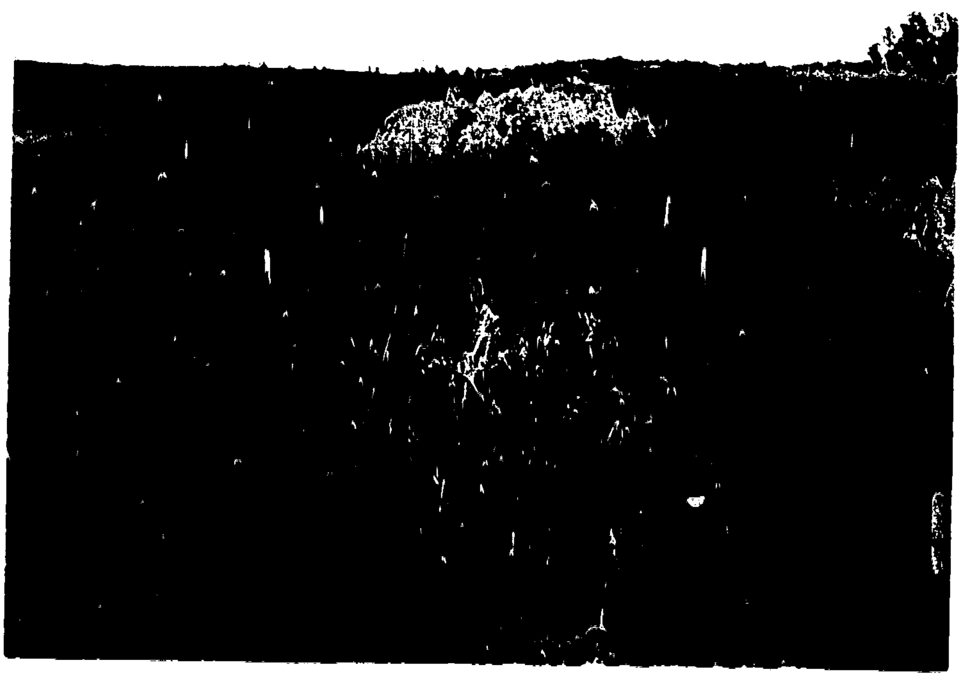


PLATE 2. GROWTH OF GRASSES WAS SIGNIFICANTLY REDUCED WHEN ESTABLISHED WITH AN OAT COMPANION CROP HARVESTED AS GREENFEED COMPARED TO GROWTH ON THE ADJACENT PLOT (LEFT) ESTABLISHED WITHOUT A COMPANION CROP.



of grasses seeded without the companion crop. Although the oat crop was removed at a height of 25 cm, it appears that grass material was cut at the same time (by comparison, grass height in grain companion crop averaged 61.1 cm).

Results from the 1986 establishment year of Trial A showed that grass leaf area index was not significantly different between the four agronomic practices at the July sampling date (Table 35). Grass species had a lower leaf area index during the August and September sampling dates when seeded with a oat companion crop compared to the grass-only control. At the end of the first growing season, the leaf area index of grasses seeded alone in combination with (2.99) or without (2.82) herbicide was more than four times higher than when seeded with a companion crop removed as greenfeed (0.22) or grain (0.62).

The results from Trial B showed that grass yield and tiller height in July was not significantly different among agronomic practices, but tiller height was generally greater when grass species were seeded with a companion crop than when seeded alone (Table 32, 33 and 34). In August and September, grass yields, tiller numbers and heights were higher when treated with a herbicide application than the grass-only control. Grasses seeded alone with or without herbicide had higher yields, tiller numbers and tiller heights during the September sampling date than when seeded with a companion crop. By the end

TABLE 35. GRASS LEAF AREA INDEX IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	GRASS LEAF AREA INDEX (leaf area/ground area)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
CONTROL (NO OATS)	0.13 a*	2.39 a	2.82 a
HERBICIDE (NO OATS)	0.06 a	2.51 a	2.99 a
GREENFEED (OATS)	0.09 a	0.56 b	0.22 b
GRAIN (OATS)	0.11 a	0.65 b	0.62 b
MEAN	0.10	1.53	1.66
S.E.	0.027	0.152	0.180

* Means in the same column (within subtables) followed by the same letter are not significantly different at $P=0.05$ (Duncan's multiple range test).

of the first growing season, grass yields were 64% higher when seeded alone in combination with herbicide (2135 kg/ha) than the grass-only control (771 kg/ha), and 45% lower when seeded with a companion crop (425 kg/ha).

Over both trials (Table 2), analysis of grass yields at the end of the first growing season (September) showed that grasses seeded alone in combination with herbicide (3441 kg/ha) had significantly higher yields than grasses seeded alone without herbicide (2635 kg/ha), while grasses seeded with an oat companion crop removed as greenfeed (370 kg/ha) had the lowest yield (S.E. = 234 ; P = 0.05). Grass tiller height (Table 3) was not significantly different when seeded alone with (56.9 cm) or without (58.4 cm) herbicide, but was significantly shorter when the oat companion crop was removed as greenfeed (31.5 cm) (S.E. = 1.3 ; P = 0.05). Grass tiller number (Table 4) was significantly highest when seeded alone with herbicide (691 $\#/m^2$), while tiller number was higher for grasses seeded alone without herbicide (518 $\#/m^2$) than with an oat companion crop removed as greenfeed (249 $\#/m^2$) (S.E. = 24 ; P = 0.05).

.2 Growth of Oats During the Establishment Year

Growth characteristics of oats during the 1986 establishment year of Trial A were not significantly different between the two companion crop agronomic practices at all sampling dates (Table 36, 37 and 38).

TABLE 36. OAT DRY MATTER YIELD IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	OAT DRY MATTER YIELD (kg/ha)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
GREENFEED (OATS)	3047 a*	13805 a	-
GRAIN (OATS)	2721 a	13881 a	14870
MEAN	2884	13843	-
S.E.	179	794	-
	TRIAL B (1987)		
GREENFEED (OATS)	719 a	6335 a	-
GRAIN (OATS)	813 a	5223 a	-
MEAN	766	5779	-
S.E.	61	450	-

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE 37. OAT TILLER HEIGHT IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	OAT TILLER HEIGHT (cm)		
	JULY	AUGUST	SEPTEMBER
		TRIAL A (1986)	
GREENFEED (OATS)	69.7 a*	101.0 a	-
GRAIN (OATS)	69.3 a	101.5 a	105.7
MEAN	69.5	101.2	-
S.E.	1.2	1.1	-
		TRIAL B (1987)	
GREENFEED (OATS)	56.1 a	80.5 a	-
GRAIN (OATS)	54.1 a	79.3 a	-
MEAN	55.1	79.9	-
S.E.	2.5	0.9	-

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE 38. OAT TILLER NUMBER IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	OAT TILLER NUMBER (#/m^2)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
GREENFEED (OATS)	326 a*	497 a	-
GRAIN (OATS)	296 a	486 a	555
MEAN	311	492	-
S.E.	13	29	-
	TRIAL B (1987)		
GREENFEED (OATS)	110 a	326 a	-
GRAIN (OATS)	115 a	252 a	-
MEAN	113	289	-
S.E.	10	25	-

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

Oat leaf area index during the 1986 establishment year of Trial A was not significantly different among the two companion crop agronomic practices at all sampling dates (Table 39).

Growth characteristics of oats during the 1987 establishment year of Trial B were not significantly different between the two companion crop agronomic practices at the July and August sampling dates (Table 36, 37 and 38).

Over both trials (Table 6, 7 and 8), there was no significant difference in oat dry matter yield, tiller height and tiller number among the agronomic practices containing oats during any sampling date.

.3 Growth of Weeds During the Establishment Year

The results from Trial A showed that weed yields were not significantly different among the four agronomic practices at the July sampling date, but were suppressed by the companion crop and herbicide application during the August and September sampling dates of the 1986 establishment year compared to the grass-only control (Table 40). In August, weed yields were about 75% lower with a companion crop to be removed as greenfeed (506 kg/ha) or grain (557 kg/ha) compared to the grass-only control (1978 kg/ha), but were 92% lower than the control when treated with herbicide (153 kg/ha). Weed yield was not significantly different when grasses were treated with a herbicide than

TABLE 39. OAT LEAF AREA INDEX IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	OAT LEAF AREA INDEX (leaf area/ground area)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
GREENFEED (OATS)	1.34 a*	1.18 a	-
GRAIN (OATS)	1.13 a	1.28 a	-
MEAN	1.24	1.23	-
S.E.	0.091	0.110	-

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE 40. WEED DRY MATTER YIELD IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	WEED DRY MATTER YIELD (kg/ha)		
	JULY	AUGUST	SEPTEMBER
		TRIAL A (1986)	
CONTROL (NO OATS)	235 a*	1978 a	2770 a
HERBICIDE (NO OATS)	217 a	153 b	138 b
GREENFEED (OATS)	216 a	506 b	8 b
GRAIN (OATS)	160 a	557 b	629 b
MEAN	207	798	886
S.E.	42	236	309
		TRIAL B (1987)	
CONTROL (NO OATS)	1912 a	2499 a	3270 a
HERBICIDE (NO OATS)	23 b	136 c	461 b
GREENFEED (OATS)	1839 a	2242 b	565 b
GRAIN (OATS)	1838 a	2358 ab	-
MEAN	1403	1808	1432
S.E.	138	84	105

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

when seeded with a companion crop, but visual observations indicated that herbicide was more effective in suppressing weed populations. Although not statistically significant, it should be noted that removal of the companion crop as greenfeed (in August) appeared to reduce weed yield during the September sampling date compared to the companion crop to be removed as grain. It was observed that the herbicide treatment resulted in weed leaf chlorosis, stem twisting, epinasty and leaf drying within hours of the application. There were no visible signs of herbicide injury to underlying grass species or adjacent oat seedlings.

The results from Trial B showed that weed yields were suppressed by the companion crop and herbicide application during the July and August sampling dates of the 1987 establishment year compared to the grass-only control (Table 40). In August, weed yields were about 10% lower when seeded with a companion crop removed as greenfeed (2242 kg/ha) or grain (2358 kg/ha) compared to the grass-only control (2499 kg/ha), but were about 95% lower when treated with herbicide (136 kg/ha). Weed yields were lowest in September when grasses were treated with herbicide (461 kg/ha) or seeded with a companion crop removed as greenfeed (565 kg/ha) compared to the grass-only control (3270 kg/ha). There were no visible signs of herbicide injury to underlying grass species or adjacent oat seedlings.

Over both trials (Table 10), analysis of weed yield at the August sampling date showed that the lowest weed yields (146 kg/ha) occurred when grasses were treated with herbicide (S.E. = 151; P = 0.05). Grasses seeded with a companion crop removed as greenfeed (1173 kg/ha) or grain (1250 kg/ha) had significantly lower weed yields than the grass-only control (2178 kg/ha).

.4 Light Penetration to Ground Level During the Establishment Year

The results from the establishment year of Trial A showed that light penetration (PPFD) through the crop canopy to ground level was higher in July when grass species were seeded alone with or without herbicide than with a companion crop (Table 41). The companion crop reduced light penetration in July by about 25% compared to light received at ground level on the grass-only control. Light penetration was 23% higher than the control when grass species were treated with herbicide. During August, light penetration to ground level was 60% higher after the companion crop had been removed as greenfeed compared to the grass-only control. An increase in light penetration to ground level could promote germination of previously dormant grass seeds. The herbicide application increased light penetration to ground level by 10% compared to the grass-only control. Light penetration to ground level was not significantly different between the grass-only control and grasses seeded with a companion crop to be harvested as grain. During September, light penetration to ground

TABLE 41. LIGHT PENETRATION TO GROUND LEVEL IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	PHOTOSYNTHETIC PHOTON FLUX DENSITY ($uM/m^2/s$)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
CONTROL (NO OATS)	697 b*(56%)	56 c (5%)	23 c (3%)
HERBICIDE (NO OATS)	985 a (79%)	181 b (15%)	33 c (4%)
GREENFEED (OATS)	289 c (23%)	787 a (65%)	475 a (53%)
GRAIN (OATS)	335 c (27%)	72 c (6%)	327 b (38%)
MEAN	576 (46%)	274 (23%)	214 (24%)
S.E.	33	22	26
	TRIAL B (1987)		
CONTROL (NO OATS)	-	154 c (10%)	17 c (1%)
HERBICIDE (NO OATS)	-	327 b (21%)	71 b (6%)
GREENFEED (OATS)	-	531 a (35%)	163 a (14%)
GRAIN (OATS)	-	122 c (8%)	-
MEAN	-	283 (18%)	83 (7%)
S.E.	-	43	18

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

Percentage of total incoming radiation shown in brackets.

level was significantly increased after both companion crops had been removed compared to light received by grasses seeded without a companion crop. Total incoming radiation averaged 1246, 1202 and 879 uM/m^2/s in July, August and September, respectively (Appendix B, Table B-3).

The results from the establishment year of Trial B showed that light penetration to ground level was 25% higher in August after the companion crop had been removed as greenfeed compared to the grass-only control (Table 41). The herbicide application increased light penetration to ground level by 11% compared to the grass-only control. Light penetration to ground level was not significantly different between the grass-only control and grasses seeded with a companion crop to be harvested as grain. During September, light penetration to ground level was significantly increased after both companion crops had been removed compared to light received by grasses seeded without a companion crop. Light penetration was increased by 5% when grasses were treated with herbicide compared to the grass-only control. Total incoming radiation averaged 1535 and 1154 uM/m^2/s in August and September, respectively (Appendix B, Table B-3).

Over both trials (Table 12), light penetration to ground level during July was significantly highest when grasses were seeded alone with herbicide (606 uM/m^2/s), while grasses seeded without herbicide (429 uM/m^2/s) had significantly more light penetrating to ground level than grasses under the oat companion crop to be harvested as greenfeed (206 uM/m^2/s) or grain (178 uM/m^2/s) (S.E. = 21 ; P = 0.05).

.5 Light Penetration to Grass Level During the Establishment Year

The results from Trial A showed that light penetration (PPFD) through the crop canopy to grass level was reduced by 45% in July when grass species were seeded with an oat companion crop compared to the grass-only control (Table 42). The herbicide application increased light penetration by 8% compared to the grass-only control. Light penetration to grass level was not significantly different between the companion crops to be removed as greenfeed and grain. During August, light penetration to grass level was 7% higher after the companion crop had been removed as greenfeed or when treated with herbicide compared to the grass-only control. The companion crop to be removed as grain reduced light penetration by 43% compared to the control. During September, light penetration to grass level was 8% higher when treated with herbicide compared to the grass-only control. The removal of the companion crop as greenfeed or grain also significantly improved light penetration to grass level. The negative impact of oat leaf area index on light reception at grass level has been shown graphically for each sampling date (Figure 4). Total incoming radiation averaged 1246, 1202 and 879 uM/m^2/s in July, August and September, respectively (Appendix B, Table B-3).

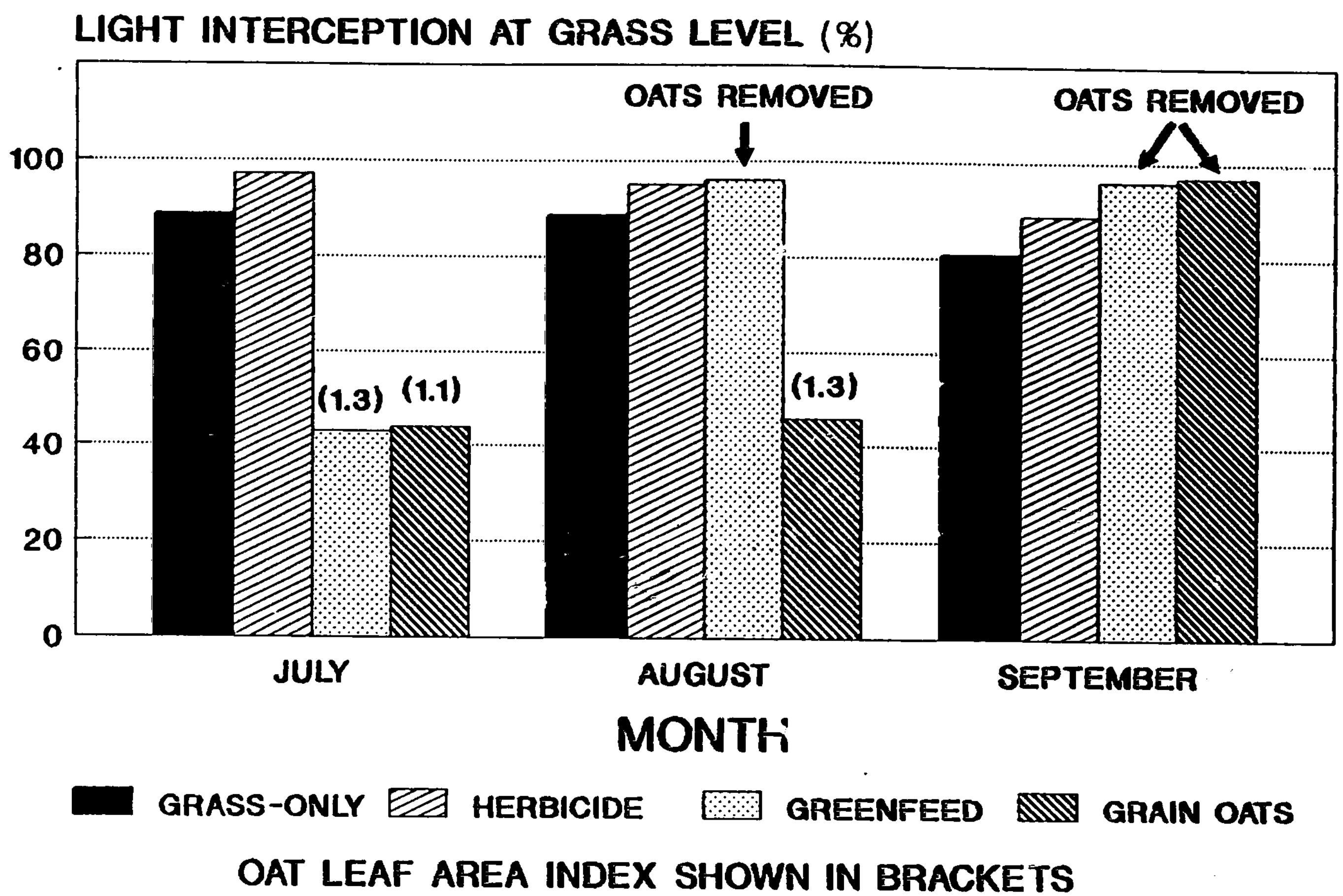
TABLE 42. LIGHT PENETRATION TO GRASS LEVEL IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	PHOTOSYNTHETIC PHOTON FLUX DENSITY ($uM/m^2/s$)		
	JULY	AUGUST	SEPTEMBER
		TRIAL A (1986)	
CONTROL (NO OATS)	1113 b*(89%)	1080 b (89%)	718 c (81%)
HERBICIDE (NO OATS)	1210 a (97%)	1146 a (95%)	791 b (89%)
GREENFEED (OATS)	533 c (43%)	1166 a (96%)	850 a (96%)
GRAIN (OATS)	547 c (44%)	532 c (46%)	833 a (97%)
MEAN	851 (68%)	981 (82%)	798 (91%)
S.E.	32	18	13
		TRIAL B (1987)	
CONTROL (NO OATS)	-	535 b (35%)	264 b (22%)
HERBICIDE (NO OATS)	-	1473 a (95%)	1037 a (92%)
GREENFEED (OATS)	-	1507 a (99%)	1063 a (92%)
GRAIN (OATS)	-	363 c (23%)	-
MEAN	-	969 (63%)	788 (68%)
S.E.	-	38	35

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

Percentage of total incoming radiation shown in brackets.

FIGURE 4 - INFLUENCE OF OAT LEAF AREA INDEX ON LIGHT INTERCEPTION AT GRASS LEVEL DURING TRIAL A (1986)



The results from Trial B showed that light penetration to grass level was about 60% higher in August after the companion crop had been removed as greenfeed or when treated with herbicide compared to the grass-only control (Table 42). The companion crop to be removed as grain reduced light penetration by 12% compared to the control. Decreased light penetration to grass level on the grass-only control in Trial B compared to Trial A was attributed to a heavier weed infestation. During September, light penetration to grass level was 70% higher when treated with herbicide compared to the grass-only control. The removal of the companion crop as greenfeed or grain also significantly increased light penetration to grass level. Total incoming radiation averaged 1535 and 1154 $uM/m^2/s$ in August and September, respectively (Appendix B, Table B-3).

Over both trials (Table 13), light penetration to grass level during August was significantly highest (689 $uM/m^2/s$) when grasses were seeded with an oat companion crop removed as greenfeed (oats and weeds clipped immediately prior to light measurement), while grasses seeded alone with herbicide (237 $uM/m^2/s$) received significantly more light at grass level than grasses seeded alone without herbicide (94 $uM/m^2/s$) or with an oat companion crop to be removed as grain in September (91 $uM/m^2/s$) (S.E. = 21 ; P = 0.05).

.6 Fall Soil Water Content During the Establishment Year

Measurements of fall soil water content during the establishment year of Trial A and B showed no significant difference among agronomic practices at 0-15 and 15-30 cm sample depths (Table 43).

Over both trials (Table 15), there was no significant difference in soil water content among agronomic practices at either sampling depth.

.7 Forage Growth During the Second Year

The results from Trial A show that grass species were 8% more productive at the first harvest (late-June) during the second year when treated with herbicide (6378 kg/ha) compared to the grass-only control (5818 kg/ha), and were about 35% less productive than the control when seeded with a companion crop removed as greenfeed (3695 kg/ha) or grain (3750 kg/ha) (Table 44). There was no significant difference in second year forage yield between grasses seeded with a companion crop removed as greenfeed or grain, suggesting that early removal of the companion crop did not have any beneficial effect on growth during the establishment year or on subsequent productivity. Forage yield measurements in the second year showed that there was no significant difference among agronomic practices during the second harvest (late-August) of 1987. The total combined yield from both harvests, however, showed that forage yields were 8% higher in the second growing

TABLE 43. FALL SOIL WATER CONTENT IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	SOIL WATER CONTENT (%)	
	0-15 cm	15-30 cm
	TRIAL A (1986)	
CONTROL (NO OATS)	33.4 a*	24.5 a
HERBICIDE (NO OATS)	32.6 a	24.0 a
GREENFEED (OATS)	31.8 a	24.1 a
GRAIN (OATS)	33.0 a	23.6 a
MEAN	32.7	24.1
S.E.	0.5	0.4
	TRIAL B (1987)	
CONTROL (NO OATS)	10.8 a	12.4 a
HERBICIDE (NO OATS)	10.5 a	13.2 a
GREENFEED (OATS)	10.5 a	11.8 a
GRAIN (OATS)	-	-
MEAN	10.6	12.5
S.E.	0.4	0.6

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE 44. SECOND YEAR FORAGE YIELDS IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	FORAGE DRY MATTER YIELD (kg/ha)		
	JUNE HARVEST	AUGUST HARVEST	COMBINED TOTAL
	TRIAL A (1987)		
CONTROL (NO OATS)	5818 b*	2583 a	8402 a
HERBICIDE (NO OATS)	6378 a	2787 a	9165 a
GREENFEED (OATS)	3695 c	2163 a	5859 b
GRAIN (OATS)	3750 c	2344 a	6094 b
MEAN	4910	2469	7380
S.E.	177	175	286
	TRIAL B (1988)		
CONTROL (NO OATS)	2712 b	2047 b	4759 b
HERBICIDE (NO OATS)	3824 a	2883 a	6707 a
GREENFEED (OATS)	2410 b	2075 b	4485 b
GRAIN (OATS)	-	-	-
MEAN	2982	2335	5317
S.E.	189	150	299

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

season when treated with herbicide (9165 kg/ha) during grass establishment compared to the grass-only control (8402 kg/ha), and about 30% lower when seeded with a companion crop removed as greenfeed (5359 kg/ha) or grain (6094 kg/ha).

The results for Trial B showed that the total combined yield in the second year was 29% more productive when treated with herbicide (6707 kg/ha) during the establishment year compared to the grass-only control (4759 kg/ha), while productivity was not significantly lower when seeded with a companion crop removed as greenfeed (44853 kg/ha) (Table 44). This result was consistent for the first (late-June) and second (late-August) harvests as well. Although not statistically significant, it should be noted that forage productivity appeared lower when seeded with a companion crop compared to the grass-only control.

Over both trials (Table 17), analysis of the combined forage yield during the second growing season showed that grasses seeded alone in combination with herbicide had significantly higher yields (8220 kg/ha) than when seeded alone without herbicide (7001 kg/ha), while grasses seeded with an oat companion crop removed as greenfeed (5330 kg/ha) had the lowest yields (S.E. = 214 ; P = 0.05).

3.3 CORRELATION COEFFICIENTS FOR PAIRED VARIABLES

3.31 Grass Characteristics During The Establishment Year

The results for Trial A showed that grass yield was positively correlated with grass tiller height (r = 0.81), tiller number (r = 0.55) and leaf area index (r = 0.90) (Table 45). Grass height was also positively correlated with grass tiller number (r = 0.49) and leaf area index (r = 0.77), while grass tiller number was positively correlated with grass leaf area index (r = 0.64).

The results for Trial B were similar, showing that grass yield was positively correlated with grass tiller height (r = 0.83) and tiller number (r = 0.77) (Table 45). Grass tiller height was also positively correlated with grass tiller number (r = 0.75).

3.32 Oat Characteristics During The Establishment Year

The results for Trial A showed that oat yield was positively correlated with oat tiller height (r = 0.81), tiller number (r = 0.85) and leaf area index (r = 0.17) (Table 46). Oat height was also positively correlated with oat tiller number (r = 0.84) and leaf area index (r = 0.39), while oat tiller number was positively correlated with oat leaf area index (r = 0.36).

The results for Trial B were similar, showing that oat yield was positively correlated with oat tiller height (r

TABLE 45. PEARSON CORRELATION COEFFICIENTS (r) SHOWING THE INTENSITY OF ASSOCIATION BETWEEN GRASS CHARACTERISTICS

Correlation Coefficient (r)

	Grass Yield	Grass Height	Grass Tiller#
	Trial A (1986)		
Grass			
Height	0.81	-	-
Tiller#	0.55	0.49	-
LAI	0.90	0.77	0.64
	Trial B (1987)		
	Grass Yield	Grass Height	Grass Tiller#
Grass			
Height	0.83	-	-
Tiller#	0.77	0.75	-

'r' values significant at P = 0.05.

N = 144 (Trial A) and 90 (Trial B) for paired variables.

Data from plots without companion crop.

TABLE 46. PEARSON CORRELATION COEFFICIENTS (r) SHOWING THE INTENSITY OF ASSOCIATION BETWEEN OAT CHARACTERISTICS

	Correlation Coefficient (r)		
	Trial A (1986)		
	Oat Yield	Oat Height	Oat Tiller#
Oat			
Height	0.81	-	-
Tiller#	0.85	0.84	-
LAI	0.17	0.39	0.36
	Trial B (1987)		
	Oat Yield	Oat Height	Oat Tiller#
Oat			
Height	0.73	-	-
Tiller#	0.95	0.79	-

'r' values significant at P = 0.05.

N = 144 (Trial A) and 75 (Trial B) for paired variables.

Data from companion crop plots.

= 0.73) and tiller number (r = 0.95) (Table 46). Oat tiller height was also positively correlated with oat tiller number (r = 0.79).

3.33 <u>Oat, Weed and Grass Characteristics During the Establishment Year</u>

The results for Trial A showed that most oat characteristics were positively correlated with grass characteristics (Table 47). Weed yields were also positively correlated with grass height and grass leaf area index. This result suggests that grasses, oats and weeds were all responding to a common environmental parameter, such as soil water. However, oat leaf area index was negatively correlated with grass yield (r = -0.25) and grass tiller height (r = -0.22) (Table 47). The results also indicated that the association between many paired variables was not significant.

The results for Trial B were somewhat different, showing that all oat characteristics were negatively correlated with one or more grass characteristics (Table 47). Weed yields were also negatively correlated with grass yields (r = -0.59) and grass tiller height (r = -0.20). The results indicated that the association between many paired variables was not significant.

TABLE 47. PEARSON CORRELATION COEFFICIENTS (r) SHOWING THE INTENSITY OF ASSOCIATION BETWEEN GRASS, OAT AND WEED CHARACTERISTICS

	Correlation Coefficient (r)				
	Trial A (1986)				
	Oat Yield	Oat Height	Oat Tiller#	Oat LAI	Weed Yield
Grass					
Yield	0.37	0.32	0.17	-0.25	ns
Height	0.67	0.46	0.37	-0.22	0.30
Tiller#	ns	ns	ns	ns	ns
LAI	0.41	0.40	0.22	ns	0.17
	Trial B (1987)				
	Oat Yield	Oat Height	Oat Tiller#	Oat LAI	Weed Yield
Grass					
Yield	-0.25	-0.63	-0.37	-	-0.59
Height	ns	-0.29	ns	-	-0.20
Tiller#	0.26	ns	ns	-	ns

'r' values significant at P = 0.05; ns = not significant.
N = 144 (Trial A) and 75 (Trial B) for paired variables.
Data from companion crop plots.

3.34 Grass Characteristics, Light Reception and Soil Water Content During the Establishment Year

The results for Trial A showed that light penetration to ground level was negatively correlated with all measurements of grass growth, while light reception at grass level was positively correlated with most grass characteristics (Table 48). The associations between soil water (0-15 and 15-30 cm depths) and grass characteristics were not significant.

The results for Trial B were similar, showing that light reception was positively correlated with most grass characteristics, although the associations between light penetration to ground level and grass characteristics were not significant (Table 48). In addition, the associations between soil water (0-15 and 15-30 cm depths) and grass characteristics were not significant.

TABLE 48. PEARSON CORRELATION COEFFICIENTS (r) SHOWING THE INTENSITY OF ASSOCIATION BETWEEN GRASS CHARACTERISTICS, LIGHT AND SOIL WATER

	Correlation Coefficient (r)		
	Trial A (1986)		
	Light at Ground Level	Light at Grass Level	Soil Water
Grass			
Yield	-0.66	0.24	ns
Height	-0.83	0.35	ns
Tiller#	-0.61	ns	ns
LAI	-0.69	0.22	ns
	Trial B (1987)		
	Light at Ground Level	Light at Grass Level	Soil Water
Grass			
Yield	ns	0.41	ns
Height	ns	ns	ns
Tiller#	ns	0.46	ns

'r' values significant at P = 0.05; ns = not significant.
N = 144 (Trial A) and 75 (Trial B) for paired variables.
Data from companion crop plots (Light to Grass Level).
Data from plots without companion crop (Light to Ground Level and Soil Water).

3.4 COST/BENEFIT ANALYSIS

For Trial A, results of the cost/benefit analysis showed that grasses seeded alone without herbicide application provided a net return of $718.40/ha over the two year growing period (Table 49). Grasses seeded with an oat companion crop removed as greenfeed provided a net return of $756.15/ha, confirming that companion crops can provide a means of economic return during grass establishment. However, grasses seeded alone in combination with herbicide application provided a net return of $781.25/ha over the two year growing period, providing the highest return of all agronomic practices. Grasses seeded with an oat companion crop removed as grain provided a net return of $706.85/ha. However, this result was based on average grain yields reported for the surrounding agricultural area (grain yields were not recorded for this experiment).

For Trial B, results of the cost/benefit analysis were similar, but returns were lower than Trial A due to lower grass yields (Table 50). Grasses seeded alone without herbicide application provided a net return of $301.60/ha over the two year growing period. By comparison, grasses seeded with an oat companion crop removed as greedfeed provided a net return of $428.50, again confirming that companion crops can provide a means of economic return during grass establishment. However, grasses seeded alone in combination with herbicide application provided a net return of $495.10/ha, providing the highest return of all agronomic practices.

TABLE 49 - COST/BENEFIT ANALYSIS FOR TRIAL A

1) GRASSES SEEDED ALONE WITHOUT HERBICIDE

Year 1			
Returns:	3801 kg/ha hay @ $71.65/1000 kg	=	$272.35/ha
Costs:	$22.00/ha mow, $34.85/ha bale	=	-$ 56.85/ha
Year 2			
Returns:	8402 kg/ha hay @ $71.65/1000 kg	=	$602.00/ha
Costs:	$22.00/ha mow, $77.10/ha bale	=	-$ 99.10/ha
Net Return Over Two Years:		=	$718.40/ha

2) GRASSES SEEDED ALONE WITH HERBICIDE

Year 1			
Returns:	4255 kg/ha hay @ $71.65/1000 kg	=	$304.90/ha
Costs:	$22.00/ha mow, $39.05/ha bale, $13.15/ha herbicide	=	-$ 74.20/ha
Year 2			
Returns:	9165 kg/ha hay @ $71.65/1000 kg	=	$656.65/ha
Costs:	$22.00/ha mow, $84.10/ha bale	=	-$106.10/ha
Net Return Over Two Years:		=	$781.25/ha

3) GRASSES SEEDED WITH AN OAT COMPANION CROP (GREENFEED)

Year 1			
Returns:	11044 kg/ha*oat @ $49.60/1000 kg	=	$547.80/ha
Costs:	$22.00/ha mow, $101.30/ha bale, $12.40/ha oat seed	=	-$135.70/ha
Year 2			
Returns:	5859 kg/ha hay @ $71.65/1000 kg	=	$419.80/ha
Costs:	$22.00/ha mow, $53.75/ha bale	=	-$ 75.75/ha
Net Return Over Two Years:		=	$756.15/ha

(* Yield reduced by 20% to reflect 25 cm harvest height used for greenfeed versus actual sample height of 5 cm)

4) GRASSES SEEDED WITH AN OAT COMPANION CROP (GRAIN)

Year 1			
Returns:	2628 kg/ha*oat @ $155.00/1000 kg	=	$407.35/ha
Costs:	$15.00/ha swath, $32.00/ha combine, $12.40/ha oat seed	=	-$ 59.40/ha
Year 2			
Returns:	6096 kg/ha hay @ $71.65/1000 kg	=	$436.80/ha
Costs:	$22.00/ha mow, $55.90/ha bale	=	-$ 77.90/ha
Net Return Over Two Years:		=	$706.85/ha

(* Average oat grain yield for surrounding region used, since no grain yields were determined in this experiment)

TABLE 50 - COST/BENEFIT ANALYSIS FOR TRIAL B

1) <u>GRASSES SEEDED ALONE WITHOUT HERBICIDE</u>

Year 1			
Returns:	771 kg/ha hay @ $71.65/1000 kg	=	$ 55.25/ha
Costs:	$22.00/ha mow, $ 7.05/ha bale	=	-$ 29.05/ha
Year 2			
Returns:	4760 kg/ha hay @ $71.65/1000 kg	=	$341.05/ha
Costs:	$22.00/ha mow, $43.65/ha bale	=	-$ 65.65/ha
Net Return Over Two Years:		=	$301.60/ha

2) <u>GRASSES SEEDED ALONE WITH HERBICIDE</u>

Year 1			
Returns:	2135 kg/ha hay @ $71.65/1000 kg	=	$152.95/ha
Costs:	$22.00/ha mow, $19.60/ha bale, $13.15/ha herbicide	=	-$ 54.75/ha
Year 2			
Returns:	6705 kg/ha hay @ $71.65/1000 kg	=	$480.40/ha
Costs:	$22.00/ha mow, $61.50/ha bale	=	-$ 83.50/ha
Net Return Over Two Years:		=	$495.10/ha

3) <u>GRASSES SEEDED WITH AN OAT COMPANION CROP (GREENFEED)</u>

Year 1			
Returns:	5068 kg/ha*oat @ $49.60/1000 kg	=	$251.35/ha
Costs:	$22.00/ha mow, $46.50/ha bale, $12.40/ha oat seed	=	-$ 80.90/ha
Year 2			
Returns:	4483 kg/ha hay @ $71.65/1000 kg	=	$321.20/ha
Costs:	$22.00/ha mow, $41.15/ha bale	=	-$ 63.15/ha
Net Return Over Two Years:		=	$428.50/ha

(* Yield reduced by 20% to reflect 25 cm harvest height used for greenfeed versus actual sample height of 5 cm)

PART IV - DISCUSSION

4.1 DIFFERENCES AMONG THE THREE CROP SPECIES

4.11 Growth During the Establishment Year

The relative growth of smooth bromegrass, meadow bromegrass and orchardgrass was assessed during the establishment year of two trials through measurements of growth parameters. Differences in growth between the three crop species were significant in Trial A, but not in Trial B. Variation in results between the two trials can be partly attributed to the drier 1987 growing season (Table 1) and the increase in weed competition during Trial B (Table 10), which impeded grass seedling growth (Table 5). Smooth bromegrass had higher dry matter yield and tiller height than orchardgrass and meadow bromegrass, as well as higher leaf area index than meadow bromegrass throughout the 1986 establishment year of Trial A (Table 19, 20 and 22). Smooth bromegrass also had the highest crop growth rate (grass dry matter yield) during the 1986 establishment year (Figure 1). Higher weed yields in association with smooth bromegrass during the September sampling date of Trial B was attributed to the low tiller number of smooth bromegrass (Table 21 and 27). Orchardgrass had the highest tiller number compared to the other grasses and a leaf area index that was not significantly lower than smooth bromegrass during Trial A (Table 21 and 22). In addition, orchardgrass was significantly more productive than meadow bromegrass during the August sampling date of Trial A (Table 19).

Orchardgrass had a crop growth rate (dry matter yield) that was similar to smooth bromegrass during the 1987 establishment year (Figure 2). Meadow bromegrass had the lowest crop growth rate during both trials, as well as the lowest yield during August and the lowest leaf area index during the August and September sampling dates of the 1986 establishment year (Table 19 and 22). Higher light penetration through the meadow bromegrass canopy compared to orchardgrass and smooth bromegrass was attributed to the significantly lower leaf area index for meadow bromegrass.

Other researchers have studied the differences in growth between grass species and showed similar results. Buxton and Wedin (1970) found that mean dry matter yield during two separate experiments was higher for smooth bromegrass (1732 and 4189 kg/ha, respectively) than orchardgrass (1230 and 3022 kg/ha, respectively) during the seeding year. Knowles (1987) demonstrated that smooth bromegrass (2841 kg/ha) was more productive than meadow bromegrass (2082 kg/ha) in Saskatchewan.

All grass characteristics (grass dry matter yield, tiller height, tiller number and leaf area index) were shown to be positively correlated (r values ranged from 0.49 to 0.90) with each other during both trials (Table 45). Similar relationships between grass tiller characteristics have been shown by other researchers. Walton (1976) demonstrated that several characteristics, including leaf area, tiller height and number, were considered predictive of higher yields in smooth bromegrass. Walton and Murchison (1979) also found a positive correlation between leaf area and yield for smooth bromegrass, indicating that yield was more predictive of leaf area than was tiller number. A relationship between leaf area and yield has been reported by Sharratt and Baker (1986), who demonstrated that alfalfa leaf area was correlated to leaf dry matter, and to a lesser extent, total dry matter determinations, such that leaf area could be estimated from these measurments indirectly. The authors indicated that the coefficient of determination (r^2) between alfalfa leaf area and dry matter was 0.98 or greater.

Comparisons of the relative seasonal increases in yield, leaf area index, tiller height and number for the three grasses indicated that early, rapid tiller growth and leaf area development appeared largely responsible for providing the competitive advantage necessary to enhance grass species growth during the establishment year (Table 19, 20, 21 and 22). Variation in growth rates between grasses was attributed to a number of factors, including: 1) the genetic makeup of the individual grass species; 2) environmental factors such as light, soil, water, nutrients, temperature, wind, etc.; and 3) management practices. The results suggested that early, rapid tiller growth and leaf area development by smooth bromegrass, and to a lesser extent, orchardgrass, promoted more efficient utilization of available resources, such as light, moisture and nutrients, compared to slow tiller growth and leaf area development by meadow bromegrass. Early, rapid tiller growth and leaf area development enabled grass species to compete more aggressively for resources, especially late in the growing season when competition between plants can increase and resources may become limiting. Slow leaf area development by meadow bromegrass was partly attributed to the development of higher specific leaf weight (leaf weight/leaf area). The higher specific leaf weight required more stored carbohydrates and newly formed photosynthates to produce each unit of leaf area, thus resulting in a slower rate of growth.

The ability of early emerging plants to capture resources at the expense of late emerging plants has been reported by several researchers and provides supporting evidence for the results of the present experiment. Ross and Harper (1971) indicated that early emerging plants increase their zone of influence and competitive ability over neighboring plants and tillers. These authors suggested that the potential for an individual plant or tiller to capture resources was dictated by the number and proximity of neighboring plants and tillers already capturing resources. In support of this finding, smooth bromegrass had a low tiller density in the present experiment, as well as the highest yield, tiller height, leaf area index and crop growth rate. Early leaf area development and stem elongation in smooth bromegrass has also been reported by Engel et al. (1987). Other studies have confirmed the rapid development of leaf area in smooth bromegrass (Bittman and Simpson, 1987). The authors indicated that smooth bromegrass tended to maintain high leaf area, even during periods of moisture stress, shading competing plants and taking advantage of intermittent rainfall. Slow establishment of meadow bromegrass compared to smooth bromegrass has been reported by Alberta Agriculture (1981b).

Grass morphological characteristics, such as leaf position and arrangement, were not measured in this study. However, it might be expected that morphological differences between grass species would have an effect on crop growth rate. For example, smooth bromegrass was observed to maintain a more erect leaf position than the other two grasses. The thick, rigid leaves of smooth bromegrass generally retained a vertical orientation, which can provide the opportunity for more efficient utilization of incoming radiation. However, light reflected into the lower canopy by the more erect leaf morphology of smooth bromegrass was likely offset by its larger leaf area, since light penetration to ground level was not significantly lower for smooth bromegrass than the other two grasses. The effect of grass leaf morphology on growth and light penetration has also been reported by other researchers. Sheehy and Cooper (1973) found that erect leaf morphology was partly responsible for higher growth rates among several forage grasses with contrasting canopy structures. The relationship between increasing leaf area and decreasing light penetration in orchardgrass has been reported by Pearce et al. (1965).

Light penetration to ground level was negatively correlated (r values ranged from 0.61 to 0.83) with grass dry matter yield, tiller height, tiller number and leaf area index during Trial A (Table 48). A reduction in light penetration to ground level can be attributed to the increase in grass leaf area as the grass canopy continued to fill in over the growing season. Light reception at grass level was positively correlated (r values ranged from 0.22 to 0.46) with grass dry matter yield, tiller height, tiller number and leaf area index (Table 49). Therefore, increased growth of grasses can be partly attributed to increases in light reception at grass level. The negative influence of the oat companion crop on light reception at grass level has been shown in Figure 4. There was an increase in light penetration to grass level from July to September as oat leaves senesced and dropped during the latter part of the growing season (Table 29). The decrease in light penetration to ground level during Trial B compared to Trial A was attributed to a higher proportion of weeds (Table 14).

Fall soil water content did not differ significantly under the three grass species during either trial (Table 30), and it was not known if differences would have occurred during May to August when crop growth and utilization of soil water would be more active. A more intensive sampling program over the entire growing season may have provided detailed information from which differences in soil water content under grass species could have been evaluated. Soil water content was considered to be a major factor limiting grass species growth, but the hypothesis was not tested thoroughly due to inavailability of facilities. Fall soil water content was higher for Trial A than Trial B when gravimetric soil determinations were made (Table 16). This was attributed to less prolific weed growth in Trial A than B (Table 10), as well as above average rainfall in September, 1986 and below average rainfall in September, 1987 (Table 1).

Observations of growth characteristics for oats during the establishment year showed that yield, leaf area index, tiller number and height were not significantly different among the three crop species (Table 23, 24, 25 and 26). This result indicated that growth of the oat companion crop was consistent across all grass species during each trial. Since the slower growing perennial grasses were considered less competitive for resources than the faster growing annual crop, no difference was expected due to the influence of individual grass species. Growth of oats was significantly lower in Trial B than Trial A (Table 9), which was attributed to increased competition from weeds in Trial B (Table 11) and lower rainfall during the 1987 establishment year (Table 1).

Oat dry matter yield, tiller height, tiller number and leaf area index were positively correlated with grass dry matter yield, tiller height and leaf area index during Trial A (Table 47). This result can be attributed to grasses and oats both responding postively to a common environmental parameter, such as light or soil water. Oat characteristics were negatively correlated with grass dry matter yield, tiller height and tiller number during Trial B, which relates to the negative impact of the oat companion crop on grass species growth. As the oat companion crop developed more leaf area, less light was able to penetrate the oat canopy to underseeded grass species, which inhibited grass growth.

All oat characteristics (oat dry matter yield, tiller height, tiller number and leaf area index) were positively correlated (r values ranged from 0.17 to 0.95) with each other over both trials (Table 46). However, Aase (1978) reported that there was no close association between leaf area and yield for winter wheat after a certain stage of growth due to leaf senescence and leaf drop.

The average yield of greenfeed oats over both trials was 10742 kg/ha (August sampling date), which was about 31% higher than the yield for forage oats (7400 kg/ha) reported for the Edmonton area by Walton (1975). However, the author indicated that oat forage yields respond favourably to high annual rainfall and a longer growing season compared to forage barley and wheat yields.

Weed yields were not significantly different among grass species during either trial (Table 27). Individual grass species were not expected to suppress weed growth in the present experiment, although the effect of grass species on weed growth has been identified by Knowles (1987). The author indicated that weed control in Saskatchewan was higher with monocultures of meadow bromegrass and smooth bromegrass than intermediate wheatgrass, crested wheatgrass, Russian wild ryegrass (Elymus junceus Fisch.), slender wheatgrass (Agropyron trachycaulum (Link) Malte), western wheatgrass (Agropyron smithii Rydb.) and northern wheatgrass (Agropyron dasystachyum (Hook) Scribn.), and that meadow bromegrass provided virtual exclusion of weed growth. The author provided no explanation regarding weed suppression by meadow bromegrass, however, its low growth habit may have provided sufficient shading at ground level to discourage weed germination and growth.

Weed yield was positively correlated with grass tiller height and leaf area index during Trial A (Table 47), which can be attributed to weeds and grasses both responding positively to a common environmental parameter, such as light or soil water. During Trial B, however, weed yield was negatively correlated with grass dry matter yield and tiller height. This was expected, since Trial B had more prolific weed growth than Trial A, which competed more severely with grass species and suppressed their growth (Table 11). There was a consistent decrease in light penetration to ground level as weeds (and grasses) increased in size and number over the growing season (Table 28). Higher than average rainfall during May, 1987 (Table 1) and an inadequate weed control program prior to plot establishment contributed to higher weed yields during the establishment year of Trial B.

4.12 Forage Growth During the Second Year

The relative productivity of forage plots seeded to smooth bromegrass, meadow bromegrass and orchardgrass was monitored through measurements of forage yield (grasses plus weeds) over two harvests (simulated hay management schedule) in the second growing season. Smooth bromegrass remained the most productive grass species during the first harvest (June) compared to the other two grasses (Table 31). Grass species yields during the second growing season were significantly different during Trial A only. There was no significant difference in forage yield during the second harvest (August). The total forage yield during the second growing season showed that smooth bromegrass (8179 kg/ha) was more productive than orchardgrass (6515 kg/ha), but not significantly more productive than meadow bromegrass (7446 kg/ha). This result was in contrast to the establishment year, when meadow bromegrass was the least productive grass species and had the lowest crop growth rate (Table 19, Figure 1 and 2). However, the results for smooth bromegrass and orchardgrass were consistent with research reported by Coulman (1987). The author demonstrated that over a three year period in two separate trials, yield of smooth bromegrass (7190 and 6820 kg/ha, respectively) was significantly higher than orchardgrass (4740 and 5220 kg/ha, respectively) when harvested as hay in Quebec.

Although considered slow to recover after clipping, regrowth of smooth bromegrass after the first harvest was not significantly different from that of meadow bromegrass and orchardgrass in either trial (Table 31). Under a more frequent defoliation schedule (using a simulated pasture management schedule of four harvests per season), smooth bromegrass would be expected to have reduced yields and persistence relative to the other two grasses. Meadow bromegrass and orchardgrass are both considered to have better regrowth capabilities than smooth bromegrass, since their growing points are situated closer to ground level, below cutting height (Alberta Agriculture, 1981). The quicker regrowth potential of meadow bromegrass compared to smooth bromegrass has also been reported by Baron and Knowles (1984).

Forage productivity was considerably higher for all grass species during the second year compared to the establishment year (Table 19, 31). The productivity of smooth bromegrass in the second year appeared to follow the same pattern of rapid, early growth observed during the establishment year. Simons and Gross (1985) indicated that the second year of growth was generally the most productive compared to subsequent years for smooth bromegrass, intermediate wheatgrass, crested wheatgrass or Russian wild ryegrass.

Winter kill was not evident in the second year for any of the grass species and thus, did not appear to contribute to lower meadow bromegrass or orchardgrass yields (Table 31). However, these observations are in contrast to those reported by Limin and Fowler (1987). The authors indicated that orchardgrass and meadow bromegrass were both more susceptible to winter kill than smooth bromegrass. Poor winter survival in orchardgrass has also been reported by Kunelius and Suzuki (1977).

4.2 DIFFERENCES AMONG THE FOUR AGRONOMIC PRACTICES

4.21 Growth During the Establishment Year

The relative impact of the oat companion crop and herbicide application on grass species growth was evaluated through measurements of growth characteristics, light penetration and soil water content during the first growing season of each trial. Light was considered a major factor limiting grass species growth, since the oat companion crop to be harvested as grain significantly reduced light penetration to underseeded grasses by 43 and 12% in Trial A and B, respectively, compared to light received by the grass-only control during August (Table 42). The result was a significant reduction in grass dry matter yield, leaf area index, tiller height and tiller number during the establishment year of Trial A (Table 32, 33, 34 and 35), but also a reduction in weed yield in both trials (Table 40). In contrast, the herbicide application increased light penetration to grass level by 6 and 60% in Trial A and B, respectively, compared to the grass-only control (Table 42). Light penetration to grass level was positively correlated with grass species growth during both trials (Table 48). The result was significantly higher grass dry matter yield, tiller number and tiller height, as well as a reduction in weed yield in Trial B (Table 40), and an increase in grass tiller number in Trial A (Table 32, 33 and 34). Light penetration to grass level in Trial A was considerably higher than in Trial B due to less extensive weed growth and thus, less shading by weeds (Table 42). The influence of oat leaf area index on light penetration to grass level has been shown in Figure 4. A proportional relationship between decreasing light penetration and increasing oat yield, tiller height and number has been reported by Flanagan and Washko (1950).

The detrimental effect of competition for light by companion crops on grass species growth has been reported by a number of researchers and provides support for the results obtained from the present experiment. Chastain and Grabe (1988a) have indicated that light penetration to red fescue seedlings was reduced by as much as 90% under a wheat or barley companion crop, which resulted in a corresponding decrease in red fescue yield and tiller number, and an increase in tiller height. A reduction in smooth bromegrass and alfalfa forage yields when established under a wheat companion crop was reported by Waddington and Bittman (1983), who suggested that shading by the companion crop was the primary cause of reduced forage seedling growth and development. Rees (1986) demonstrated that light penetration decreased as the leaf area index increased for intercropped sorghum and cowpea. Haskins and Gorz (1975) showed that an oat companion crop reduced plant height, plant number and dry matter yields of sweetclover (Melilotus officinalis (L.) Lam) compared to establishment without the companion crop.

Based on the reviewed literature, it was also expected that the oat companion crop underseeded with grasses would deplete soil water more rapidly than grass species seeded alone. However, there was no significant difference in fall soil water content between agronomic practices during either trial (Table 43). Increased soil water requirements of the companion crop may have been partially offset by reduced soil water requirements of the shaded grass seedlings, as well as increased shading of the soil surface by the companion crop, which can lower daytime soil temperatures and reduce air movement at the soil surface. A more intensive soil sampling program over the entire growing season would have provided more detailed information from which to assess changes in soil water content under different agronomic practices. Although soil water was considered to be an important limiting factor to grass species growth, the hypothesis was not pursued thoroughly due to inavailabilty of facilities. Variability in fall soil water measurements between the two trials was attributed to higher than average rainfall during September, 1986 and lower than average rainfall during September, 1987 (Table 1).

In contrast to the measurements of soil water reported for the present experiment, Klebesadel and Smith (1960) found that companion crops deprived underseeded forage grasses of available soil water. The authors indicated that soil water depletion was greater under a mature companion crop than one harvested in an immature stage of growth. Archer and Bowler (1980) have also suggested that the negative effects of an oat companion crop on forage crop establishment were largely dependent on periods of heat and moisture stress encountered during the establishment year. Lueck et al. (1949) found that smooth bromegrass yields were 4 to 17 times higher and tiller number was 2 to 5 times higher when established without an oat companion crop, and suggested that soil water content was one of the most important factors determining successful establishment.

Weed yields were reduced in both trials when grasses were seeded with an oat companion crop compared to the grass-only control (Table 40). Weed suppression by the oat companion crop was attributed to competition for resources such as light and soil water. The reduction in weed growth after clipping the oat companion crop for greenfeed appeared to be considerable during the September sampling date of Trial A, but was not significantly better than use of herbicide or the grain companion crop (Table 40). This was attributed to variability in weed growth across the experimental area.

Suppression of weed growth by companion crops has also been reported by other researchers. Janson and Knight (1973) and Janson (1975) found that weed growth in alfalfa was suppressed during the establishment year when seeded with a wheat or barley companion crop. An oat companion crop was demonstrated to be highly competitive with underseeded alfalfa, red clover, white clover and birdsfoot trefoil seedlings during establishment, but was also shown to suppress growth of volunteer weeds (Peters, 1961). The author indicated that the oat companion crop suppressed barnyard grass (Eschinochioa crusgalli (L.) Beauv.) more than yellow foxtail (Setaria glauca (L.) Beauv.).

Growth of grass species was improved when weed yields were decreased by the application of broadleaf herbicide (Table 32, 33, 34 and 35). Weed growth was significantly reduced by the herbicide application in both trials compared to the grass-only control, and provided better weed control than the oat companion crop in Trial B, when weed growth was more prolific (Table 40). During August, the herbicide application increased light penetration to grass species by 6% in Trial A under moderate weed cover and 60% in Trial B under heavy weed cover compared to the grass-only control (Table 42), resulting in higher grass tiller numbers in Trial A and higher yields, tiller numbers and tiller heights in Trial B (Table 32, 33 and 34). The herbicide application also resulted in the development of shorter grass tillers during the July sampling date of both trials (Table 33). This was attributed to increased exposure of grass seedlings which were unprotected after a herbicide application, as well as etiolation of grass tillers shaded by weeds and the companion crop in the absence of herbicide.

The positive impact of herbicide applications on grass establishment has been identified by several researchers. Moyer (1985) established alfalfa and sainfoin (Onobrychis viciifolia Scop.) crops with no weed control, a spring-applied herbicide treatment and a barley companion crop treatment, and found that alfalfa and sainfoin yields were higher for the herbicide treatment than the non-herbicide control and barley companion crop treatment during the first two years of growth. The author suggested that the increase in yield and forage quality during the establishment year made herbicide application a viable alternative to establishment with companion crops. Kust (1968) showed excellent establishment success with alfalfa using a herbicide instead of an oat companion crop, but suggested that the overall success of the herbicide application largely depended on the environmental conditions influencing the exposed seedlings. McCarty (1979) found that smooth bromegrass and intermediate wheatgrass yields were enhanced by several different broadleaf herbicide treatments. Mazzoni and Scholl (1964) demonstrated that herbicides controlled weed growth and enhanced the establishment of smooth bromegrass and orchardgrass when seeded without a companion crop, although the establishment of smooth bromegrass was consistently superior to that of orchardgrass during several summer planting dates. The positive impact of herbicide applications on alfalfa and birdsfoot trefoil yields during the establishment year was also shown by Wakefield and Skaland (1965).

There was no evidence during Trial A to suggest that early removal of the companion crop as greenfeed improved growth of grass species compared to late removal as mature grain (Table 32, 33, 34 and 35). Early removal of the companion crop in August restored nearly 100% of light penetration

(PPFD) to grass level (Table 42), but did not have any positive short-term effects on grass establishment and growth (Table 32, 33, 34 and 44). In fact, during the September sampling date, grass tiller heights were significantly reduced when the companion crop was removed as greenfeed compared to uncut grasses in the grain companion crop, due to clipping of grass tillers that extended beyond the 25 cm cutting height (Table 33, Plate 2). Early removal of the oat companion crop may also encourage regrowth of grasses, which can unnecessarily utilize stored carbohydrates essential for winter survival and vigorous growth in the following year. The results suggested that reduced competition for resources by early companion crop removal was not sufficient to offset the detrimental effects of grass leaf loss, even when the companion crop was clipped at a relatively generous height.

The results from the present experiment are in contrast to those reported by Brink and Martin (1986a, 1986b). The authors found that alfalfa yield was reduced when established with an oat or barley companion crop, but that the negative effects of the companion crop could be reduced by removing the companion crop at an early stage of growth. The morphological differences between alfalfa and grasses likely contributed to the different results.

4.22 Forage Growth During the Second Year

The relative impact of agronomic practices during the establishment year on subsequent forage productivity was evaluated through measurements of forage yield over two harvests (simulated hay management schedule) during the second growing season. Total forage yields were about 30% lower in the second year of Trial A when grasses had been seeded with an oat companion crop during the establishment year compared to the grass-only control (Table 44). Second year forage productivity was highest during the first harvest (June) of both trials when grasses were seeded alone and treated with herbicide, indicating that the herbicide application provided the best conditions for grass species establishment and subsequent growth. Forage yields in Trial B were not significantly different when grasses were seeded alone without herbicide compared to when seeded with an oat companion crop. This result was attributed to the influence of more intensive weed competition during the establishment year of Trial B (Table 11). Forage yields in Trial A were not significantly different when grasses were seeded with a companion crop removed as greenfeed compared to grain, indicating that early removal of the companion crop had no beneficial effect on grass establishment and subsequent growth.

The second year forage yield averaged 5330 kg/ha over both trials when grasses had been seeded with an oat companion crop removed as greenfeed during the establishment year.

These results were about 14% higher than the ten year average (1978 to 1987) tame hay yield of 4610 kg/ha reported by Alberta Agriculture for the surrounding region (Agricultural Reporting Area #5) (personnal communication with Ms. M. Timko, Crop Statistician, Statistics Branch, Alberta Agriculture, 2 December, 1988). By comparison, the second year forage yield in the present experiment averaged 8220 kg/ha and 7001 kg/ha over both trials when grasses were seeded alone with and without a herbicide application, respectively. These results were about 45% and 34% higher, respectively than the 4610 kg/ha average tame hay yield reported for the surrounding region.

The negative effects of companion crops on grass species establishment and subsequent productivity have been reported by a number of researchers and provided support for the results of the present experiment. Waddington and Bittman (1984a, 1984b) studied the long term effects of Polish and Argentine rapeseed companion crops on establishment and growth of smooth bromegrass and alfalfa, and found that forage yields in the second year were about 50 to 75% higher when seeded alone than when seeded with a companion crop. The authors found that forage yield was reduced during the establishment year and second year of growth, but there was little evidence of yield reduction beyond the third year. The reduction of Russian wild ryegrass yields for two years after establishment with a wheat companion crop was demonstrated by Lawrence (1967). Hoveland and McCormick (1974) showed that forage yield of tall fescue (<u>Festuca</u> <u>elatior</u> var. <u>arundinacea</u> (Schreb.)

Wimm.) and koleagrass (*Phalaris aquatica* L.) was reduced by 150% in the establishment year and 25 to 62% in the second year when established with a fall rye companion crop.

4.3 COST/BENEFIT ANALYSIS

The cost/benefit analysis confirmed that an oat companion crop can generate income when establishing grass species in this region compared to the return from grasses seeded alone without herbicide (Table 49 and 50). However, the net economic return from an oat companion crop and subsequent forage growth was lower than when grasses were treated with broadleaf herbicide for weed control. This result was consistent in both trials. Although the net economic return was lowest during Trial A when the companion crop was removed as mature grain, it was not known if the actual net return from grain oats would have been higher or lower than the regional average. In any event, the use of an oat companion crop during forage grass establishment can not be economically justified over the use of herbicide and therefore, is not recommended under these growing conditions unless considered essential for soil conservation purposes and/or herbicides are not readily available.

The cost/benefit analysis and recommendations reported for the present experiment are generally in contrast to those reported by researchers in other regions. Chastain and Grabe (1988b) found that red fescue seed yields in Oregon were reduced by wheat and barley companion crops during the establishment year only, and that net economic returns could be maximized by seeding with a wheat companion crop at 15 cm spacings. Schmid and Behrans (1972) found that the net economic return during the establishment year in

Minnesota was higher when an alfalfa hay crop was seeded with an oat companion crop than when seeded alone in combination with a herbicide application, and that the net return for mature grain was higher than for oat greenfeed. However, it should be noted that these authors assumed alfalfa yields during the second growing season would be the same for all methods of establishment (which was not the case in the present experiment using grasses). The variation in costs and benefits identified between these researchers and the present experiment appears related to the relative long-term impact of companion crops on forage establishment, such that companion crops significantly reduced grass yields in both the establishment year and second year of growth. In addition, the environmental factors influencing the crop, such as local rainfall patterns and length of growing season, and the economic conditions that interact for a specific region and period in time, such as crop price and forces of supply and demand, would influence the economic outcome of similar experiments.

PART V - CONCLUSIONS

The three grass species were assessed in terms of their relative growth during the establishment year in the Highvale region of central Alberta. The results indicated that smooth bromegrass grew better during the establishment year than orchardgrass, while meadow bromegrass had the poorest growth. Smooth bromegrass had the fastest crop growth rate in Trial A, as well as the highest dry matter yield, tiller height and leaf area index of all grasses. Orchardgrass had a higher crop growth rate in Trial B, as well as the highest tiller number, higher initial yields than meadow bromegrass and a leaf area index that was not significantly lower than smooth bromegrass in Trial A. Meadow bromegrass had the slowest crop growth rate, low initial yields and the lowest leaf area index of all grasses in Trial A. Comparison of the relative increases in growth characteristics suggested that early, rapid tiller growth and leaf area development was largely responsible for providing the competitive advantage necessary to achieve successful establishment. Growth of grass species was slower in Trial B than in Trial A due to more prolific weed growth.

The three grasses were also monitored in the second growing season to determine their relative productivity after establishment using a two harvest simulated haying system. The results indicated that smooth bromegrass was the most productive grass species during the first harvest of Trial A, while meadow bromegrass yields improved in the second harvest and were not significantly less productive than smooth bromegrass. Orchardgrass tended to have the lowest productivity. These results may have differed under a four harvest simulated grazing system due to differences in regrowth capability. Forage productivity was not significantly different between grass species during Trial B, which was partly attributable to lower rainfall and higher weed yields. Productivity in the second year did not appear to have been negatively influenced by winterkill for any of the three grass species.

The four agronomic practices were evaluated in terms of their relative impact on grass species growth during the establishment year. The results indicated that grasses seeded alone had higher dry matter yields, leaf area index, tiller heights and numbers than when seeded with an oat companion crop. The negative impact on grass species growth was partially attributed to shading of underseeded grasses by the companion crop, since the companion crop reduced light penetration to grasses by up to 50%. Competition for soil water was also considered a limiting factor, but was not assessed adequately due to inavailability of facilities. Weed yields were reduced by the presence of the oat companion crop, but herbicide was more effective in controlling weed growth. Grass species growth was not enhanced when established with an oat companion crop removed as greenfeed compared to grain. In contrast to the negative effect of the companion crop, growth of grass species was enhanced when treated with a broadleaf herbicide. The herbicide application resulted in higher grass dry matter yields, tiller numbers and tiller heights, as well as lower weed yields in Trial B, and higher tiller numbers in Trial A. Light penetration to grasses was improved by 6% under moderate weed growth in Trial A and 60% under heavy weed growth in Trial B compared to the grass-only control.

The four agronomic practices were evaluated in terms of their relative impact on subsequent forage productivity in the second growing season. The results indicated that grasses seeded alone continued to be more productive in the second year than when seeded with an oat companion crop. During the first harvest, second year forage productivity was 8 and 29% higher in Trial A and B, respectively, when grasses were treated with herbicide during the establishment year compared to the grass-only control, while productivity was about 35% lower than the control when established with an oat companion crop. The beneficial effects of the herbicide application were most apparent when weed growth was more prolific in Trial B. A cost/benefit analysis over the two year growing period of both trials indicated that an oat companion crop removed as greenfeed would result in an economic return during the grass establishment year. However, use of a herbicide application during grass establishment provided a better net return. Therefore, the use of an oat companion crop instead of herbicide during grass establishment under these growing conditions cannot be economically justified, and is not recommended, unless considered essential for soil conservation purposes and/or herbicides are not readily available.

BIBLIOGRAPHY

Aase, J.K. 1978. Relationship between leaf area and dry matter in winter wheat. Agronomy Journal 70: 563-565.

Agriculture Canada. 1974. Forage crop production in the aspen parklands of Western Canada, pg. 18. Melfort Research Station Publication #1545.

Alberta Agriculture. 1975. Seeding pastures in Alberta. Print Media Branch, Alberta Agriculture, Agdex 130/22.

Alberta Agriculture. 1980. Meadow Bromegrass - A new pasture grass for Western Canada. Print Media Branch, Alberta Agriculture, Agdex 127/30-1.

Alberta Agriculture. 1981a. Alberta forage manual. Print Media Branch, Alberta Agriculture, Agdex 120/20-4.

Alberta Agriculture. 1981b. Varietal description of Regar Meadow Bromegrass. Print Media Branch, Alberta Agriculture, Agdex 127/33-7.

Alberta Agriculture. 1984. Alberta fertilizer guide. Print Media Branch, Alberta Agriculture, Agdex 541-1.

Alberta Agriculture. 1986a. Varieties of annual forage crops for Alberta 1986. Print Media Branch, Alberta Agriculture, Agdex 120/32-1.

Alberta Agriculture. 1986b. Varieties of perennial hay and pasture crops for Alberta 1986. Print Media Branch, Alberta Agriculture, Agdex 120/32.

Alberta Agriculture. 1986c. Forage crops in Alberta. Print Media Branch, Alberta Agriculture, Agdex 000-12.

Alberta Agriculture. 1986d. Oats production in Alberta. Print Media Branch, Alberta Agriculture, Agdex 113/20-2.

Alberta Agriculture. 1988a. Farm machinery costs as a guide to custom rates - 1988. Farm Business Management Branch, Alberta Agriculture, Agdex 825-4.

Alberta Agriculture. 1988b. Soil sampling guide. Print Media Branch, Alberta Agriculture, Agdex 533-4.

Archer, K.A., and J.K. Bowler. 1980. Pasture establishment using oats as a companion crop on the Northern Tablelands of N.S.W.. In: Proceedings of the Australian Agronomy Conference on Pathways to Productivity, New South Wales, p. 17.

Baker, R.J. 1982. Effect of seeding rate on grain yield, straw yield and harvest index of eight spring wheat cultivars. Canadian Journal of Plant Science 62: 285-291.

Baron, V.S., and R.P. Knowles. 1984. Use and improvement of meadow brome as a pasture species for western Canada. In: Siemer, E.G., and R.H. Delaney (eds.). Proceedings of the Second Intermountain Meadow Symposium, July 11-13, Sponsored by the Colorado State University Experiment Station, Mountain Meadow Research Center and University of Wyoming, Fort Collins, Colorado.

Berkenkamp, B., and J. Meeres. 1987a. Mixtures of annual crops for forage in central Alberta. Canadian Journal of Plant Science 67: 175-183.

Berkenkamp, B., and E.J. Meeres. 1987b. Yields of annual forages under three harvest modes. Canadian Journal of Plant Science 67: 831-834.

Bittman, S., and G.M. Simpson. 1987. Soil water deficit effect on yield, leaf area, and net assimilation rate of three forage grasses: crested wheatgrass, smooth bromegrass and Altai wildrye. Agronomy Journal 79: 768-774.

Blaser, R.E., T. Taylor, W. Griffeth, and W. Skrdla. 1956. Seedling competition in establishing forage plants. Agronomy Journal 48: 1-6.

Briggs, K.G. 1975. Effects of seeding rate and row spacing on agronomic characteristics of Glenlea, Pitic 62 and Neepawa wheats. Canadian Journal of Plant Science 55: 363-367.

Brink, G.E., and G.C. Marten. 1986a. Barley vs. oat companion crops. I. Forage yield and quality response during alfalfa establishment. Crop Science 26: 1060-1067.

Brink, G.E., and G.C. Marten. 1986b. Barley vs. oat companion crops. II. Influence on alfalfa persistence and yield. Crop Science 26: 1067-1071.

Bula, R.J., D. Smith, and E.E. Miller. 1954. Measurements of light beneath a small grain companion crop as related to legume establishment. Botanical Gazette 115: 271-278.

Buxton, D.R., and W.F. Wedin. 1970. Establishment of perennial forages. I. Subsequent yields. Agronomy Journal 62: 93-100.

Canada Soil Survey Committee. 1978. Canadian system of soil classification. Subcommittee on Soil Classification, Canada Department of Agriculture, Publication #1646, Supply and Services Canada, Ottawa, ON.

Center, D.M., M.B. Jones, and C.E. Vaughn. 1984. Effects of sulfur and nitrogen levels and clipping on competitive interference between two annual grass species. Agronomy Journal 76: 65-71.

Chastain, T.G., and D.F. Grabe. 1988a. Establishment of red fescue seed crops with cereal companion crops. I. Morphological responses. Crop Science 28: 308-312.

Chastain, T.G., and D.F. Grabe. 1988b. Establishment of red fescue seed crops with cereal companion crops. II. Seed production and economic implications. Crop Science 28: 313-316.

Cooper, C.S., and H. Ferguson. 1964. Influence of a barley companion crop upon root disribution of alfalfa, birdsfoot trefoil and orchardgrass. Agronomy Journal 56: 63-66.

Cooper, C.S. 1967. Relative growth of alfalfa and birdsfoot trefoil seedlings under low light intensity. Crop Science 7: 176-178.

Coulman, B.E. 1987. Yield and composition of monocultures and mixtures of bromegrass, orchardgrass and timothy. Canadian Journal of Plant Science 67: 203-213.

Darwent, A.L., H.G. Najda, J.C. Drabble, and C.R. Elliott. 1987. Effect of row spacing on seed and hay production of eleven grass species under a Peace River Region management system. Canadian Journal of Plant Science 67: 755-763.

Depuis, G. 1983. Influence of nitrogen fertilizer and row spacing of companion crop harvested at forage on the establishment of alfalfa. Canadian Journal of Plant Science 63: 443-452.

Engel, R.K., L.E. Moser, J. Stubbendieck, and S.R. Lowry. 1987. Yield accumulation, leaf area index, and light interception of smooth bromegrass. Crop Science 27: 316-321.

Environment Canada. 1982. Canadian climate normals. Volume 3. Precipitation 1951-1980, p.104. Atmospheric Environment Service, Ottawa, ON.

Environment Canada. 1987. Highvale Meteorological Station unpublished data. Atmospheric Environment Service, Ottawa, ON.

Finlay, R.C., E. Reinbergs, and T.B. Daynard. 1971. Yield response of spring barley to row spacing and seeding rate. Canadian Journal of Plant Science 51: 527-533.

Flanagan, T.R., and J.B. Washko. 1950. Spring grain characteristics which influence their value as companion crops. Agronomy Journal 42: 460.

Frasier, G.W., J.R. Cox, and D.A. Woolhiser. 1985. Emergence and survivial response of seven grasses for six wet-dry sequences. Journal of Range Management 38: 372-377.

Genest, J., and H. Steppler. 1973. Effects of companion crops and their management on the undersown forage seedling environment. Canadian Journal of Plant Science 53: 285-290.

Haggar, R.J. 1979. The influence of herbicides, nitrogen fertilizer, seed rate and method of sowing, on the establishment and long-term composition of a perennial ryegrass ley. Weed Research 19: 231-239.

Harper, H.J. 1946. Effect of row spacing on the yield of small grain nurse crops. Journal of the American Society of Agronomy 38: 785-794.

Haskins, F.A., and H.J. Gorz. 1975. Influence of seed size, planting depth, and companion crop on emergence and vigor of seedlings in sweetclover. Agronomy Journal 67: 652-654.

Hoveland, C.S., and R.F. McCormick, Jr. 1974. Establishment of tall fescue and koleagrass with rye as a companion forage crop. Agronomy Journal 66: 394-396.

Hume, D.J., R.S. Fulkerson, and W.E. Tossell. 1969. Seedling year management of alfalfa-grass mixtures established without a companion crop. Canadian Journal of Plant Science 49: 477-481.

Janson, C.G. and T.L. Knight. 1973. Establishment of lucerne with cover crops under different soil moisture conditions. New Zealand Journal of Experimental Agriculture 1: 243-251.

Janson, C.G. 1975. Autumn lucerne establishment under irrigation with cover crops and herbicides. New Zealand Journal of Experimental Agriculture 3: 71-76.

Kelly, T.K. 1972. Companion crops in pasture establishment. Queensland Agricultural Journal 98: 497-499.

Kilcher, M.R., and D.H. Heinrichs. 1960. The use of cereal grains as companion crops in dryland forage crop establishment. Canadian Journal of Plant Science 40: 81-93.

Klebesadel, L.J., and D. Smith. 1959. Light and soil moisture beneath several companion crops as related to the establishment of alfalfa and red clover. Botanical Gazette 121: 39-46.

Klebesadel, L.J., and D. Smith. 1960. Effects of harvesting an oat companion crop at four stages of maturity on the yield of oats, on light near the soil surface, on soil moisture, and on the establishment of alfalfa. Agronomy Journal 52: 627-630.

Knowles, R.P. 1987. Productivity of grass species in the Dark Brown soil zone of Saskatchewan. Canadian Journal of Plant Science 67: 719-725.

Kunelius, H.T. and M. Suzuki. 1977. Seeding year yields and quality of orchardgrass as influenced by N rates and harvest systems. Canadian Journal of Plant Science 57: 427-431.

Kust, C.A. 1968. Herbicides or oat companion crops for alfalfa establishment and forage yeilds. Agronomy Journal 60: 151-154.

Lawrence, T. 1967. Effect of a wheat companion crop on the seed yield of Russian wild ryegrass. Canadian Journal of Plant Science 47: 585-592.

Lawrence, T. 1970. Effect of a wheat companion crop on the seed and dry matter yield of crested wheatgrass. Canadian Journal of Plant Science 50: 81-86.

LeClerg, E.L., W.H. Leonard, and A.G. Clark. 1962. Field plot technique (2nd ed), pg. 83. Burgess Publishing Company, Minneapolis, Minnesota.

Limin, A.E., and D.B. Fowler. 1987. Cold hardiness of forage grasses grown on the Canadian prairies.

Canadian Journal of Plant Science 67: 1111-1115.

Looman, J. 1976. Productivity of permanent bromegrass pastures in the parklands of the prairie provinces. Canadian Journal of Plant Science 56: 829-835.

Lueck, A.G., V.G. Sprague, and R.J. Garber. 1949. The effects of a companion crop and depth of planting on the establishment of smooth bromegrass (Bromus inermis Leyss.). Agronomy Journal 41: 137-140.

Maillette, L. 1986. Canopy development, leaf demography and growth dynamics of wheat and three weed species growing in pure and mixed stands. Journal of Applied Ecology 23: 929-944.

Malik, N., and J. Waddington. 1988. Polish rapeseed as a companion crop when establishing sweetclover for dry matter production. Canadian Journal of Plant Science 68: 1009-1015.

Marten, G.C., and A.W. Hovin. 1980. Harvest schedule, persistence, yield, and quality interactions among four perennial grasses. Agronomy Journal 72: 378-387.

Mazzoni, L.E., and J.M. Scholl. 1964. Effect of chemical and mechanical weed control in spring-seeded legumes on establishment of interseeded grasses. Agronomy Journal 56:403-405.

McCarty, M.K. 1979. Yield and quality of two cool-season grasses as affected by selected herbicides. Weed Science 27: 415-421.

McGowan, A.A., and W.A. Williams. 1971. Growth of subterranean clover established with a cereal companion crop. Agronomy Journal 63:643-646.

McKeague, J.A. (ed.). 1978. Manual on soil sampling and methods of analysis, 2nd ed., p. 173, 177, 179. Canadian Society of Soil Science, Ottawa, ON.

Moyer, J.R. 1984. Yield and nutrient composition of orchardgrass hay as affected by dandelion control. Canadian Journal of Plant Science 64: 295-302.

Moyer, J.R. 1985. Effect of weed control and a companion crop on alfalfa and sainfoin establishment, yields and nutrient composition. Canadian Journal of Plant Science 65: 107-116.

Pearce, R.B., R.H. Brown, and R.E. Blaser. 1965. Relationships between leaf area index, light interception and net photosynthesis in orchardgrass. Crop Science 5: 553-556.

Pelton, W.L. 1969. Influence of low seeding rates on wheat yield in Southwestern Saskatchewan. Canadian Journal of Plant Science 49: 607-614.

Pendleton, J.W., and G.H. Dungan. 1953. Effect of different oat spacings on growth and yield of oats and red clover. Agronomy Journal 45: 442-444.

Peters, R.A. 1961. Legume establishment as related to the presence or absence of an oat companion crop. Agronomy Journal 53: 195-198.

Pritchett, W.L., and L.B. Nelson. 1951. The effect of light intensity on the growth characteristics of alfalfa and bromegrass. Agronomy Journal 43: 172-177.

Rees, D.J. 1986. The effects of population density, row spacing and intercropping on the interception and utilization of solar radiation by Sorghum bicolor and Vigna unguiculata in semi-arid conditions in Botswana.

Journal of Applied Ecology 23: 917-928.

Remison, S.U., and R.W. Snaydon. 1978. Yield, seasonal changes in root competitive ability and competition for nutrients among grass species. Journal of Agricultural Science 90: 115-124.

Remison, S.U., and R.W. Snaydon. 1980. Effects of defoliation and fertilizers on root competition between Dactylis glomerata and Lolium perenne. Grass and Forage Science 35: 81-93.

Roberts, H.M. 1964. The effect of a cover crop on the seed production of leafy cocksfoot S26. Journal of the British Grassland Society 19: 62-64.

Ross, M.A., and J.L. Harper. 1972. Occupation of biological space during seedling establishment. Journal of Ecology 60: 77-88.

Santhirasigaram, K., and J.N. Black. 1965. Agronomic practices aimed at reducing competition between cover crops and undersown pasture. Herbage Abstracts 35: 221-225.

Santhirasegaram, K., and J.N. Black. 1968. The relationship between light beneath wheat crops and growth of undersown clover. Journal of the British Grassland Society 23: 234-239.

SAS Institute Incorporated. 1985. SAS users guide: Statistics, Version 5 Edition. SAS Institute Inc., Cary, North Carolina. 956 pp.

Schmid, A.R., and R. Behrens. 1972. Herbicides vs oat companion crops for alfalfa establishment. Agronomy Journal 64: 157-159.

Scott, T.W., J. Mt. Pleasant, R.F. Burt, and D.J. Otis. 1987. Contributions of ground cover, dry matter, and nitrogen from intercrops and cover crops in a corn polyculture system. Agronomy Journal 79: 792-798.

Scott, W.R. 1974. Establishment of undersown white clover as affected by wheat sowing rate, time of white clover introduction, and irrigation. New Zealand Journal of Experimental Agriculture 2: 151-154.

Sharratt, B.S., and D.G. Baker. 1986. Alfalfa leaf area as a function of dry matter. Crop Science 26: 1040-1043.

Sheaffer, C.C., A.W. Hovin, and D.L. Rabas. 1981. Yield and composition of orchardgrass, tall fescue and reed canarygrass mixtures. Agronomy Journal 73: 101-106.

Sheehy, J.E., and J.P. Cooper. 1973. Light interception, photosynthetic activity, and crop growth rate in canopies of six temperate forage grasses. Journal of Applied Ecology 10: 239-250.

Simmons, S.R., D.C. Rasmusson, and J.V. Wiersma. 1982. Tillering in barley : genotype, row spacing and seeding rate effects. Crop Science 22: 801-805.

Simons, R.G., and A.T.H. Gross. 1985. Growth of four grass species as affected by rate of nitrogen application an year of establishment on two soil types. Canadian Journal of Plant Science 65: 581-588.

Smith, D., H.J. Howe, A.M. Strommen, and G.N. Brooks. 1954. Establishment of legumes as influenced by the rate of sowing the oat companion crop. Agronomy Journal 46: 449-451.

Steel, R.G.D., and J.H. Torrie. 1980. Analysis of variance: IV. Split-plot designs and analysis. p. 377-400. In Principles and procedures of statistics: A biometrical Approach (2 ed.). McGraw-Hill Book Company, New York, NY.

Stoskopf, N.C. 1981. Understanding crop production, pg. 206. Reston Publishing Company, Inc., Reston, Virginia.

Temme, D.G., R.G. Harvey, R.S. Fawsett, and A.W. Young. 1979. Effects of annual weed control on alfalfa forage quality. Agronomy Journal 71: 51-54.

Tossell, W.E., and R.S. Fulkerson. 1960. Rate of seeding and row spacing of an oat companion crop in relation to forage seedling establishment. Canadian Journal of Plant Science 40: 500-508.

Waddington, J., and S. Bittman. 1983. Bromegrass and alfalfa establishment with a wheat companion crop in Northeastern Saskatchewan. Canadian Journal of Plant Science 63: 659-668.

Waddington, J., and S. Bittman. 1984a. Establishment and subsequent productivity of bromegrass and alfalfa seeded with an Argentine rapeseed companion crop in Northeastern Saskatchewan. Canadian Journal of Plant Science 64: 303-308.

Waddington, J., and S. Bittman. 1984b. Polish rapeseed as a companion crop for establishing forages in northeastern Saskatchewan. Canadian Journal of Plant Science 64:677-682.

Waddington, J., and N. Malik. 1987. Effects of establishment method and a rapeseed companion crop on alfalfa seed yield. Canadian Journal of Plant Science 67: 263-266.

Wakefield, R.C., and N. Skaland. 1965. Effects of seeding rate and chemical weed control on establishment and subsequent growth of alfalfa (Medicago sativa L.) and birdsfoot trefoil (Lotus corniculatus L.). Agronomy Journal 57: 547-553.

Walton, P.D. 1975. Annual forages seeding rates and mixtures for Central Alberta. Canadian Journal of Plant Science 55: 987-993.

Walton, P.D. 1976. A genetic study of the factors which constitute forage yield in Bromus inermis Leyss.. Zeitschrift fur pflansenzuchtung 77: 43-55.

Walton, P.D., and C. Murchison. 1979. Tiller weight and density of Bromus inermis Leyss. in Western Canada. Genetica Agraria 33:341-354.

Walton, P.D. 1983. Production and management of cultivated forages, pg. 139. Reston Publishing Company, Inc., Reston, Virginia.

Watson, D.J., and S.A.W. French. 1971. Interference between rows and between plants within rows of a wheat crop, and its effects on growth and yield of differently spaced rows. Journal of Applied Ecology 8: 421-445.

APPENDIX A

EXPERIMENTAL LAYOUT

FIGURE A-1. EXPERIMENTAL LAYOUT FOR TRIAL A

MAIN PLOTS

A=MEADOW BROMEGRASS

B=SMOOTH BROMEGRASS

C=ORCHARDGRASS

SPLIT PLOTS

1=CONTROL

2=HERBICIDE

3=GREENFEED OATS (AUGUST)

4=GRAIN OATS (SEPT)

REP 1	A	4	1	2	3	B	2	3	1	4	C	3	4	1	2
REP 2	B	3	1	2	4	C	2	4	3	1	A	1	3	4	2
REP 3	A	1	3	4	2	C	2	3	4	1	B	2	3	1	4
REP 4	C	4	3	2	1	B	1	3	2	4	A	4	2	1	3
REP 5	A	3	4	2	1	C	4	1	2	3	B	3	2	4	1
REP 6	A	3	2	1	4	B	2	3	1	4	C	1	4	3	2
REP 7	C	1	3	2	4	B	2	4	3	1	A	2	4	1	3
REP 8	B	1	2	3	4	A	1	3	4	2	C	1	4	3	2

FIGURE A-2. EXPERIMENTAL LAYOUT FOR TRIAL B

MAIN PLOTS

A=MEADOW BROMEGRASS

B=SMOOTH BROMEGRASS

C=ORCHARDGRASS

SPLIT PLOTS

1=CONTROL

2=HERBICIDE

3=GREENFEED OATS (AUGUST)

4=GRAIN OATS (SEPT)

	C					A					B				
REP 1	1	3	2	4	***	3	4	1	2	***	3	4	2	1
	A					B					C				
REP 2	4	1	3	2	***	1	4	3	2	***	2	4	1	3
	C					A					B				
REP 3	2	1	3	4	***	2	3	1	4	***	3	4	2	1
	A					B					C				
REP 4	4	3	1	2	***	3	4	1	2	***	4	3	2	1
	A					C					B				
REP 5	3	4	1	2	***	4	3	1	2	***	4	3	1	2

APPENDIX B

LIGHT RECEPTION ABOVE THE CROP CANOPY

TABLE B-1. ANALYSIS OF VARIANCE FOR LIGHT RECEPTION ABOVE CROP CANOPY OVER TRIAL A (1986) AND B (1987)

SOURCE OF VARIATION	DF	MEAN SQUARE (X 100)	
		AUGUST HARVEST	SEPTEMBER HARVEST
Trial (T)	1	41226 *	20221 *
Error a (Rep(T))	11	733	3371
Crop (C)	2	45 ns	41 ns
Crop x Trial	2	1 ns	88 ns
Error b (C x Rep(T))	22	90	63
Practice (P)	3	13 ns	65 ns
Practice x Trial	3(2)	144 *	79 ns
Practice x Crop	6	40 ns	18 ns
Practice x Trial x Crop	6(4)	47 ns	41 ns
Residual Error c	99(87)	47	30
Total	155(140)		

* Significant at P=0.05; ns, not significant.

DF Degrees of Freedom (September harvest in brackets).

No July measurements in Trial B.

TABLE B-2. LIGHT RECEPTION ABOVE OAT LEVEL IN RELATION TO THE THREE CROP SPECIES

CROP SPECIES	PHOTOSYNTHETIC PHOTON FLUX DENSITY ($uM/m^2/s$)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
MEADOW BROME	1222 a*	1206 a	891 a
SMOOTH BROME	1251 a	1189 a	854 a
ORCHARD GRASS	1265 a	1209 a	891 a
MEAN	1246	1201	879
S.E.	25	18	13
	TRIAL B (1987)		
MEADOW BROME	-	1540 a	1135 a
SMOOTH BROME	-	1526 a	1164 a
ORCHARD GRASS	-	1540 a	1163 a
MEAN	-	1535	1154
S.E.	-	20	23

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).

TABLE B-3. LIGHT RECEPTION ABOVE OAT LEVEL IN RELATION TO THE FOUR AGRONOMIC PRACTICES

AGRONOMIC PRACTICES	PHOTOSYNTHETIC PHOTON FLUX DENSITY ($uM/m^2/s$)		
	JULY	AUGUST	SEPTEMBER
	TRIAL A (1986)		
CONTROL (NO OATS)	1246 a*	1216 a	880 a
HERBICIDE (NO OATS)	1252 a	1205 a	884 a
GREENFEED (OATS)	1236 a	1217 a	888 a
GRAIN (OATS)	1250 a	1167 a	863 a
MEAN	1246	1201	879
S.E.	9	14	10
	TRIAL B (1987)		
CONTROL (NO OATS)	-	1524 a	1179 a
HERBICIDE (NO OATS)	-	1545 a	1125 a
GREENFEED (OATS)	-	1518 a	1158 a
GRAIN (OATS)	-	1555 a	-
MEAN	-	1535	1154
S.E.	-	17	18

* Means in the same column (within subtables) followed by the same letter are not significantly different at P=0.05 (Duncan's multiple range test).