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Title: The Effect of Date of Planting, Row Spacing, and Seeding Rate on Seed Yield and Seed Yield Components of Red Clover (Trifolium pratense L.) in the Willamette Valley.

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Abstract approved:

Harold W. Youngberg

The effects of various planting dates, row spacings and seeding rates on seed yield, seed yield components and certain other agronomic characters were studied on red clover (*Trifolium pratense* L.), in two experiments.

Results indicated that optimum seed yield under the growing conditions of this study was obtain with sowing made from the end of August (723 kg ha^{-1}) to the end of September (726 kg ha^{-1}) for the fall planting, and middle March (261 kg ha^{-1}) for the spring planting dates. Late fall and spring seeding produced lower yields.

The few significant effects of row spacing indicated that narrow spacings (15, 30 and 45 cm) tended to increase yield up to 798 kg ha^{-1}. Although no interaction between row spacing and seeding rate was observed, lower seeding rate (2 kg ha^{-1}) generally resulted in higher yields.

The experimental results of both planting date and row spacing trials showed no interaction with the two seeding rates used. Seeding rate had virtually no effect on any seed yield component, although an increase in the seeding rate up to 4 kg ha^{-1} resulted in higher number of vegetative stems.

Certain components of yield, such as florets per inflorescences, seeds per inflorescence, and percent of seed set, were not affected at the different planting dates and row spacing. Weight of 1000-seed decreased as planting date was delayed. Differences in seed yield in both planting date and row spacing studies were attributable to total production of inflorescences per unit area.

Later fall and spring plantings (October and May) were reflected in lower plant number per unit area and less reproductive stems than earlier dates. There was a highly significant difference in plant number at the different row spacing. An increase in plant density was associated with a negative effect upon inflorescences per unit area.

A high positive correlation between plant height and seed yield was observed; plant height decreased with delayed of date of planting and increased row distance.

Dry matter at the spring forage cut was positively correlated with seed yield at the different dates of planting and row spacing.

The Effect of Date of Planting, Row Spacing and Seeding Rate on Seed Yield and Seed Yield Components of Red Clover (*Trifolium pratense L.*) in the Willamette Valley

by

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DEDICATION:

To my parents and sister, who provided trust, love and emotional support, and always believed in me. I could never repay the debt of gratitude I owe to them.
To my wife Graciela and my two children, Valeria and Esteban, words cannot express my love and appreciation for the encouragement, patience, and affection each of you has shown during this sometimes difficult and always stressful period. Without each of you achievement of this degree would have been impossible.

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I. INTRODUCTION

The beneficial effects of clovers have not always been known or appreciated by farmers. In 1924, Piper (47) stated that red clover (*Trifolium pratense* L.) had a greater influence on civilization than the potato (*Solanum tuberosum* L.) and much greater than any other forage plant.

Red clover is a legume that has a wide range of adaptability. It can be grown as a companion species with grasses and other legumes for hay, pasture and silage in short-term rotations (43). The benefits of clover to soil have been recognized by its heavy root system. The importance of clover's forage to agriculture include: improving soil fertility and soil structure, protecting soil from the destructive effects of rainfall, preventing water runoff and soil erosion, reducing pollution in streams and rivers, and increasing animal productivity (58). One of the major reasons for the success of clovers (and other legumes) is their potential for fixing atmospheric nitrogen. The clover-rhizobium symbiosis was first recognized less than 100 years ago.

In the United States red clover is the most widely grown of the true clovers. In recent years, annual US production has been about 11,300 to 13,600 t from about 202,000 ha (51). Seed of other perennial clovers such as alsike, strawberry and white is produced in the western states of California, Idaho, Oregon and Washington, but their combined production is less than one half the amount of red clover produced in the USA.

Red clover seed production is concentrated in two regions of the US, the Midwest and the Northwest. In the Midwest, seed production is normally secondary to forage production. The first crop is generally used for forage and the subsequent crop taken for seed. Weather is the principal reason for low seed yieldsin the Midwest, regardless of the attention given to all other operations. Cloudy, rainy weather at time of flowering may reduce the number of seed heads per unit area, interfere with ovary development and greatly retard the pollination activity of bees (19). Therefore, midwestern seed producers may not follow the best production practices as the costly operations of good seed crop management can be nullified by weather.

In the Intermountain and Western States unfavorable weather is not a significant factor. The bright sunny weather during flowering, seed setting, and harvesting periods is favorable to large yields and high seed quality, making seed production a profitable enterprise (19).

In the Northwest, seed production is the primary enterprise and seed yields are generally greater than in the Midwest (59). Red clover is the most important legume crop grown for seed production in Oregon, with 9,396 ha harvested in 1988, a production of 3,476,520 kg of seed, and a value of production of $8,078,000 (36).

Regardless of its genetic constitution, the actual yield of a plant can be greatly influenced by environmental factors such as temperature, rainfall and day length. Man can manipulate some of these factors to the advantage of the crop species growing under specific climatic conditions. As new cultivars are developed or introduced into a region, efficient cultural practices such as row spacing, rate and date of seeding must be developed to promote higher yields. When determining factors responsible for problems in seed production it is useful to estimate potential and harvestable yields. The method of studying crop yield by isolating its components is widely used in many economic crops (30). In order to increase seed yield, one or more of the components of the final yield must be increased but very often, the increase in one component leads to the decrease in another component, resulting in final yield remaining constant. The need for a greater understanding of factors affecting yield components in red clover seed production under the environmental conditions of the Willamette Valley, stimulated this present study.

Red clover responds favorably to the environmental conditions of the Willamette Valley, and thus, has high yield potential. However, several important questions need to be answered from a practical standpoint regarding red clover grown for seed production. Specifically, what cultural practices are needed to obtain maximum yield? Definite answers are not available for the following questions:

a. What is the optimum planting date for a maximum seed production during the establishment year?

b. What is the best row spacing for red clover grown for seed?

c. At what seeding rate will red clover perform best?

d. Is there any interaction between these factors?

The investigation conducted in this thesis is designed to provide answers to these questions and obtain specific information on the effects of different row spacings and planting date, and their interaction with different seeding rates on seed yield during the establishment year within the growing conditions of the Willamette Valley. Emphasis was given to effects of these variables on seed yield components.

II. LITERATURE REVIEW

The few references to row spacing, seeding rate and planting date in red clover are almost exclusively confined to forage production techniques, which have little relevance for seed production.

The magnitude of the seed yield obtained from a given crop was determined by Stoddart (57) as a complex interaction of variables. Low yields were generally due to one or more of the following factors: (i) an unsatisfactory establishment; (ii) an inadequacy of pollinating agents during flowering; (iii) a low number of blooms per unit area; or (iv) unfavorable weather conditions during pollination and seed ripening.

In the Midwestern States, red clover seed crop harvested is usually of secondary importance to the individual farmer. Here, red clover is used primarily for forage and/or a rotation crop. Following establishment, hay or silage is first harvested from the stand and a second crop may be harvested for seed, providing that the hay requirements have been met and there is enough seed to make a profitable crop. On the other hand, in the Western States, red clover seed production is generally a planned enterprise. It is grown on specialized farming operations under an environment that is conducive to large seed yields, provided that all operations in the growing and harvesting of the seed crop be thoroughly and timely done. However, neglecting one operation may result in a small yield from what was potentially a large crop (19).

Planting Date

Seeding rates and time of sowing practices used in commercial practice are largely based on grower experience, although some earlier experiments using small plots have produced some guidelines particularly for time of planting. The effect of several planting dates x seeding rates on seed yield and seed yield components of specific cultivar of red clover has not previously been reported.

Seeding dates for red clover are often determined by weather conditions; however, seeding date can be of considerable importance in determining seed yield. Proper planting date may often be as important as cultivar selection and appropriate cultural practices. While climatic variation makes it impossible to predict the optimum seeding date for a particular year, consistently high yields can be obtained by timely seeding.

Throughout the world, red clover sowing is timed to coincide with reliable rainfall and moderate soil temperatures, as well as to avoid aggressive weeds, high soil temperatures, damaging insects, and high intensity rainfall. It is also necessary to have the stand well established before prolonged droughts or killing frosts are likely.

The recommendation proposed by Frame (20) in England for red clover forage production is to sow during April to July to obtain significantly higher dry matter yields than later sowing. He reported plant numbers in the spring were depressed by late sowing but sowing date effects on production did not persist into the second year. Adverse effects of late sowing on production were not fully offset by increased seed rate.

Early season sowing is advisable when direct seeding pure red clover stands and the detrimental effect of late sowing cannot be fully compensated by increasing seed rates of clover. Based on an experiment done at London, where red clover was sown at seed rates of 6, 12 and 18 kg ha^{-1} on six dates from April to September, Frame (21) concluded: (i) that April to July sowing dates gave significantly higher dry matter yields than later sowing; (ii) the influence of seeding rate was less marked than sowing date; and (iii) the total herbage dry matter increasing as seed rate increased from 6 to 18 kg ha^{-1}. Plant numbers in spring of the first harvest year, and hence percentage survival from sowing, were depressed by late sowing; plant numbers rose but percentage survival declined as seed rate was increased. The stage of development which clover plants reach in the establishment year may affect their overwintering capacity.

Choo and Suzuki (8, 9) suggest that the seeding of red clover in the field should be carried out on such a date that red clover plants will have at least 12 weeks of summer growth to insure survival from freezing.

It is apparent that red clover varieties respond differently to low temperature. Smith (55) found that date of seeding had a marked influence on the proportion of flowering and non-flowering plant types in medium red clover. Date of seeding and rapidity of plant development can influence the amount of flowering in the seedling year. Bird (2) and Smith (55) have shown an association between habit of growth in the seedling year and winter survival in red clover. Non-flowering plants survived the first winter better than flowering plants. Seedings made at five different dates at two-week intervals from May 15 to July 15 at Wisconsin, showed that the percentage of flowering plants in spaced populations was highest at the earliest seeding date and declined with later seeding dates. No plants flowered in the July 15th seeding. A high percentage of winter-killing occurred in the flowering plants than in the non-flowering plants.

Hawkins (27) described the three different types grown in England:

(i) Double-cut red clover is a true biennial sown in spring, cut for hay the following June and a second crop cut for hay or saved for seed in September-October.

(ii) Single-cut red clover is also sown in spring but produces relatively little herbage until the following May or June. It is cut for hay in June and is harvested for seed in August. It lasts a year longer than double-cut.

(iii) Late-flowering red clover is like single-cut since it produces only a crop of hay or seed but is more persistent and will last from 4 to 8 years.

Most American red clovers are of the early flowering type, known collectively as medium red clover, with a true biennial growth habit; while American mammoth red clover is the principal late flowering type grown in the U.S (59).

In New Zealand, red clover is generally sown in the spring or early summer, as late summer and autumn sowing are more likely to suffer from attacks by insects and from weed competition (71).

In all areas, it is difficult if not impossible to establish red clover after the onset of hot, often dry, summer weather; therefore, summer planting should be avoided. Early planting is desirable to permit the plants to become well established before the onset of sub-freezing temperatures (51).

Clovers grown for seed production are usually planted in the spring or fall months in the northern and western states (51). Red clover seed production in the northern and central part of the Midwest clover belt is usually undersown with small grains in late winter or early spring (33, 56). However, it may be sown directly with the application of a pre- or post-plant herbicide to reduce competition from weeds. In the southern part of the US where red clover is used as a winter annual, seedings are made from October 15 to December 15 depending upon latitude (56). Stands of red clover were satisfactory at Crossville (Tennessee) when fall seeding took place from mid-July to early-August, and during April in the spring; at Tennessee good stands resulted from seeding made from mid- to late-April and from mid-July to early-August (23).

In California red clover is spring-planted (mid-February to mid-March) or fall planted (mid-September to November 1) (31).

In the Pacific Northwest, Rincker and Rampton (51) proposed red clover as spring planted in mid-April to mid-May or fall seeded in mid-August to mid-September.

Row Spacing and Seeding Rate

Row spacing and seeding rates are two management factors that have an effect on seed production of alfalfa, soybeans, white clover, and alsike clover among other crops (42).

Studies by Kolar and Torrel (34) indicated that highest seed yield of alfalfa was obtained from 56 and 91 cm spacing, respectively, at two different locations, Twin Falls and Parma, Idaho. This study indicated that not only latitude and farm equipment should be considered for growers to determine the spacing best suited to their growing conditions, but also that production of alfalfa (*Medicago sativa* L.) seed from rows is advantageous compared to use solid stands, providing that row width does not become excessive. The results of these studies were consistent with those reported by other workers, where the opening stands by row planting and by thinning stands within rows stimulated seed production. Jones and Pomeroy (32) obtained their best three-year average alfalfa seed yields in California from thinned stands in seeded rows 61 to 122 cm apart. Pederson et al. (45) suggested a row spacing of 1.2-1.5 m on sandy soils, 0.9-1.2 m on medium-textured soils, 0.6-0.9 m on clay or shallow hard pan soils and as low as 23 cm on heavy clay soils. The same authors comparing seed yields of three cultivars seeded at low seeding rates in row spaced 20 and 61 cm apart, found that the three different cultivars responded differently to the thinned treatments.

In alfalfa, seeding rates as low as 3.4 kg ha^{-1} in solid seeding and 1.1 kg ha^{-1} in row plantings were recommended by Pederson et al. (45).

The yield response of determinate soybeans (*Glycine max* (L.) Merr.) to row spacing has received much attention and these studies have produced conflicting results. Wiggans (64) concluded soybean yields were maximized when plants were uniformly distributed. While some other authors (22, 35, 65) reported soybeans planted in row spacing of 25 and 50 cm producing yields higher than those obtained from soybeans planted in row spacings of 96 to 101 cm. However, other authors (7, 26) have reported that soybean yielded as much in row spacing of 96 to 101 cm as they did when planted in narrower spacings. Part of the cause for conflicting results among row spacing studies is reflected in the interaction among variables (cultivar x row spacing or row spacing x planting date). Row spacing, planting date and variety have been reported by Boquet (3) to produce a highly significant influence on seed yield of soybean. Soybeans had the ability to compensate by branching for differences in stand caused by different seeding rates (38).

Clifford (13) provided information on pure autumn-established white clover (*Trifolium repens* L.) crops taken for seed in the first productive season. Rows precision sown at spacing of 15, 30 and 45 cm, all at the same intra-row density, reached a maximum potential yield at 30 cm spacing and then declined. This decline resulted from plant development being insufficient to make maximum use of the available area at 45 cm. Both the percentage of stolons flowering and the inflorescence numbers borne by individual stolons were enhanced with each increase in row spacing. Data collected at Abertyswyth by Griffiths and Roberts (25) show a 50% advantage in the seed yield of white clover varieties when sown in 60 cm spaced drills at 1 kg ha^{-1} compared with the usual broadcast sowing at 3 kg ha^{-1}. The thinner plant population tends to produce more inflorescences and a higher number of seeds per inflorescence. Wider drill spacings produce more seed than closer spacing in narrow drills and broadcast sowing.

Differences in seed yield in alsike clover (*Trifolium hybridum* L.) have been demonstrated by Pankiw et al. (42) to be affected primarily by seed head production. Narrow row spacings (15 cm) gave the highest yield; intermediate seeding rates (2.2-4.5 kg ha^{-1}) were the most efficient, with both higher and lower seeding rates producing less seed.

From a forage production standpoint, Winch and Tossel (70) found that hay yields were affected by seeding rate; forage yields were increased when the seeding rate of red clover was raised from 3.3 to 6.7 kg ha^{-1} but not beyond this rate. In a dense sward, the level of light, water, nutrients and space is limited and is generally below the combined demand of all plants. As a result, individuals are forced to compete with each other and the level of competition is determined largely by plant population, the greater the density, the greater is the level of competition (5, 17).

In the humid states, broadcast red clover seeding appears to be best, particularly for control of weeds. Under irrigation in the western states, planting in rows has proved to be most satisfactory when clover is planted alone for seed production. The plants are cultivated during the seedling stage for weed control and it is believed that additional light which the plants receive during the vegetative stage of plant development increases seed yield and seed quality (19). Cullen (14) showed that differences in broadcast sowing rates influence seed yields at the first harvest, but had no effect at the second. However, Clifford (10), working with a tetraploid red clover G 4706, concluded that wide-spaced planting (60 cm inter-row and

10 cm intra-row plant spacing) gave higher seed yield and higher number of flowering stems per plant than the narrow-spaced rows.

Where the first red clover crop is used for hay or grazing and the second crop for seed, seeding broadcast in companion grain crops is described as an usual practice by Fergus et al. (19). A seeding rate of 8-10 kg ha^{-1} for diploid varieties and 11-13 kg ha^{-1} for tetraploid varieties has been used. In some regions it is usual to add 3-5 kg of a perennial ryegrass or timothy to increase forage values of broadcast stands.

Pankiw et al. (42) confirmed that companion crops inhibit stand establishment and reduce first-year seed yields by one-third or more depending on the crop. Seed yields are improved by reducing the seeding rate of companion crops and seeding in alternate rows or cross seeding. Besides, nurse crops reduce height of legume stands which in dry seasons could present some problem in harvest, but which in wet seasons could reduce lodging (41). It was pointed out by Winch and Tossel (70) that when the red clover was seeded alone the first crop seed yield was higher than those of the second.

In New Zealand, red clover is seldom sown specifically for seed but is included in a general purpose pasture seed mixture with white clover and grasses. The planting is used for stock grazing as well as for red clover seed production. Under these circumstances the optimum seeding rate of red clover is about 5 kg ha^{-1} to give a population of about 45-60 plants m^{-2} (14).

Winch and Tossel (70) found no differences in seed yield among the seeding rates used (3-12 kg ha^{-1}) regardless of whether seed was harvested from the first growth or from the aftermath. Therefore, under the conditions in Ontario, Canada, the seed producer should choose a rate of seeding which will result in the highest return of forage, knowing that the seeding rate used will not affect seed yield from the aftermath.

Sheaffer and Swanson (53) reported that with proper soil conditions and seed placement, alfalfa and red clover seeding rates could be reduced to 4.4 and 3.3. kg ha^{-1} respectively, for forage production.

Information is relatively scarce about the influence of row spacing and seeding rate on red clover, and the influence of these factors on the components of seed yield. According to Clifford (13), distance between rows is important to ensure sufficient and evenly distributed space for floral expression. The results of a row spacing study conducted at Beaverlodge, Canada, by Pankiw (40) provided some useful information. The seed yield in 15, 30, 46 and 61 cm row spacings was very similar in the first seed crop year but there was a reduction in yield at the 61 cm spacing in the second seed crop year. The 91 cm spacing had lower yield and weed problems were encountered. The yields from the various seeding rates which ranged from 0.16 to 22 kg ha^{-1}, indicated a satisfactory seeding rate range of 1 to 8 kg ha^{-1} with the highest yield at 3-4 kg ha^{-1}. Pankiw (39) provided the practical recommendations that the lowest effective rates were 2.2 kg ha^{-1} for the 30, 45 and 60 cm spacing, and that seeding rates above 5.6 kg ha^{-1} are not warranted. Row spacings of 15 to 46 cm are recommended by Pankiw et al. (43). Rolston et al. (52) reported that seed yields from 80 cm rows were lower than seed yields from 50 or 30 cm rows. Results from England (27) show differences between seed yield from 15 cm and 61 cm row spacing were not significant (the difference in yield was less than 12%). However, when the same quantity of seed was sown per row, 61 cm drilling appeared to have a thinner plant. Thus, red clover appears to be adaptable to a wide range of both row spacing and seeding rate, although wider spacings offer less competition to weeds, make harvesting more difficult, and tend to reduce seed yields.

Seed Yield

According to Huxley et al.(30), species of *Trifolium* are known for their fluctuations in yield of seed. Red clover like all other exclusively cross-fertile species, is exceedingly variable. Practically every plant is heterozygous for one or more characters (66).

Dijktra (16), reported that seed yield of red clover is quite variable and low in countries with a temperate maritime climate. Only in years when the summer season is dry, are the yields as high as 700-800 kg ha^{-1}. On the average, yield is fairly low, namely 200-250 kg ha^{-1}.

Seed yield of tetraploid red clover is 15% to 35% lower than that of diploid cultivars. Mean total seed yields of 1150, 1050 and 660 kg ha^{-1} have been recorded by Clifford (12) for the diploid varieties Hamaua and Turoa, and for the tetraploid Pawera, respectively, in a study of closing date on seed production of red clover in Lincoln, New Zealand.

In the humid eastern and central regions of the US average seed yield seldom attain 135 kg ha^{-1}. However, a yield over 785 kg ha^{-1} has been produced in Ohio in a very favorable season (19). In contrast, seed yields average 335 to 560 kg ha^{-1} annually in the arid regions of the Pacific Coast states. Seed yields of 753, 1,030 and 485 kg ha^{-1} have been reported for the cultivar Kenland at Prosser, Washington and Shafter and Techachapi, California, respectively (50). Red clover in western Oregon normally has a stand life of two years, with the second crop producing lower yields than the first crop (52).

Grandfield (24), working with alfalfa, concluded that any factor that influences the vigor and type of plant growth, thereby influencing carbohydrate storage and utilization, may have a direct effect on seed production and stand life.

In alfalfa, Dovrat et al. (18), found that seed yields were positively associated with percent carbohydrate of the roots. Cultural practices which tend to conserve root reserves during the period of regrowth are likely to increase the seed potential of alfalfa. The numbers of secondary branches, raceme per stem and pods per raceme were greater in thinned than in unthinned rows. Pederson (44) reported that plants in thinned stands of alfalfa, were several centimeters shorter, lodged less, were more accessible to pollinating insects, and flowered earlier than those in unthinned stands. He attributed the reduced growth in thinned stands of alfalfa to those conditions that root growth proceeded at the expense of top growth, eventually producing an imbalance in favor of the storage of high levels of carbohydrate reserves which in turn stimulated reproductive rather than vegetative development.

The correlation between yield of seed and certain meteorological data when the clover is flowering and the ripening seed is harvested has been demonstrated by Hawkins (27). Both rainfall and hours of sunshine had a marked effect. The most important periods of the year, from the point of view of quality and seed yields, are the time of maximum bloom and the time of harvesting. It is essential in order to secure seed of good quality that the crop be harvested at the right time. Also equally important from the point of view of seed yield is that the weather during the pollination period be warm and sunny.

Seed Yield Components

The seed yield per unit area of red clover is the product of number of inflorescence per unit area, florets per inflorescence, seed setting, and unit seed weight. Collectively, these are referred as components of seed yield (30, 48).

a. Inflorescence per unit area

Red clover requires high metabolic reserves before floral development will proceed (6). The discrepancy in the photoperiodic requirements observed in several reports may be due to a temperature effect. The relationship between light intensity and the length of the light period appears to be one providing a maximal growth rate until the plant is receptive to the flowering stimulus. Thus, floral stems would be initiated whenever a plant in the proper physiological condition (ripe-to-flower), is placed under a favorable photoperiod. A trend toward higher top to root ratios was noted with increasing illumination period. Approximately 4 to 5 times more dry weight was accumulated in the tops than in the roots indicating that the bulk of the photosynthate in red clover is used to produce aerial tissues (6).

Stem development in red clover is slow due to its photoperiodic requirement to initiate stems (5). Several authors (5, 6, 62) have reported that medium red clover requires a photoperiod of at least 13 to 14 hours to flower; longer photoperiods are needed for flowering in mammoth red clover.

It has been shown by Williams (66) that red clover seed crops ripen very unevenly with some of the heads being fully ripe before others are in flower. This is a consequence of the wide range in the time of flowering of the different plants within each variety, and of the variation in heading within the individual plants. The major proportion of seed yield was from heads formed during early- and mid-flowering. Consequently relatively large yields losses may occur if harvest is delayed to wait for maturity of a minimal amount of late-formed seed (12).

A seed yield components study in a white clover done by Huxley et al. (30) found the major components were heads m^{-2} and seed weight, which accounted for 40.3% and 58.6% of the diversity in yield. It appears that cultural practices leading to greater head numbers, such as stand defoliation in early spring, would be a promising means of increasing seed yield.

In a study done at Lexington, Kentucky, and at Prosser, Washington, to asses the role of differential red clover seed-production capacity as factor in genetic shifts during seed multiplication, Taylor et al. (60) found that the number of heads was the primary factor in governing seed yields since it was significantly correlated with seed yield within each location. Number of seeds per head and seed weight were of less importance within each location.

The potential yield depends on the number of clover heads ha^{-1} as well as the number of seeds per head according to Hawkins (27). Dijktra (16) has shown that the correlation between the calculated number of heads and the seed yield per plant is high, and concluded that the number of heads per plant was decisive in determining seed yield. In addition, the number of heads per stem has been mentioned as an important factor in a dense crop (16). Williams (66) found the number of heads on spaced plants was considerably greater than on plants subjected to the severe competition of ordinary field crops. Seed yield might still depend upon environmental or other factors influencing seed number or size, but such effects would add to those of head number since heads m^{-2} is independent of seed number and seed size (30).

Research by Stoddart (57) indicated that the number of red clover blossoms per plant in the seed crop was closely related to the height of the crop when cut for silage, or to the severity of grazing. Recovery is dependent upon the number of axilary buds and vegetative tiller apices remaining below the cutting level.

b. Florets per Inflorescence

Huxley et al. (30) related the number of florets produced per raceme in red and white clover with the time during the season that the raceme is initiated. The number of seeds per head can be modified by insect damage or pollination and other environmental factors. The number of florets per head varies greatly not only in different plants but in different heads on the same plant, according to their position on the stem (66). Pankiw et al. (42) associated florets per head with climatic factors (primarily rainfall).

Only a few florets on a head open at the same time; those at the base of the head are usually open first, the others opening in a more or less regular succession. It generally takes from 6 to 10 days according to the weather conditions, for all the florets on a head to open (66).

At wide row spacing, plants produced not only a greater number of flowering stems, but also a greater number of flowers per stem (10). However, another report (11) indicated that the components of the potential seed yield per inflorescence had no effect on potential seed yield per meter of row.

Research by Pergament et al. (46) indicated that the cultivar Kenland responded with fewest flowering stems in the seedling year, while maximum floral production occured during the period following the first winter. Taylor and Kendal (61) found that reproductive stems were more uniform in the second than in the first year.

A range of 70 to 150 florets in the red clover heads had been reported by Wexelsen (63). According to Clifford (10) a bloom contains about 129 florets and blooms over a 7 day interval. This indicates that about 18 (129/7=18) florets are open per day per head. Studies by Pankiw et al. (43) report an average of 100 to 135 florets per head with one seed per pod. Bird (1) pointed out that the number might vary according to the position of the head on the plant, and ranged from 10 to 300, with the greatest number being on the main terminal heads which opened first, while the smallest number occurred on the late developed heads borne on the lower branches. When red clover is sown with other crops, number of florets per head were not affected by the nurse crops (41).

c. Seed Set

Seed set was dependent on the pollinator populations available and the weather conditions affecting their performance according to research done by Pankiw et al. (42). Although density of stand and profusion of bloom may determine the lower and upper limits of seed yields per hectare, wide fluctuations between such limits from season to season and from place to place may result from variation in seed set as was indicated by the average number of seed per head. It is important, however, to realize that the number of seeds per head is dependent, in turn, upon the number of floret per head, their condition at the time of pollination and fertilization, and the number and activity of pollinating insects (1).

The reproductive process is the obligatory sequence of floret formation, ovary, ovule and pollen grain formation, floret opening, fertilization, ovule maturation and provisioning through to mature harvestable seed. This sequence, as observed through flowering, is repeated many times over the reproductive period. In general the stages from floret to pollen grain formation occur under more beneficial environmental conditions (up to 10 weeks earlier) than the later stages from fertilization through to mature seed (13). Several authors (13, 16) reported that poor seed set in red clover was caused by the failure to produce embryo sacs, the loss of unfertilized embryo sacs soon after pollination and by embryo abortion. Therefore stress effects may not only be evident between inflorescences but also within the inflorescence itself. With the onset of stress, nutrient partitioning may favor vegetative growth at the expense of supported reproductive growth (13).

Wilsie (67) found a significant correlation between the size of the red clover head and the amount of seed set. Thus, the larger heads produced more seeds than did the smaller heads.

Seed yield was found by Hawkins (27) to be closely correlated with the number of seeds per head from crops of single-cut grown in England. He proposed that any factor which increased or reduced the number of seeds per head was likely to exert a similar effect on the yields of seed harvested. Further evidence of the importance of seed set in estimating the yield of red clover seed was provided by the study of length of corolla tube, number of pollinators and number of florets (28).

Hollowell (29) pointed out that an average of 25 seeds per head was considered sufficient to assure a fair seed crop under field conditions. Wexelsen (63) counted the number of seeds per head in a series of heads and obtained an average of 52.5 seeds per head. The pods of red clover normally contain one seed, although one or three ovules can be found (16).

It was found by Bird (1) that the ripest heads which had bloomed the earliest had the poorest set of seed. From the avilable data it would seem that, even under the most favorable conditions during this study, the florets setting seed did not exceed 75% of those available for pollination. The number of florets per head was, therefore, a rather minor factor in determining the number of seeds per head.

The effect of the season on rate of development of red clover seed was clearly brought out by an experiment conducted by Williams (66). The heads flowering later on the season produced lighter seeds than those flowering during the earlier part of the season. It is, however, probable that this very marked difference in the weight of the seeds may not be entirely due to the effect of the season. A reduced seed set was explained by Williams (66) partly by the fact that the weather conditions during the latter part of the season were less favorable to pollination, and partly by the fact that some of the very light seeds were lost during threshing and cleaning.

Weather conditions during the period of bloom are known to affect the condition of the flowering and the activity of pollinating insects from day to day. Sunshine combined with appropriate atmospheric moisture provided the most favorable weather for seed setting of red clover. A long period of heat with extremely dry air during the blooming period was found harmful by Bird (1), with the fewer heads tending to dry without attempting to form seed. The low set of seed obtained in periods of cold rainy weather was conditioned by a lack of pollinating insect visitors. Lower temperature accompanied by cloudy weather and intermittent precipitations when the red clover was in full bloom has been demonstrated by Pankiw et al (42) to reduce the efficiency of the pollinators and thus reduce the percent seed set.

Hawkins (27) has observed that the natural flowering period of red clover must coincide with the optimum pollination period to avoid variation in seed set. The rate of seed development depends to a large extent on the time of the year the flowers are pollinated. Under

Aberystwyth conditions the flowers pollinated during the second week in July were fully ripe within 34 to 38 days of pollination (66).

d. Seed Weight

In most cases, the seed weight determination is primarily important for the purpose of calculating the appropriate seed rates for sowing. The weight of the seed of individual plants within a cultivar was found to be extremely variable (66).

Variation in factors such as density of flowers, florets per flower and 1000-seed weight, did not appear to have been important contributions. Clifford (10) suggested that greater seed yield at the second than at the first harvest was associated with higher density of flowers, increased seed set, and, in particular, greater 1000-seed weight. Closing date may have effect on 1000-seed weight, number of florets per flower-head and flower-heads per stem depending of area of production and cultivars (12).

Plant Density

Plant density, which can affect stem, branch, and flower production, is one of the principal factors governing the number of blooms produced per unit area (57).

Studies on red clover at Aberystwyth (57) have shown that flower production falls when the population density deviates considerably in either direction from approximately 30 plants m^{-2}. On a field scale this density would result from a broadcast sowing at just under 2 kg ha^{-1} and it has been calculated that with adequate numbers of effective pollinators operating under ideal conditions, the theorical seed potential is about 1700 kg ha^{-1}.

An excessively large plant population was demonstrated to have a negative effect upon flower production under field conditions (57). Seventeen red clover plants m^{-2} is considered optimum for seed production in New Zealand (12), while Stoddart (57) data shows that optimum flowering is obtained with a population of 10 plants m^{-2}.

Stem density is a function of a number of plants and the number of stems per plant. Bowley et al. (4) noted that a pattern of stand deterioration occurs in red clover since although individual red clover plants produce more stems as the stand ages, but this is not sufficient to compensate for the continual decline in plant density, hence, yield declines.

From rate of seeding trials, Winch and Tossel (70) concluded that a range from 3.3 to 10 kg ha^{-1} resulted in corresponding range of established plants, but seeding rates had no influence on seed production. Thus, plant population did not affect seed yield. Pankiw et al (42) obseved that red clover has the ability to compensate for the varying plant populations within the rows at seeding rate between 1 and 5 kg ha^{-1} and spacing between 15 and 60 cm.

Pollination

It is well established that red clover flowers require insect pollination to produce seed. Although red clover is infrequently visited by honey bees, it does not necessarily follow that it is inadequately pollinated. It is believed that red clover flowers fail to attract honey bees because the long corolla tubes prevent honey bees with their short tongues from reaching the nectaries, whereas the longer-tongued bumble bees were always able to do so (27). The bumble bee has been generally considered the principal pollinating agent. It has been regarded as the most regular insect visitor, working rapidly and remaining active under weather conditions sufficiently adverse to restrict the activity of other pollinating insects. The honey bee has been considered a less efficient pollinator than the bumble bee since it lacks a proboscis of sufficient length to reach the nectar easily and is a more intermittent visitor with a slower rate of working. Bird (4) reported results in Iowa indicating that, while the honey bee might be as efficient as the bumble bee in the pollination of red clover during dry summers, they were less reliable in cool wet ones.

Wilsie and Gilbert (68), contrary to a popular expectations, said that the length of corolla tube was not a factor of importance in diploid cultivars since bees tend to visit those flowers where pollen was more abundant whether or not they could reach the bottom of the corolla tube to obtain all of the nectar present.

Crop attraction to pollinators is also a function of management practices to maximize inflorescence density and thereby yield (13). In red clover, nectar secretion depends on a carbohydrate surplus over and above that needed for growth, respiration and other concurrent processes (54). Therefore, the cultural practices for maintaining a good balance in nutrient partitioning between reproductive and vegetative growth must also be conductive to nectar secretion. A greater attractiveness for honey bees would presumably result in more pollination in the field and, consequently, an increase in seed setting (37, 68).

References by Williams (66) to the time of flowering of different cultivars brings out the fact that the period of maximum bloom of all the cultivars should coincide with the period during which the useful bees are present in greater numbers. The time of maximum bloom can be adjusted by the time of cutting. This point should be kept constantly in mind when scheduling the cutting.

Since unpollinated red clover florets remain open and capable of being pollinated for several days, such sporadic period of attractiveness may be sufficient for a satisfactory level of pollination to be achieved (27). Low seed yields can be due to many other causes than lack of pollination, including bad harvesting conditions, pest damage and, perhaps, some variation in the physiological ability of the plants to develop the fertilized ovules (27).

Cutting

Unfortunately, results of many of the American and European investigations of cutting for seed production of red clover give only the yields of seed per hectare and do not consider the effects upon seed yield components, the presence of absence of effective pollinators and losses in harvesting. Nevertheless, the results strongly indicate that for high seed yields of red clover, the first crop should be removed either by cutting or grazing when in the early bloom stage. Removal of the first crop at the early bloom stage usually (i) reduces the amount of damage from the seed-destroying insects and diseases, (ii) produces a vigorous second growth conducive to the production of many flowers per unit area, (iii) brings the second crop into bloom during the time when environmental factors favor flowering and pollination, and (iv) gives adequate time for seed maturation and harvesting during favorable weather (19).

Clipping red clover seed fields is a means of gaining a hay crop and delaying flowering (15). Mowing red clover to increase seed yields has been recommended by many authors. Wilsie and Hollowell (69) suggested the period June 1 to 15 as the most favorable time to harvest the hay crop when a seed crop is to be taken. They stated that the clover during this period would be in early bloom, quarter, or possibly nearly full bloom. Winch and Tossel (70) found that an early clipping produced higher seed yields but that seed harvested from the aftermath was lower in unit weight than seed from unclipped material. Contradictory results have been obtained by Williams (66), Stoddart (57), Winch and Tossel (70), and Hawkins (27), who observed that harvesting seed from the second crop may result in lower seed yield and quality; they found that heads flowering during the later part of the season produced lighter seed than those flowering early in the season.

When using grazing animals, an appropriate closing date is a prime determinant of the seed yield (13), and consistently higher seed yields were associated with increased number of flowering stems (12).

The differences in response to clipping between locations is undoubtedly due to the direct influence of environment. In western environments removing a hay crop in red clover resulted in reduced seed yields. However, the response of the morphological components of seed yield to environmental pressures varied with cultivar (50). Several authors (12, 50, 70) have recommended clipping the first spring growth of red clover to increase seed yields in the eastern and central red clover seed producing areas.

Irrigation

The function of irrigation for seed crops is to eliminate moisture stress over the reproductive phase. However in doing so, rate and frequency of application must be consistent to ensure the best level of nutrient partitioning between reproductive and vegetative growth (13). Stressing or wilting of the plants while they are in bloom reduces seed yields (51). Fergus at al. (19) recognized that by withholding of irrigation water from full bloom to seed harvest is possible to reduce seed yields and obtain lower seed quality. High seed yields are obtained by irrigating frequently throughout the growing and seed formation periods, using 2.5 to 5 cm of water per irrigation.

Red clover seed produced in the midwestern states is grown under natural rainfall conditions. It is most important that new seeding and established stands of red clover go into the winter months with adequate soil moisture, otherwise severe winter-killing may occur from freeze desiccation (51). Timely applications of irrigation water are required in the arid western states to obtain optimum growth and flowering for seed production of perennial clovers. In most areas red clover grown for seed requires from 90 to 140 cm of irrigation water applied during the growing season. However, in the more humid

Willamette Valley of Oregon, large amounts of red clover seed are grown with little or no irrigation water applied (51).

Irrigation water for red clover is usually surface applied in furrows about 0.5 to 1.0 m apart depending on soil types and cultural practices, however, in some areas of the Pacific Northwest it is applied by sprinklers. Flood irrigation is used on some red clover fields in California (51).

III. MATERIAL AND METHODS

1. Establishment

Two experiments were conducted during the crop season 1987-88 at Oregon State University's Hyslop Crop Science Field Laboratory, six miles northeast of Corvallis, in Benton County, Oregon (latitude 44.63 degrees north, longitude 123.20 degrees west, and elevation 69 m above sea level); on a Woodburn silt loam (fine-silty, mixed, mesic Aquultic Argixeroll) soil.

The crop history of the research area during the four preceding years was as follows: 1983, crimson clover; 1984, fallow; 1985, cuphea; and 1986, fallow.

Average annual rainfall was 974.1 mm. The weather conditions (temperature and rainfall) for the cropping season are summarized in Appendix Table 1.

The entire experimental area was plowed in June 1987 and summer-fallowed until time of seeding to controll weeds. The final seed bed was prepared prior to planting date by discing and harrowing. Soil pH was adjusted on the trial site, since it was less than 5.5, by incorporation of 9,800 kg ha^{-1} of agricultural limestone on August 28, 1987. At the same time fertilizer (250 kg ha^{-1} of 10-20-20-7,[S]) was applied uniformly over the block to be seeded and disked-in.

Kenland, a diploid (2x) cultivar, the most popular red clover variety presently grown in the Willamette Valley, was selected for this trial. The seed was produced in 1984 and belonged to a certified class. A germination test prior to planting by the Oregon State

University Seed Laboratory found 87% viable seed. All seed was inoculated with appropriate *Rhizobium* culture inmediatly prior to use.

Row width, rate of planting and date of planting were the main object of the study. The method of establishment used in the studies was by direct seeding of each individual row. Rows were marked with a hand marker and the seed was planted directly in the soil with a single row precision New Zealand Cone Planter.

Weeds were completely controlled by herbicide and timely cultivation. Pronamide (Kerb 50W, 1.1 kg ha^{-1}) was applied on November 25. A small hand cultivator was used to keep the area between rows free of competitive weeds.

At about 10% bloom (maximum vegetative growth) forage yield was determined by using a small plot flail harvester to remove 0.61 m wide samples from the length of each plot. Subsequently, forage from the entire plot area of each experiment was removed with a commercial flail chopper. These activities simulate haying of the spring growth, which is considered of prime importance for bringing regrowth to peak bloom during the best environmental conditions for seed production.

A border plot was planted 1.50 m from the last plot in each treatment to reduce edge effect.

Four colonies of honey bees (*Apis melifera* L.) were placed near the plots when the first planting was 10% bloom in attempts to saturate all the available bee-crops in the area and hence to overcome competition between the clover and other crops. A high activity of bumble bees (*Bombus* spp.) was also observed.

a. Experiment I: Planting date

The experiment was initiated in 1987 with two different seeding rates (2 and 4 kg ha^{-1}) and seeded at biweekly intervals during fall and spring. Fall and spring planting were made in separate but in adjacent blocks in the same field. The fall plantings were made on August 30, September 15 and 30, October 15 and 30, 1987; and the spring planting on March 15, April 1 and 15, May 1 and May 18, 1988. The seed bed was prepared again prior to each planting date by hand-rotovator and harrowing. Favorable weather and soil conditions permitted to do each seeding date as planned. Both experiments included a factorial combination of all date and seed rate possibilities.

Plots were seeded by planting seven rows. Each row was 4 m long spaced 30 cm apart. Planting depth was between 0.5 and 1 cm.

Field capacity was maintained in the top 10 cm of soil during the month following seeding (2 to 4 cm of water per irrigation delivered by overhead sprinklers). Irrigation was applied after the first and second seeding dates on the fall and after the herbage harvest on both fall and spring trials, while natural rainfall was sufficient for emergence on the rest of the plantings.

b. Experiment II: Row spacing

This experiment was conducted as a factorial arrangement to determine the influence of two different seeding rates and five row spacings on seed yield and yield components of red clover. The five row spacings were 15, 30, 45, 60, and 75 cm. The seeding rates were 2 and 4 kg ha^{-1}. Each plot was 3 m wide and 5 m long; thus, the 15 cm spacing included 34 rows; the 30 cm spacing included 17 rows; the 45 cm included 11 rows; the 60 cm included 9 rows, and the 75 cm spacing included 7 rows per plot. The date of planting was at fall on September 23.

Irrigation was applied after the sowing and as needed thereafter in the fall. No additional water was applied in the spring and summer.

2. <u>Data collection</u>

In order to achieve the objectives of this study the following measurements were made at the time of harvest or calculated afterwards:

a. Dry Matter:

Total herbage was measured by clipping all trials on June 10, 1988. All plots were defoliated (10 cm stubble) with a flail chopper at 10% flowering; the green forage was subsampled and dried in an oven at 71 C for 24 hours and re-weighed for calculation of percentage of dry weight yield per plot.

b. Height:

Plant height of regrowth at seed maturity was taken from two different areas of each plot from the crown of the plant to the base of the terminal flowering head.

c. Vegetative and Reproductive stems:

These measurements were taken at the flowering time before the plants reached full bloom, counting all vegetative and reproductive branches carrying florets and buds in 0.5 m row.

d. Plant Density:

Plant counts were taken from each plot in both trials. The stand counts were taken from two random subplots, 0.5 meters in length, after clipping in June to establish the plant population that produced a second-crop for seed.

e. Seed Yield:

Plants were considered mature when the majority of the heads had brown calyces and stems below the heads were yellowish green, and when seed readily shook free from the rest of the inflorescence if agitated between the hands. All plots were mechanically harvested with a small plot harvester. After harvest, the material was placed in burlap bags and dried under natural air. The seed was threshed in a continuous belt thresher and further cleaned with a M2-B Clipper air-screen cleaner and a seed blower. Weight in grams of the total number of seeds produced by each plot was recorded as seed yield and expressed in kg ha^{-1}.

Samples of 1 x 4 m were harvested for seed yield from all the plots in experiment 1; in the row spacing trial, entries were harvested across the rows in an area of 5 m^{-2}.

f. Seed Yield Components:

- Flower Density: at peak flowering, two observations were made on an area of 0.5 x 0.5 m in each plot to evaluate the number of flowers m^{-2}.

- Heads per stem: the number of heads per stem was counted from five reproductive stems, choosen at random.

- Florets per Head: five flowers were selected at random in each plot. Counting was done at the time of peak flowering.

- Seed Set: at maturity five head samples were taken at random from each plot and analyzed for number of florets per head and percent seed set (percent of flowers with seed).

- 1000-Seed Weight: the weight in grams of 1000-seed was used as a measure of seed weight. Five samples of 1000 seeds, each taken at random from the total seeds produced by each plot were used to estimate the 1000-seed weight.

g. Harvest Index:

It was calculated as the ratio of clean seed weight produced by each plot to the total above ground plant weight expressed as a percentage.

3. <u>Statistical analysis</u>

Both experiments -planting date and row spacing- were analyzed as a two-factorial in a randomized complete block design. Statistical analyses were conducted using the MSUSTAT Statistical Analysis Package. Analyses of variance (ANOVA) was calculated for all the data. The LSD (Least Significant Difference) was used for testing differences among entries for characteristic. A Student t-test was used to show mean differences. All differences are significant at the 5% level of probability unless otherwise indicated.

Simple correlation coefficients were used to estimate the degree of association between seed yield and the agronomic characters.

IV. RESULTS AND DISCUSSION

The results will be discussed in two major sections: planting date and row spacing, and the interaction of these factors with seeding rate. The following agronomic characters will be discussed within each section: seed yield, seed yield components and other agronomic characters.

In the establishment year air temperature and rainfall amounts were 8.7 C above and 17.03 cm below the 30-year averages, respectively. However, the climatic conditions during flowering and maturity were excellent for seed production. A summary of rainfall an temperature data for the crop season are presented in Appendix Table 1.

The observed mean squares from the analysis of variance for the selected agronomic characters measured are presented in Appendix Tables.

It should also be emphasized that the results apply only to a weed-free crop system and where pollination was not limiting.

Planting Date

Seed yield

The results in the fall and spring experiments are shown with the levels of significance in Tables 1 and 2. An analyses of variance (Appendix Table 4 and 5) of the seed yield in both seasons, fall and spring, showed that changes in seeding date caused highly significant differences in yield, while both rates of seeding, 2 and 4 kg ha^{-1} did

Table 1. Mean seed yield (kg ha^{-1}) of red clover at different fall planting dates and seeding rates.

Seeding Rate (kg ha^{-1})	Planting date					Mean*
	Aug 30	Sep 15	Sep 30	Oct 15	Oct 30	
2	756	749	793	605	451	671 a
4	690	703	695	589	522	640 a
Mean*	723 c	726 c	744 c	597 b	487 a	

* Means within columns or rows followed by the same letter are not significantly different from each other at 5% level.

Table 2. Mean seed yields (kg ha^{-1}) of red clover at different spring planting dates and seeding rates.

Seeding Rate (kg ha^{-1})	Planting date			Mean*
	Mar 15	Apr 1	Apr 15	
2	283	175	136	198 a
4	238	175	114	176 a
Mean*	261 b	175 a	125 a	

* Means within columns or rows followed by the same letter are significantly different from each other at 5% level.

not have any significance. There was no significant interaction between the main factors. Red clover produced higher seed yields from the earliest planting dates. The optimum fall planting ranged from the end of August (723 kg ha^{-1}) to the end of September (744 kg ha^{-1}). The optimum date for the spring planting was March 15 (261 kg ha^{-1}). Irrigation was necessary during the two first fall planting dates.

No completely satisfactory explanation can be given for these yields performance, but it is apparently associated with the moisture-temperature relationship. It is necessary to have the stand well established before prolonged rainfall or drought, and killing frost. Even so, earlier planting significantly outyielded later planting, presumably because of the higher amount of carbohydrate reserves available for the initiation of spring growth. Rather, the lower temperature and sometimes excessive soil moisture during October seemed to be the primary contributing factor to a slow rate of plant development that ultimately resulted in reduced plant size and low yields for the later seeding dates.

The last two spring seeding dates, May 1 and May 15, were not well established and did not produce a first year seed crop. A thin stand was established due to poor germination, probably a consequence of the higher temperatures, dry conditions and poor soil tilth conditions prior to seeding.

This tendency for higher yields from early plantings agree, in general, with data by other workers. Frame (20) proposed that early season growing of red clover when direct seeding is advisable and the influence of seed rates was less marked than sowing date. Also, early planting was preferred by Rincker and Rampton (51) to permit the plants to become well established before the onset of sub-freezing temperature during the winter and the onset of hot and dry summer weather. Early spring seeding was also preferred by Pankiw et al. (42). In general, these results are partially coincident with those proposed for the Pacific Northwest by Rincker and Rampton (51) who suggested fall seeded in mid-August to mid-September.

Is is unlikely that seeding rate could be increased sufficiently to compensate effectively for sowing in late season. Frame (20) obtained similar conclusions on red clover for forage production where adverse effects of late sowing were not fully offset by increased seed rate. Related with this are the results of Pankiw et al. (42) who showed that red clover has the ability to compensate for the varying plant population within the rows at seeding rate between 1 and 5 kg ha^{-1}.

Seed yields under farm conditions would have been lower than those obtained in these experiments. The land on which these experiments were planted was plowed and fallowed until planting time. All weed growth was controlled during the fallow period and chemical application. However, hand weeding control was used for the last two fall seeding dates. Thus, the areas where seedings were made had favorable moisture at planting time due to irrigation or rainfall, and were free of weed competition.

Seed yield components

The experimental results from both planting date trials showed, without exception, that date of sowing and rate of seeding interaction was not significant for all the seed yield components studied (Appendix Tables from 7a to 8b).

There were no measurable differences between the mean values of inflorescences per m^{-2}, florets per head, seeds per head, seed set, and weight of 1000-seed at the two seeding rates (Table 3).

The only component of seed yield that showed a highly significant difference was inflorescence per m^{-2}. The earliest planting dates producing the highest number of heads per unit area. Fall sown results showed that the mean number of heads from the first (August 30) planting was 70% higher than the last date of planting (October 30). The mean number for spring planting was significantly high, with the earliest (March 1) date producing the highest number of inflorescences per unit area (Table 4). Apparently, the decreased inflorescence number per m^{-2} for later seedings, is related with the concept in which red clover requires high metabolic reserves before floral development occurs. Similar results were reported by Taylor et al. (60) who stated that the number of heads was the primary factor in governing seed yields. Other yield components were of less importance.

Under the conditions of the fall planting date experiment, seeding dates on the average for maximum florets per head appears to be October 30, but September 15 and 30 did not appreciably alter the number of florets. However, early (August 30) and mid (October 15) plantings gave considerably lower yields (Table 5). Earlier spring planting dates gave a significantly higher mean number of florets per head (Table 6). Rate of seeding was also significant when spring sown, with a greater number of florets per head at the lower seeding rate

Table 3. Mean of seed yield components at different fall and spring planting dates and at two seeding rates.

	Date of planting			
	Fall		Spring	
	Seeding rate (kg ha^{-1})			
Seed yield components	2	4	2	4
Heads m^{-2}	463	489	160	158
Florets $head^{-1}$	97	104	115 b	76 a
Seeds $head^{-1}$	125	124	115	119
Seed set (%)	79	83	73	57
Wt 1000-seed (g)	1.72	1.71	1.61	1.61

* Means in each row do not vary significantly at the 5% level.

Table 4. Means of seed yield component: inflorescence m^{-2} at fall and spring planting dates.

Seeding Rate (kg ha^{-1})	Planting date				
	Aug 30	Sep 15	Sep 30	Oct 15	Oct 30
2	639	562	490	438	319
4	576	498	473	373	394
Means*	607 c	530 b	481 b	405 a	356 a
Seeding Rate (kg ha^{-1})	**Spring planting**				
	Mar 1	Apr 1	Apr 15	May 1	May 15
2	239	179	62	--	--
4	275	131	68	--	--
Means*	257 c	159 b	65 a	--	--

* Means within rows followed by the same letter are not significantly different at the 5% level.

Table 5. Means of seed yield components at different fall planting dates.

Seed yield components	Planting date				
	Aug 30	Sep 15	Sep 30	Oct 15	Oct 30
Florets $head^{-1}$	91 a	101 ab	104 ab	88 a	119 b
Seeds $head^{-1}$	123 a	119 a	136 a	117 a	128 a
Seed set (%)	75 a	86 a	79 a	76 a	89 a
Wt 1000-seed (g)	1.75 b	1.71 ab	1.72 ab	1.69 a	1.71 ab

* Any pair of means followed by the same letter are not significantly different at the 5% level.

Table 6. Means of seed yield components at different spring planting dates.

Seed yield components	Planting date		
	Mar 15	Apr 1	Apr 15
Florets head^{-1}	115 b	112 b	59 a
Seeds head^{-1}	118 a	124 a	109 a
Seed set (%)	101 b	66 ab	28 a
Wt 1000-seed (g)	1.65 b	1.59 ab	1.58 a

* Any pair of means followed by the same letter are not significantly different at the 5% level of probability.

(Table 4). However, florets per head was not correlated with seed yield (Table 7).

At all the fall planting dates, seeds per head and seed set were not affected by the five dates of planting. However, spring planting at the earliest date resulted in a significantly higher percentage in seed set (Table 5 and 6). Results from both fall and spring dates of planting indicated a significant decrease in the weight of 1000-seed as planting date was delayed (Table 5 and 6). This component of yield presented a high positive correlation with seed yield in the spring planting trial (Table 7).

Although a positive correlation between heads per stem and seed yields was observed at the spring sowing, heads m^{-2} showed a high positive correlation with seed yield at both planting date trials (Table 7). Thus, results indicated that inflorescences per unit area was the major yield component affecting seed yields.

Other agronomic characters

Plant density

Plant number per m^{-2} were higher at September 30 and April 15, and at the higher seeding rate of 4 kg ha^{-1} (Table 8).

Since plant counts were made after the spring cutting of the establishment year, it was not possible to determine whether some of late-sown seed did not germinate or whether it germinated but did not survive over winter. The latter is most probable for the fall dates since temperature and soil moisture were rather favorable at time of germination. According to Frame (21) the stage of development of the

Table 7. Coefficients of correlation between seed yield and seed yield components at fall and spring planting dates.

Traits	Seed yield	Heads m^{-2}	Heads $stem^{-1}$	Florets $head^{-1}$	Seed $head^{-1}$	Seed set	Wgt. 1000-seed
				Fall planting			
Seed yield	1.0	.67**	.14	-.12	.04	-.11	.17
				Spring planting			
Seed yield	1.0	.75**	.48*	.33	.38	.11	.83**

*, ** Significant correlation coefficient at the 5% and 1% level, resspectively

Table 8. Means of plants m^{-2} at fall and spring planting dates and two different seeding rates.

Seeding Rate ($kg\ ha^{-1}$)	Fall Planting					Means*
	Aug 30	Sep 15	Sep 30	Oct 15	Oct 30	
2	31	36	39	40	18	33 a
4	51	53	61	45	24	47 b
Means*	41 b	44 cb	50 c	42 b	21 a	
	Spring Planting					Means*
	Mar 15	Apr 1	Apr 15	May 1	May 15	
2	45	37	58	20	39	40 a
4	59	76	112	50	56	70 b
Means*	52 b	57 b	85 c	35 a	47 ab	

* Means within columns or rows followed by the same letter(s) are not significantly different from each other at 5% level.

clover plants at the establishment year is really important in determining their overwintering capacity; he affirmed that plant number was depressed by late sowing.

There was significant differences for seeding rates, increasing plant number as seed rate was increased. The highest seed rate produced mean densities of 47 plants m^{-2} and 70 plants m^{-2} for the fall and spring date trials, respectively (Table 8). These data were higher than other studies made at Abertyswyth (57), where any deviation from 30 plants m^{-2} altered one of the most important components of seed yield such as flower production.

Vegetative and reproductive stems

These characters were considered of importance since stem density is a function of the number of vegetative and reproductive stems per plant. A significant difference in the effect of date of sowing on reproductive stems was observed. The last fall date produced 15% less reproductive stems than the other sowing dates; while spring planting produced 43% more at earlier dates (Tables 9 and 10). The relevance of this trait was reflected by the high correlation found with seed yield at both planting date studies (Appendix Tables 15 and 17). Pederson (44) speculated that high levels of carbohydrate reserves stored in the roots stimulated reproductive rather than vegetative development. It was concluded that a high number of reproductive stems was needed for red clover to produce a satisfactory number of heads per unit area.

The number of vegetative stems was not significant for planting date or seeding rate at either fall or spring establishment (Tables 9 and 10).

Plant height

The canopy height of red clover declined with delayed date of planting, with the highest at August 30 and March 15 and with the lowest at the two later dates. It was noted that at the earliest planting date, plant height was 5 cm longer than the closer treatments (Tables 9 and 10). Decreased plant height among the different treatments was directly related with a decrease in seed yield since a high positive correlation was found between the two traits. No lodging was observed in any treatment. Seeding rates did not affect plant height.

Dry matter and Harvest Index

When removal of the crop at the early bloom stage was done at the fall planting trial, total dry matter yields differed significantly according to both seeding rate and date of sowing (Table 11). There was no significance planting date x seeding rate interactions. The most marked sowing date effect was at the earlier dates, which resulted in dry matter yields greater than 4.0 t ha^{-1}.

Seeding rate significantly affected the crop as dry matter yield increased from 2.7 t ha^{-1} at the lowest to 3.2 t ha^{-1} at the highest seeding rate (Table 11).

Table 9. Means of agronomic characters at five fall planting dates and two seeding rates.

Planting date	Vegetative Stems 50 cm^{-1}		Reproductive Stems 50 cm^{-1}		Plant Height
	No.	%	No.	%	(cm)
Aug 30	29 a	45	36 b	55	79 c
Sep 15	26 a	44	33 b	56	74 a
Sep 30	28 a	45	34 b	55	73 b
Oct 15	34 a	52	32 b	48	68 a
Oct 30	21 a	54	18 a	46	67 a
Seeding rate (kg ha^{-1})					
2	24 a		28 a		71 a
4	31 a		33 a		73 a

* Means within columns followed by the same letter are not significantly different from each other at 5% level.

Table 10. Mean agronomic characters at different spring planting dates and seeding rates.

Planting date	Vegetative Stems 50 cm^{-1}		Reproductive Stems 50 cm^{-1}		Plant Height
	No.	%	No.	%	(cm)
Mar 15	25 a	58	18 b	42	46 d
Apr 1	29 a	67	14 ab	33	40 c
Apr 15	34 a	76	11 a	24	35 b
May 1	--	--	--	--	12 a
May 15	--	--	--	--	8 a
Seeding rate ($kg\ ha^{-1}$)					
2	20 a		14 a		28 a
4	38 b		14 a		28 a

* Means within columns followed by the same letter are not significantly different from each other at 5% level.

Table 11. Means of dry matter and harvest index at fall and spring planting dates and at two seeding rates.

	Fall Planting					Seeding rate ($kg\ ha^{-1}$)	
	Aug 30	Sep 15	Sep 30	Oct 15	Oct 30	2	4
Dry matter ($t\ ha^{-1}$)	4.8 d	4.2 cd	4.1 c	1.5 b	0.2 a	2.7 a	3.2 b
Harvest index (%)	14 a	14 a	13 a	14 a	14 a	14 a	13 a

	Spring Planting				
	Mar 15	Apr 1	Apr 15	May 1	May 15
Harvest index (%)	15 a	11 a	14 a	--	--

Any pair of means followed by the same letter are not significantly at the 5% level of probability.

Since the amount of herbage in the spring dates at the cutting time was not sufficient, it was not possible to determine dry matter yields in this trial.

Previous work of Dade (15), Wilsie and Hollowell (68), and Fergus et al. (19), showed the importance of mowing red clover to increase seed yields. In the current study it was observed that clipping red clover at the early bloom stages is a means of gaining a hay crop and delaying flowering; it produces a vigorous second growth conducive to the production of many flowers per unit area, and brings the second growth crop during the time when environmental factors favor flowering, pollination, maturation and harvesting. Besides, an economic return of the hay should also be considered.

A range of 11 to 15% was reported for harvest index (Table 11). There were no differences at any planting date and seeding rate, with the only exception of a significant difference in rate of seeding at the fall dates. Because of the lack of published information it was not possible to make any comparison about harvest index with previous research.

Row Spacing

Seed yield

Competition among plants is an important factor in determining seeding rate and row spacing recommendations for high seed yield. When grown in the field, the individual plant is obscured by the population and yield is based on the seed weight from a given unit area.

Competition for light, nutrients and moisture are major considerations along with other unique factors in each selected environment. The yield of an individual plant of red clover is the product of number of inflorescences per unit area, florets per inflorescence, seed setting and unit seed weight. These have been reported as important seed yield components by Puri et al. (48) and Huxley et al. (30).

Results of these studies showed no interaction between row spacing and seeding rate; however, highly significant differences were noted when row spacings were compared. An increase in row width from 15 to 45 cm had no significant effect on seed yield within a range from 798 to 748 kg ha^{-1}. At wider row spacing (60 and 75 cm) seed yield was significantly lower (660 and 605 kg ha^{-1}, respectively). Also, significantly higher seed yield was attained when seeded at 2 kg ha^{-1} (Table 12).

Similar results were observed by Pankiw (40, 43), indicating that highest seed yield can be obtained from rates of 3-4 kg ha^{-1} and at 15, 30, 46, and 61 cm spacings. Pankiw (39) also concluded that the lowest rates of 2.2. kg ha^{-1} for the 30, 45 and 60 cm spacings are capable of producing the highest seed yield. Clifford (13) has suggested that lower seeding rates may result in greater use of sunlight by the plants, evenly distributed space for floral expression, better utilization of nutrients, and improve the attraction of pollinators to the crop, particularly in the narrow row spacing.

Several factors must be considered in determining the optimum seeding rate. One is the amount of moisture and its distribution during the growing season. According to Rincker and Rampton (51) most areas where red clover is grown for seed requires from about 90 to 140

Table 12. Means of seed yield (kg ha^{-1}) at different row spacings and seeding rates.

Seeding rate (kg ha^{-1})	Row spacing (cm)					Means*
	15	30	45	60	75	
2	877	845	740	653	647	752 b
4	719	726	756	668	563	686 a
Means*	798 c	786 c	748 bc	660 ab	605 a	

* Means within columns or rows followed by the same letter(s) are not significantly different from each other at 5% level.

cm of irrigation water applied during the growth season. Plants must have adequate moisture during the autumn months so that plants develop sufficient root reserves to escape from severe winter-killing that can occur from freeze desiccation. During this study 97.41 cm of rainfall was distributed throughout the crop season, with irrigation done during September, immediatly after the planting, and after the spring forage cut, with very dry conditions prevailing from the bloom stage on to maturity.

Seed yield components

No significant interaction between row spacing and seeding rates was observed for any of the seed yield components (Appendix Tables 12a and 12b).

Highly significant differences in both heads m^{-2} and heads per stem were observed at different row spacings. Inflorescence per unit area responded similarly to the seed yield mean comparisons, by producing more heads flowers per m^{-2} at the narrow (15, 30, and 45 cm) than at the wide row spacings (Table 13). However, at wide row spacings a significantly greater number of heads per stem were observed (Table 13). A positive correlation between heads m^{-2} and seed yield is evidence of the importance of this yield component (Table 14).

As would be expected, it is possible to find an appropriate row spacing for an optimum number of heads since this factor is significantly affected by competition of the crop. The number of heads per unit of area as a primary factor in governing seed yields was also pointed out by Taylor et al. (60), Hawkins (27) and Dijkstra (16);

Table 13. Mean of seed yield components: heads m^{-2} and heads $stem^{-1}$ at different row spacings and seeding rates.

Seeding Rate ($kg\ ha^{-1}$)	Row spacing (cm)					Means*
	15	30	45	60	75	
Heads m^{-2}						
2	727	568	665	524	493	595 a
4	714	711	668	581	477	630 a
Means*	720 c	639 bc	667 c	552 ab	485 a	
Heads $stem^{-1}$						
2	5	5	6	6	8	6 a
4	5	7	6	6	5	6 a
Means*	5 a	6 ab	6 ab	6 ab	7 b	

* Means within columns or rows followed by the same letter(s) are not significantly different from each other at 5% level.

while the number of heads per stem as an important factor in determining seed yield was reported by Dijkstra (16).

Row spacing and seeding rate are not the only factors that determine seed yield; other cultural practices can affect certain traits. Stoddart (57) related the number of red clover inflorescence per plant with the height of the crop when cut for silage, giving importance to the numbers of axilary buds and vegetative stems apices remaining below the cutting level. Therefore, it appears that cultural practices leading to a greater head number, such as appropriate row spacing and stand defoliation at appropriate time and height, should also be considered as a means of increasing seed yield.

The number of florets per inflorescence and seed per head were similar at the different row spacings and seeding rates studied (Table 15), and although no statistical differences were observed, the number of seed per head was high in all the treatments in this study. Florets per head and seeds per head were not correlated with seed yield (Table 14).

Bird (1) stated that the number of florets per head and the number of seed per heads were a minor factor in determining seed yields. Bird (1) also affirmed that seed per head is dependent upon the number of florets per head, their condition at the moment of pollination and fertilization, and the number and activity of pollinators.

The number of florets per head observed in this study was consistent with that reported by Wexelsen (63) and Pankiw et al. (43). However, the number of seeds per head are higher than those reported by Wexelsen (63) and Hollowell (29), which probably indicate the incidence

Table 14. Coefficients of correlation between seed yield and seed yield components at different row spacings and seeding rates.

Traits	Seed yield	Heads m^{-2}	Heads $stem^{-1}$	Florets $head^{-1}$	Seed $head^{-1}$	Seed set	Wgt. 1000-seed
Seed yield	1.00	.50**	-.06	-.05	.08	-.18	.45**

** Significant correlation at the 1% level.

Table 15. Means of seed yield components at different row spacings and seeding rates.

	Seed Yield Components			
Row spacing (cm)	Florets $head^{-1}$	Seeds $head^{-1}$	Seed set (%)	Weight 1000-seed
15	107 a	127 a	86 a	1.73 a
30	105 a	111 a	92 a	1.72 a
45	104 a	131 a	83 a	1.72 a
60	101 a	124 a	83 a	1.72 a
75	103 a	120 a	92 a	1.73 a
Seeding rate (kg ha^{-1})				
2	106 a	120 a	90 a	1.71 a
4	102 a	125 a	84 a	1.74 b

* Means in each column followed by the same letter do not differ significantly at the 5% level.

of an excellent pollinator activity and favorable weather conditions at the bloom period under Oregon conditions.

Seed set was not significantly affected by the treatments in this study (Table 15). This is in agreement with results reached by Pankiw et al. (42) in Canada. Use of pollinators and Oregon's ideal weather conditions may account for the exceptionally high seed set reported in this study.

An increase in seeding rate from 2 to 4 kg ha^{-1} was accompanied by a decrease in 1000-seed weight. There was no significant differences in 1000-seed weight among row spacings (Table 15). However, this yield component was positively correlated with seed yield (Table 14). This observation is consistent with those of Clifford (10) who found greater seed yield associated with greater 1000-seed weight.

Other agronomic characters

Plant density

Stand density was affected by both row spacing and seeding rates; however, no interaction between these factors was observed. A significantly lower plant number at the lower seeding rate suggest a logical relationship between the seeding rate and the plant density. Also, there was a highly significant difference in plant number at different row spacings, with the highest number in rows 15 cm apart (66 plants m^{-2}) and the lowest number at row spacings of 60 and 75 cm (26 and 24 plants m^{-2}, respectively) (Table 17). Decreased plant number per unit area was associated with a negative effect upon flower production per unit area. A relatively high negative correlation between plant density and seed yield was found (Table 16). Stoddart (57) observed the same phenomenon. Probably it was caused by an excessive intra-row competition.

Mean comparisons of plant density and reproductive stems were closely related, with stem density as a function of number of plants and number of stems. Similar results were reported by Stoddart (57), who found plant density was one of the principal factors altering the number of blooms produced per unit area affecting stem, branch and flower production.

Reproductive and vegetative stems

When number of stems were measured in different treatments, little attention was paid to the size or number of the heads, but all stems classified as reproductive were seed-head bearing. Thus, the reproductive and vegetative stems indicated an effect on seed yield. A highly significant difference in the effect of row spacing on reproductive stems numbers was observed, producing more at wide (75, 60 and 45 cm) than at narrow spacings (Table 17).

Significant differences were also obtained for vegetative stems, with fewer stems produced as row spacing decreased from 75 to 15 cm (Table 17).

Seeding rates affected only the production of vegetative stems. Increasing the seeding rate increased the vegetative stem number. A high negative significant correlation existed between vegetative stem

Table 16. Coefficients of correlation between seed yield and other agronomic characters at different row spacings and seeding rates.

Traits	Seed yield	Dry matter	Harvest index	Plant density	Veg. stems	Reprod. stems	Plant height
Seed yield	1.00	.07	.36*	-.51**	-.54**	-.33*	.60**

*, ** Significant correlation coefficient at the 5% and 1% level, respectively.

Table 17. Mean agronomic characters at different row spacing and seeding rates.

Row Spacing (cm)	Plant Density No.m^{-2}	Plant Height (cm)	Vegetative Stems 50 cm^{-1} No.	Vegetative Stems 50 cm^{-1} %	Reproductive Stems 50 cm^{-1} No.	Reproductive Stems 50 cm^{-1} %
15	66 d	80 b	13 a	29	32 a	71
30	52 c	79 ab	24 a	35	44 b	65
45	40 b	77 ab	46 b	46	53 c	54
60	26 a	75 a	59 b	48	64 c	52
75	24 a	76 a	60 b	50	61 c	50
Seeding Rate (kg ha^{-1})						
2	39 a	77 a	35 a		49 a	
4	45 b	78 a	46 b		51 a	

Means in each column followed by the same letter(s) do not differ significantly at the 5% level of probability.

number and seed yield (Table 16); this was expected because a high herbage production could be detrimental for seed production.

Plant height

A significant difference of about 5 cm in plant height among row spacings was observed (Table 17). Plant height has frequently been considered important in plant competition for light, aeriation and better pollinator activity. Row spacing affects the height of growing plants; decreased distance between rows generally results in taller plants. This concept was pointed out in this experiment since the plant height decreased when the row distance between rows increased. A high positive correlation between plant height and seed yield was observed (Table 16). Seeding rate had no effect upon plant height.

Dry matter and Harvest index

Red clover produced essentially the same yield of dry matter (3.5 and 3.7 t ha^{-1}) from both seeding rates used and there was a little difference in rows spaced 15 cm apart (Table 18). The high plant density per unit area may be one of the consequences of the high dry matter at this spacing. Total dry matter was not correlated with seed yield (Table 16).

Previous investigations discuss the beneficial (12, 15, 50, and 70) and negative (27, 61, and 57) effects of cutting red clover seed fields. Under the trial conditions, the treatments presented a maximum vegetative growth in June, as a consequence, mowing was considered of prime importance for bringing the second growth crop to peak bloom during best environmental conditions for seed production and pollinator activity.

Row spacing and seeding rate showed no variability in harvest index, with a general value of 13% (Table 18). A significant correlation of 0.36 existed between seed yield and harvest index (Table 16).

Table 18: Means of dry matter and Harvest index at different row spacings and seeding rates.

Planting date	Dry matter ($t\ ha^{-1}$)	Harvest index (%)
15	4.2 b	13 a
30	3.5 a	13 a
45	3.7 ab	13 a
60	3.3 a	13 a
75	3.3 a	13 a
Seeding rate ($kg\ ha^{-1}$)		
2	3.5 a	13 a
4	3.7 a	13 a

Any pair of means followed by the same letter are not significantly at the 5%.

V. SUMMARY AND CONCLUSIONS

The objectives of these experiments were to study the effects of selected row spacings and planting dates on seed yield, seed yield components, and agronomic characteristics of a selected variety of red clover, and the interaction of seeding rate with planting date and row spacing, under the environmental conditions of the Willamette Valley.

Data were obtained for seed yield, seed yield components (inflorescences per m^{-2}, inflorescences per stem, florets per inflorescence, seeds per inflorescence, seed set, weight of 1000-seed) and other agronomic characters (dry matter, harvest index, plant density, plant height, reproductive and vegetative stems).

Analysis of variance and coefficients of correlation were utilized to evaluate the different traits studied.

Fall seedings were made at 15-day intervals from August 30 to October 30, and from March 15 to May 15, during the spring. Two rates of seeding (2 and 4 kg ha^{-1}) were included for each date of planting. Five row spacings (15, 30, 45, 60, and 75 cm) and two seeding rates (2 and 4 kg ha^{-1}) were included in a second experiment.

The effects of different planting date, row spacing and seeding rate on the various agronomic traits measured are summarized for each experiment.

Planting date

Seed yield

Date of planting had significant effects on seed yields. Highest seed yields were obtained from the end of August to the end of

September for the fall planting, and middle March for the spring planting dates. Progressively lower yields were obtained for later seedings in fall and spring. Many of the late spring seedings failed to produce seed in the establishment year. Late fall and spring seeding were most heavily infested by weeds. It is probable that the decrease in yield with latter sowing is associated with the decrease of plant density when soil moisture and temperature conditions are less favorable for seed germination.

There was no significant effect of seeding rate on planting date.

Seed yield components

Seed heads per m^{-2} was the main seed yield component affecting both fall and spring dates of planting. Highest number of florets per unit area came from the earliest planting and it was positively correlated with seed yield.

Weight of 1000-seed was the other yield component found to be correlated with seed yield but only at the spring dates of sowing. Variation in other factors which might have influenced seed yield such as florets per head, seeds per head and seed set, did not appear to make important contributions.

Rate of seeding was significant only at the spring dates for the component florets per head, with the highest at the low rate. There was no effect of seeding rate on any other of the seed yield components studied.

Other agronomic characters

The best stand was obtained from September 30 and April 15 plantings. Both fall and spring experiments suggested that latter plantings were reflected in lower number of plants per unit area. There were significant differences for plant density between seeding rates.

Later fall and spring planting produced less reproductive stems than earlier dates. This trait was found highly correlated with seed yield. Vegetative stems were not influenced by planting date or seeding rate at either fall or spring establishment.

Decrease in plant height was directly related with a decrease in seed yield, with the higher plant height at the earlier planting. This trait was positively correlated with seed yield. Seeding rate did not affect plant height.

There was a significant difference in the dry matter production at forage harvest at the early bloom stage as a result of both seed rate and date of planting in the fall planting trial. Earlier planting, August 30 and September 15, resulted in the highest dry matter yields of 4.8 and 4.2 t ha^{-1}, respectively. As seeding rate increased from 2 to 4 kg ha^{-1}, dry matter increased. A high correlation of dry matter with seed yield was observed.

Dry matter was not determined for the spring planting dates because a limited amount of herbage was present at the time of cutting.

Planting date and seeding rate appear to have no influence on harvest index, with the only exception at the fall dates where a difference was observed at the low rate. Harvest index was not correlated with seed yield.

These results suggest that seed growers should sow red clover early in the fall for both a hay cut and a high seed yield in the establishment year. Early spring planting is another good alternative, although the seed yields at the first year are reduced compared with the fall planting dates.

Row spacing

Seed yield

A significant influence on seed yield of both row spacing and seeding rate was noted. Spacings of 15, 30 and 45 cm produced maximum seed yields. Although there was no interaction between row spacing and seeding rate, highest yields were obtained at 2 kg ha^{-1}.

Using narrow rows appear to be one of a series of steps that has led to higher crop yields for growers. However, to obtain a high yield response from narrow row widths, the growers must have already adopted other management tools leading to high yields (e.g. using adapted varieties, fertilization, timely cultural practices, weed control, uniform plant distribution within the rows). Weeds should be considered when row spacing for seed production is chosen; they may have some effect on seed production since in the width row spacing and particularly at lower rates of seeding the weeds can become a problem, but less evident in narrow spacings. Besides, weed control is difficult in rows too narrow when cultivation is considered.

Seed yield components

The major component of yield in this study was inflorescence per unit area. Correlation coefficients showed that heads m^{-2} contributed the most to yield. Planting rows 15, 30 and 45 cm apart resulted in a higher number of heads per unit area.

No differences were evident at the various rates and spacings in either number of florets per head, seeds per head, or seed set. Increased seeding rate resulted in an increase of the weight of 1000-seed, presenting a positive correlation with seed yield. A low correlation was observed between seed yield and other yield components, which supports the conclussion that heads per unit area are the most important yield component.

Other agronomic characters

Any decrease in the plant number per unit area affected seed yield. Range from 66 to 40 plants m^{-2} produced the highest seed yield. Both vegetative and reproductive stems were influenced by the different row spacings. Vegetative stems had a negative correlation with seed yield. Narrow row spacings presented a high percentage of reproductive stems compared with vegetative stems, what is related with the highest seed yield obtained at these row spacings. A seeding rate of 4 kg ha^{-1} resulted in a higher number of vegetative stems per unit area.

Height of plants was decreased at increased row distances; no influence was observed at different rate of seeding. A high positive correlation between this trait and seed yield was observed.

Dry matter production was higher at rows spaced 15 cm apart and was positively correlated with seed yield. No effect of seeding rate on dry matter at the spring forage cut was observed.

Harvest index was positively correlated with seed yield.

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APPENDIX

Appendix Table 1: Weather summary for crop year 1987-88. Corvallis, Oregon (49).

Air temperature (C)

Year	Month	Mean Max.	Mean Min.	Mean	Dev. Norm.	High	Low
1987	August	28.8	11.0	19.9	+1.2	36.7	7.2
	September	26.1	8.2	17.1	+0.7	38.3	2.8
	October	23.0	5.3	14.1	+2.4	31.1	0.6
	November	12.1	4.9	8.5	+1.4	17.8	-1.1
	December	6.5	1.4	3.9	-0.9	15.0	-5.0
1988	January	7.1	0.7	3.9	0.0	13.9	-5.0
	February	11.2	1.6	6.4	+0.5	17.2	-3.3
	March	13.5	2.5	8.0	+0.8	21.1	-1.7
	April	16.1	5.6	10.8	+1.4	25.6	-0.6
	May	17.9	6.6	12.2	-0.4	30.0	1.7
	June	22.0	9.2	15.6	-0.2	31.1	3.9
	July	28.0	11.0	19.5	+0.8	38.3	3.3
	August	28.1	10.1	19.1	+0.4	37.8	5.6
	September	26.0	8.0	17.0	+0.6	39.4	1.1
Total					+8.7		

Precipitation and Evaporation (cm)

Year	Month	Rain	Dev. Norm.	Snow	Evap.	Dev. Norm.
1987	August	0.43	-1.63	0.0	21.06	+3.28
	September	0.13	-3.63	0.0	13.54	+1.47
	October	0.69	-7.92	0.0	11.61	+6.29
	November	9.91	-5.76	0.0	M	
	December	29.01	+9.27	4.3	M	
1988	January	18.08	-1.10	1.5	M	
	February	4.32	-8.02	1.5	M	
	March	9.91	-1.85	0.0	M	
	April	8.46	+2.21	0.0	6.68	-0.28
	May	9.75	+4.87	0.0	9.63	-1.70
	June	4.65	+1.06	0.0	13.34	-1.14
	July	0.23	-0.56	0.0	22.23	+2.47
	August	0.00	-2.06	0.0	21.13	+3.35
	September	1.85	-1.91	0.0	15.09	+3.02
Total		97.41	-17.03	7.3		

Appendix Table 2. Mean seed yield (kg ha^{-1}) at fall planting dates and at two seeding rates.

Seeding Rate (kg ha^{-1})	Fall Planting					Means
	Aug 30	Sep 15	Sep 30	Oct 15	Oct 30	
2	784	781	870	719	592	749
4	668	648	645	685	542	637
2	820	745	1006	583	468	724
4	750	731	652	596	565	659
2	634	770	612	616	447	616
4	789	690	785	536	493	658
2	786	701	683	501	298	594
4	554	744	699	540	487	605
Means	723	726	744	597	486	

Appendix Table 3. Mean seed yield (kg ha^{-1}) at spring planting dates and at two seeding rates.

Seeding Rate (kg ha^{-1})	Spring Planting			Means
	Mar 15	Apr 1	Apr 15	
2	349	284	190	274
4	234	177	155	189
2	392	173	151	239
4	309	241	104	218
2	251	130	40	141
4	280	150	14	148
2	141	112	164	139
4	130	105	184	140
Means	261	172	125	

Appendix Table 4. Mean seed yield (kg ha^{-1}) at diferent row spacings and seeding rates.

Seeding Rate (kg ha^{-1})	Row Spacing					Means
	15	30	45	60	75	
2	980	992	795	900	801	894
4	796	690	897	758	547	737
2	881	945	614	609	626	735
4	740	695	871	654	576	707
2	772	833	834	677	509	725
4	718	817	626	561	560	656
2	874	609	717	424	653	655
4	622	703	629	698	570	644
Means	798	786	748	660	605	

Appendix Table 5. Summary of the observed mean squares from analysis of variance for seed yield at different fall planting dates and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Seed Yield	Reps	3	20710	
	SR	1	9560	1.32 NS
	PD	4	98880	13.64 **
	SR x PD	4	8193	1.13 NS
	Error	27	6248	

** Significance level at 1% of probability.
SR = Seeding rate
PD = Planting date

Appendix Table 6. Summary of the observed mean squares from analysis of variance for seed yield at different spring planting dates and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Seed Yield	Reps	3	14930	
	SR	1	3026	.67 NS
	PD	2	37620	8.30 **
	SR x PD	2	992.30	.22 NS
	Error	15	4532	

** Significance level at 1% of probability.
SR = Seeding rate
PD = Planting date

Appendix Table 7a. Summary of the observed mean squares from analysis of variance of seed yield components at different fall planting dates and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Heads m^{-2}	Reps	3	14170	
	SR	1	7129	1.32 NS
	PD	4	79030	14.58 **
	SR x PD	4	7359	1.36 NS
	Error	27	5421	
Heads $stem^{-1}$	Reps	3	.76	
	SR	1	.004	.002 NS
	PD	4	3.33	1.98 NS
	SR x PD	4	1.74	1.03 NS
	Error	27	1.69	
Florets $head^{-1}$	Reps	3	1248	
	SR	1	396.90	1.08 NS
	PD	4	1169	3.17 *
	SR x PD	4	486	1.32 NS
	Error	27	369.10	

*,** Significance level at 5 and 1%.
SR = Seeding rate
PD = Planting date

Appendix Table 7b. Summary of the observed mean squares from analysis of variance of seed yield components at different fall planting dates and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Seeds head^{-1}	Reps	3	84.82	
	SR	1	24.02	.06 NS
	PD	4	474.1	1.24 NS
	SR x PD	4	7.65	.02 NS
	Error	27	381.4	
Seed set	Reps	3	549.5	
	SR	1	211.6	.73 NS
	PD	4	289.9	.99 NS
	SR x PD	4	132.7	.46 NS
	Error	27	289.9	
Weight 1000-seed	Reps	3	.0019	
	SR	1	.0005	.39 NS
	PD	4	.0038	2.99 *
	SR x PD	4	.0004	.31 NS
	Error	27	.0013	

* Significance level at 5% of probability.
SR = Seeding rate
PD = Planting date

Appendix Table 8a. Summary of the observed mean squares from analysis of variance of seed yield components at different spring planting and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Seeds head^{-1}	Reps	3	653.4	
	SR	1	121.5	.71 NS
	PD	2	463.0	1.55 NS
	SR x PD	2	389.6	1.30 NS
	Error	15	299.7	
Seed set	Reps	3	2522	
	SR	1	1634	1.12 NS
	PD	2	10740	7.35 **
	SR x PD	2	3081	2.11 NS
	Error	15	1460	
Weight 1000-seed	Reps	3	.0015	
	SR	1	.0001	.60 **
	PD	2	.0098	3.54 *
	SR x PD	2	.0003	.12 NS
	Error	15	.0028	

*,** Significance level at 5 and 1%.
SR = Seeding rate
PD = Planting date

Appendix Table 8b. Summary of the observed mean squares from analysis of variance of seed yield components at different spring planting dates and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Heads m^{-2}	Reps	3	4161	
	SR	1	2817	.008 NS
	PD	2	73440	23.12 **
	SR x PD	2	3670	1.16 NS
	Error	15	3177	
Heads $stem^{-1}$	Reps	3	1.17	
	SR	1	2.10	2.61 NS
	PD	4	8.17	10.16 **
	SR x PD	4	.72	.90 NS
	Error	27	.80	
Florets $head^{-1}$	Reps	3	73.34	
	SR	1	9124	75.96 **
	PD	4	7966	66.32 **
	SR x PD	4	9211	76.69
	Error	27	120.10	

** Significance level at 1%.
SR = Seeding rate
PD = Planting date

Appendix Table 9a. Observed mean squares from analysis of variance of agronomic characters at different fall planting dates and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Vegetative stems	Reps	3	306.2	
	SR	1	469.2	1.96 NS
	PD	4	183.5	.77 NS
	SR x PD	4	102.2	.43 NS
	Error	27	239.4	
Reprod. stems	Reps	3	51.90	
	SR	1	193.60	1.98 NS
	PD	4	409.60	4.19 **
	SR x PD	4	86.85	.89 NS
	Error	27	97.81	
Plant density	Reps	3	110	
	SR	1	1960	36.07 **
	PD	4	988.80	18.20 **
	SR x PD	4	131.70	2.42 NS
	Error	27	54.34	

*,** Significance level at 5 and 1%.
SR = Seeding rate
PD = Planting date

Appendix Table 9b. Observed mean squares from analysis of variance of agronomic characters at different fall planting date and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Plant height	Reps	3	.83	
	SR	1	30.63	2.01 NS
	PD	4	211.70	13.88 **
	SR x PD	4	40.20	2.64 NS
	Error	27	15.24	
Dry matter	Reps	3	.77	
	SR	1	2.12	5.97 *
	PD	4	31.49	88.86 **
	SR x PD	4	.15	.42 NS
	Error	27	.35	
Harvest index	Reps	3	6.56	
	SR	1	21.02	17.70 **
	PD	4	.65	.55 NS
	SR x PD	4	1.15	.97 NS
	Error	27	1.19	

*,** Significance level at 5 and 1%.
SR = Seeding rate
PD = Planting date

Appendix Table 10a. Summary of the observed mean squares from analysis of variance of seed yield components at different spring planting dates and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Vegetative stems	Reps	3	128.20	
	SR	1	1998.00	15.84 *
	PD	2	147.20	1.17 NS
	SR x PD	2	235.50	1.87 NS
	Error	15	126.10	
Reprod. stems	Reps	3	17.39	
	SR	1	2.67	.21 NS
	PD	2	94.54	7.45 **
	SR x PD	2	1.79	.14 NS
	Error	15	12.69	
Plant density	Reps	3	349.2	
	SR	1	9303	44.00 **
	PD	4	2728	12.90 **
	SR x PD	4	559.1	2.64 NS
	Error	27	211.4	

** Significance level at 1% level of probability.
* Significance level at 5% of probability.
SR - Seeding rate
PD - Planting date

Appendix Table 10b: Summary of the observed mean squares from analysis of variance of seed yield components at different spring planting dates and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Plant height	Reps	3	193.60	
	SR	1	3.03	.12 NS
	PD	4	2343.00	92.84 **
	SR x PD	4	10.85	.43 NS
	Error	27	25.23	
Harvest index	Reps	3	.82	
	SR	1	15.04	1.12 NS
	PD	2	28.67	2.13 NS
	SR x PD	2	.67	.05 NS
	Error	15	13.45	

** Significance level at 1% level of probability.
 * Significance level at 5% of probability.
SR = Seeding rate
PD = Planting date

Appendix Table 11. Summary of the observed mean squares from analysis of variance for seed yield at differeent row spacings and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Seed Yield	Reps	3	49720	
	SR	1	43520	4.48 *
	RS	4	55790	5.74 **
	SR x RS	4	12430	1.28 NS
	Error	27	9713	

** Significance level at 1% level of probability.
* Significance level at 5% of probability.
SR = Seeding rate
RS = Row spacing

Appendix Table 12a. Summary of the observed mean squares from analysis of variance of seed yield components at different row spacings and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Seeds head^{-1}	Reps	3	270.4	
	SR	1	292.7	.64 NS
	RS	4	462.0	1.01 NS
	SR x RS	4	505.2	1.10 NS
	Error	27	458.2	
Seed set	Reps	3	78.7	
	SR	1	313.6	.42 NS
	RS	4	165.7	.22 NS
	SR x RS	4	492.3	.66 NS
	Error	27	748.9	
Weight 1000-seed	Reps	3	.0150	
	SR	1	.0093	10.01 **
	RS	4	.0004	.40 NS
	SR x RS	4	.0012	1.31 NS
	Error	27	.0009	

** Significance level at 1% level of probability.
SR = Seeding rate
RS = Row spacing

Appendix Table 12b. Summary of the observed mean squares from analysis of variance of seed yield components at different row spacings and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Heads m^{-2}	Reps	3	44950	
	SR	1	12040	1.02 NS
	RS	4	70210	5.93 **
	SR x RS	4	8984	.76 NS
	Error	27	11830	
Heads $stem^{-1}$	Reps	3	1.81	
	SR	1	.12	.07 NS
	RS	4	2.35	1.37 NS
	SR x RS	4	5.23	3.04 *
	Error	27	1.71	
Florets $head^{-1}$	Reps	3	133	
	SR	1	156	.4 NS
	RS	4	34.22	.09 NS
	SR x RS	4	325	.82 NS
	Error	27	394.8	

** Significance level at 1% level of probability.
* Significance level at 5% of probability.
SR = Seeding rate
RS = Row spacing

Appendix Table 13a. Observed mean squares from analysis of variance of agronomic characters at different row spacings and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Vegetative stems	Reps	3	843.3	
	SR	1	1103	4.76 *
	RS	4	3633	15.69 **
	SR x RS	4	271.1	1.17 NS
	Error	27	231.5	
Reprod. stems	Reps	3	73.03	
	SR	1	21.02	.25 NS
	RS	4	1200	14.39 **
	SR x RS	4	117.4	1.41 NS
	Error	27	83.38	
Plant density	Reps	3	209.80	
	SR	1	360	7.66 *
	RS	4	2543	54.12 **
	SR x RS	4	33.50	0.71 NS
	Error	27	46.99	

** Significance level at 1% level of probability.
 * Significance level at 5% of probability.
SR = Seeding rate
RS = Row spacing

Appendix Table 13b. Observed mean squares from analysis of variance of agronomic characters at different row spacings and seeding rates.

	Source of Variation	Degrees of Freedom	Mean Squares	F
Plant height	Reps	3	63.12	
	SR	1	1.60	.09 NS
	RS	4	38.16	2.15 *
	SR x RS	4	19.29	1.09 NS
	Error	27	17.75	
Dry matter	Reps	3	.19	
	SR	1	.27	.84 NS
	RS	4	1.10	3.38 *
	SR x RS	4	.27	.83 NS
	Error	27	.33	
Harvest index	Reps	3	5.73	
	SR	1	1.23	.69 NS
	RS	4	.40	.23 NS
	SR x RS	4	.35	.20 NS
	Error	27	1.77	

** Significance level at 1% level of probability.
 * Significance level at 5% of probability.
SR = Seeding rate
RS = Row spacing

Appendix Table 14. Coefficients of correlation between seed yield and seed yield components at fall planting dates.

Traits	Seed yield	Heads m^{-2}	Heads $stem^{-1}$	Seeds $head^{-1}$	Seed set	Wgt. 1000-seed
Seed yield	1.0	.66**	.14	.04	-.12	.17
Heads m^{-2}		1.0	.32*	-.03	-.10	.41**
Heads $stem^{-1}$			1.0	-.10	-.02	.03
Seeds $head^{-1}$				1.0	-.38	.11
Seed set					1.0	-.14
Wgt. 1000-seed						1.0

** Significant correlation at the 1% level.
* Significant correlation at the 5% level.

Appendix Table 15. Coefficients of correlation between seed yield and other agronomic characters at different fall planting dates.

Traits	Seed yield	Plant density	Veg. stems	Reprod. stems	Plant height	Harvest index	Dry matter
Seed yield	1.0	.30	.05	.41**	.55**	.15	.69**
Plant density		1.0	.20	.33*	.35*	-.28	.50**
Veg. stems			1.0	.25	.01	-.15	.04
Reprod. stems				1.0	.14	-.08	.49**
Plant height					1.0	-.07	.67**
Harvest index						1.0	-.14
Dry matter							1.0

*, ** Significant correlation coefficient at the 5% and 1% level, resspectively

Appendix Table 16. Coefficients of correlation between seed yield and seed yield components at different spring planting dates.

Traits	Seed yield	Heads m^{-2}	Heads $stem^{-1}$	Seed $head^{-1}$	Seed set	Wgt. 1000-seed
Seed yield	1.0	.75**	.48*	.38	-.11	.83**
Heads m^{-2}		1.0	.50*	.18	-.28	.60**
Heads $stem^{-1}$			1.0	-.14	-.1	.51*
Seed $head^{-1}$				1.0	-.25	.19
Seed set					1.0	-.09
Wgt. 1000-seed						1.0

** Significant correlation at the 1% level.
 * Significant correlation at the 5% level.

Appendix Table 17. Coefficients of correlation between seed yield and other agronomic characters at different spring planting dates.

Traits	Seed yield	Plant density	Veg. stems	Reprod. stems	Plant height	Harvest index
Seed yield	1.0	-.25	-.15	.65**	.79**	-.26
Plant density		1.0	.44*	-.14	-.13	.07
Veg. stems			1.0	-.05	.02	-.13
Reprod. stems				1.0	.39	-.13
Plant height					1.0	.01
Harvest index						1.0

*, ** Significant correlation coefficient at the 5% and 1% level, resspectively

Appendix Table 18. Coefficients of correlation between seed yield and seed yield components at different row spacings and seeding rates.

Traits	Seed yield	Heads m^{-2}	Heads $stem^{-1}$	Seeds $head^{-1}$	Seed set	Wgt. 1000-seed
Seed yield	1.0	.50**	-.06	.08	-.18	.45**
Heads m^{-2}		1.0	-.09	.08	-.19	.49**
Heads $stem^{-1}$			1.0	.14	-.22	.13
Seeds $head^{-1}$				1.0	-.74**	.21
Seed set					1.0	-.31
Wgt. 1000-seed						1.0

** Significant correlation at the 1% level.

Appendix Table 19. Coefficients of correlation between seed yield and other agronomic characters at different row spacings.

Traits	Seed yield	Dry matter	Harvest index	Plant density	Veg. stems	Reprod. stems	Plant height
Seed yield	1.0	.07	.36*	-.51**	-.54**	-.33*	.60**
Dry matter		1.0	.03	-.17	-.35*	-.35*	.22
Harvest index			1.0	-.27	-.28	.05	.45**
Plant density				1.0	.59**	.40*	-.41**
Veg. stems					1.0	.65**	-.48**
Reprod. stems						1.0	-.13
Plant height							1.0

*, ** Significant correlation coefficient at the 5% and 1% level, respectively.