Late Summer Irrigation and Establishment of Winter Annual Legumes in a Mediterranean-type Climate[1]

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ABSTRACT

Winter annual legumes have low fall and early winter forage yields in California's Mediterranean-type climate. A 2-year field study was conducted to determine the effects of late summer irrigation on seedling development, forage yield potential, and management problems of subterranean clover (*Trifolium subterraneum* L.), rose clover (*Trifolium hirtum* All.), and bur clover (*Medicago polymorpha* Gaertn). A mixture of three annual grasses, slender wild oats (*Avena barbata* Pott. ex Link), 'Blando' brome (*Bromus mollis* L.), and annual ryegrass (*Lolium multiflorum* L.), and a natural stand of indigenous species were included in the study for comparison. By irrigation prior to fall rains, we subjected six successive seedings, 2 weeks apart, to higher temperatures and longer fall-growth periods than usual.

Rates of morphological development of subclover and rose clover were measured until the seven-leaf stage. In the 1972-73 season, rose clover showed the largest differences in growth rates between planting dates. Rose clover from the 23 October planting required 90 more days to reach the seven-leaf stage than when planted 29 September. Early-flowering subclover from the 23 October planting grew more rapidly than did mid-flowering subclover and rose clover. In the 1973-74 season, late-flowering subclover had the fastest growth rate following 7 August irrigation; there were no differences between clovers following 20 September irrigation.

Forage yields for August and September plantings were similar but were greater than those from the October planting. Plants irrigated in August were subjected to daylengths which promoted fall flowering. Summer insect problems, primarily with beet armyworm (*Spodoptera exigua* Hübner), were associated with August plantings. Subterranean clover produced more dry matter and had fewer problems than did the other legumes tested.

Additional index words: **Leaf index number, Planting date, *Trifolium subterraneum, Trifolium hirtum, Medicago polymorpha.***

CISMONTANE California has a Mediterranean climate, i.e., cold, wet winters and hot dry summers. Seeds of the winter annual plants germinate in the late fall, when both air and soil temperatures are declining, and plants grow very slowly through the winter months.

Cold temperatures reduce plant growth even with an excess of nutrients available (3, 4). McKell et al. (4) reported that subterranean (*Trifolium subterraneum* L.) and crimson (*T. incarnatum* L.), clovers responded to P fertilization at lower temperatures than six other legume species. Soil temperatures appear to have more effect on plant growth than do air temperatures. The growth rate of subterranean clover was reduced when soil temperature was 10 C and air temperature an optimum 20 C (7).

The purpose of this study was to measure seedling development, forage-yield potential and management problems of winter annuals, primarily legumes, when supplemental irrigation was used to start growth in late summer.

MATERIALS AND METHODS

The 2-year experiment was conducted at the University of California Sierra Foothill Range Field Station, Browns Valley, Calif., starting 3 Aug. 1972. Seven plant species treatments, three of subterranean clover and one each of rose clover (*Trifolium hirtum* All.), bur clover (*Medicago polymorpha* Gaertn), grass species, and indigenous species, were planted on six dates, 2 weeks apart. The six planting dates, 3 Aug., 16 Aug., 31 Aug., 13 Sept., 29 Sept., and 23 October 1972 were assigned planting date numbers of 1 through 6, respectively. The sixth planting date (23 October) was 10 days later than planned because of an early rain. The three subterranean clover treatments were three maturity classes, consisting of cultivars that were early-flowering (subsp. *subterraneum* L. 'Geraldton', 'Daliak', and

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Table 1. Days required for plant to reach seven-leaf stage of morphological development and b-values of linear regressions for rates of morphological development.

Legumes	Planting dates (1972)						Irrigation dates (1973)			
	13 Sept. (4)		29 Sept. (5)		28 Oct. (6)		7 Aug.		20 Sept.	
Subclovers	Days	b-value	Days	b-value	Days	b-value	Days	b-value	Days	b-value
Early	42	0.21 a**	47	0.15 a	120	0.09 a	48	0.18 a	70	0.13 a
Mid	42	0.20 a	47	0.15 a	125	0.07 b	46	0.19 a	77	0.11 a
Late	40	0.23 a	48	0.15 a	123	0.08 ab	43	0.22 b	77	0.12 a
Rose clover	44	0.19 a	52	0.14 a	140	0.07 b	51	0.18 a	92	0.09 a

** b-values followed by the same letter in a column do not differ significantly ($P = 0.01$).

subsp. *yanninicum* Katnelson and Morley, 'Yarloop'), mid-flowering (subsp. *subterraneum* L. 'Howard', 'Dinninup', and 'Woogenellup'), and late-flowering (subsp. *subterraneum* L. 'Tallarook' and 'Mt. Barker'). The rose clover treatment contained the cultivars 'Wilton' and 'Hykon.' The grass treatment consisted of slender wild oats (*Avena barbata* Pott. ex Link), 'Blando' brome (*Bromus mollis* L.), and annual ryegrass (*Lolium multiflorum* L.). The indigenous species treatment consisted of plots placed on an adjacent undisturbed area containing the resident annual grasses, forbs, and legumes found on the experimental site.

Each plant-species treatment was planted in 1 × 1-m plots, replicated four times per planting date. A completely randomized block design was used, blocking only the seven plant-species treatments. These replicated blocks were randomized through the field for each planting date.

The plot area, excluding the indigenous-species plots, was sprayed with paraquat (0.56 kg/ha) prior to each planting to eliminate resident volunteer plants. All plots were fertilized with 44 kg/ha of P at planting. The grass and indigenous species plots had a split application of 56 kg/ha of N, half applied at planting and half on November 9. All legume seeds were inoculated with appropriate commercial cultures of *Rhizobium* and pelleted using gum arabic and $CaCO_3$ (4). Seedling rates were 8.4 kg/ha for the legumes and 11.2 kg/ha for the grasses. The seed and fertilizer were broadcast, and then using a rake covered with 6 mm of soil.

The plots were sprinkler-irrigated three times a week during hot weather, and as needed during October to maintain a moist seed bed for germination and seedling establishment. Irrigation was terminated when the fall rains started in November.

In late summer 1973, these same plots were divided into two equal main blocks, each containing 12 plant-species treatment sub-blocks or a total of 84 plots. One main block was irrigated on 7 August, the other on 20 September. Thereafter, both were irrigated twice a week except during hot periods, when the frequency was increased as needed.

Morphological development of the subterranean and rose clovers was measured twice weekly in the first growing season until the seven leaf stage on five plants per plot in two replications each from planting dates 4 (13 September), 5 (29 September), and 6 (23 October), as described by Raguse et al. (5). This technique assigns a plant a "leaf index number" based on the number and stages of development of its trifoliate leaves. In the second growing season, morphological development was measured following the two irrigation dates.

Dry matter yields were determined from samples cut from within 30-cm² frames at a height of 1 cm. The first growing season, (1972-73), plants from planting dates 1 through 4 were harvested 15 November and those from all planting dates (1 through 6) were harvested in April. After the spring harvest in 1973 the plants were allowed to set mature seed, then grazed to an average residue level of 100 kg/ha. All plots were harvested twice (November and April) during the second growing season (1973-74).

Seasonal soil and air temperatures were obtained from the Sierra Foothill Range Field Station's official weather station. Observations were made on all fall-flowering plants, and on problems brought about by early germination.

RESULTS AND DISCUSSION

Rates of morphological development of the several legumes in the 1972-73 season were similar within, but not between planting dates. Correlation coefficients for the relationship between stage of development (leaf index number) and days from germination were 0.98 to 0.99.

In the 1972-73 season, legume growth rates varied between planting dates from 40 to 140 days to reach the seven-leaf stage (Table 1). A comparison of b-values from regression analysis of legume plant development in the 1972-73 season indicated that all growth rates were different between planting dates. Legume growth rates from planting dates 4 and 5 differed by only 5 to 8 days for plants to reach seven leaves, but a much larger difference existed between planting dates 5 and 6. The largest difference between planting dates 5 and 6 was for rose clover, 50 to 140 days, respectively. With the exception of planting date 6, growth rates of the legumes within planting dates were not different (Table 1). In planting date 6, the growth rate of early-flowering subclover was more rapid than those of mid-flowering subclover and rose clover by 5 and 20 days, respectively. The early-flowering subclover grew more rapidly during the cold temperatures of November and December than did the mid-flowering subclover and rose clover.

In the 1973-74 season, the growth rate was slower than in 1972-73. Rose clover reached the seven-leaf stage 51 and 92 days after the August and September irrigations. The subclover varieties averaged 46 and 74 days for the August and September irrigations, respectively.

Following the August irrigation, growth rate of the late-flowering subclover was greater than that of the other clovers (Table 1). September irrigation b-values were not different. Rates of trifoliate development of rose clover and subclover were similar, but the total number of days to reach seven leaves was not. This was explained by the slower growth of rose clover during the unifoliate leaf stage, resulting in initiation of trifoliate leaf development 3 to 11 days later than in subclover.

Analysis of variance for total dry forage yield data revealed differences between planting dates and between species with interactions between planting dates and species in the 1972-73 season. Forage yields were lowest for planting date 6 (Table 2). The grass yielded less than other species in planting date 1. When planted in August, slender wild oats, Blando brome, and annual ryegrass flowered in the fall, and this may have accounted for their lower yields. In planting date 2, mid and late-flowering subclovers out-yielded all species except early-flowering subclover. In planting date 3, the grass and bur clover yielded less than all other species. In planting date 4, only the grass treatment yielded significantly less. Rose clover in planting date

Table 2. Comparison of treatment yields, 1972-73 season.

Species	Planting dates*						
	3 Aug. (1)	16 Aug. (2)	31 Aug. (3)	13 Sept. (4)	29 Sept. (5)	23 Oct. (6)	Mean
Early subclover	2,710 a w	3,260 ab w	3,480 a w	2,800 a w	1,800 c x	900 a x	2,130
Mid subclover	3,220 a x	4,470 a w	3,700 a wx	3,260 a x	2,250 bc y	990 a z	2,550
Late subclover	3,180 a w	3,910 a w	2,580 b xy	2,870 a x	2,230 bc y	1,100 a z	2,260
Rose clover	2,830 a w	2,750 b w	3,510 a w	3,480 a w	3,290 b w	1,300 a x	2,450
Annual grasses	2,170 b w	2,310 b w	1,610 c w	2,320 b w	2,310 bc w	670 a x	1,580
Bur clover	3,100 a w	3,060 b x	1,460 c x	2,840 a w	3,130 ab w	470 a x	2,003
Indigenous species	2,620 a w	2,290 b wx	2,810 ab w	2,790 a w	1,670 c xy	1,380 a y	1,930
Mean	2,380	3,150	2,730	2,908	2,380	970	

* Means are compared within and among treatments. Mean followed by the same letters (a through c) in vertical sequence or by the same letters (w through z) in horizontal sequence are not significantly different (P = 0.05) using Duncan's new multiple range test.

Table 3. Comparison of forage yields, 1973-74 season.

Species	7 Aug. Irrigation			20 Sept. Irrigation			Mean
	Fall	Spring	Total	Fall	Spring	Total	
Early subclover	1,520 b*	4,320 c	5,840 b	840 b	4,700 b	5,540 b	5,690
Mid subclover	2,000 a	6,230 a	8,230 a	840 b	6,020 a	6,860 a	7,540
Late subclover	2,080 a	5,860 ab	7,940 a	810 c	5,970 a	6,780 a	7,360
Rose clover	1,100 bc	4,670 bc	5,770 b	510 e	5,910 a	6,420 a	6,090
Annual grasses	710 c	4,010 c	4,720 b	400 f	4,500 b	4,900 b	4,810
Bur clover	660 c	4,330 c	4,990 b	580 d	4,350 b	4,930 b	4,960
Indigenous species	1,380 b	4,580 c	5,960 b	960 a	5,170 b	6,130 ab	6,045
Mean			6,200			5,930	

* Yields followed by the same letter in a column do not differ significantly (P = 0.05) Duncan's new multiple range test.

5 yielded more than all other species except bur clover. There were no species yield differences in planting date 6.

Fall forage yields in 1973 were significantly different between irrigation dates, but spring 1974 yields were not (Table 3). Also, total seasonal yield differences for the two irrigation dates were not significant. The mid and late-flowering subclovers yielded more than all other species in the August irrigation fall harvest (Table 3). After September irrigation, fall yields of the indigenous species were greater than those of the other treatments. Subclover produced more than did rose clover, bur clover, and the annual grasses. In the spring, yield differences for the two irrigation dates were not significant. The mid and late-flowering subclovers yielded more than all other species in the August irrigation fall harvest (Table 3). After September irrigation, fall yields of the indigenous species were greater than those of the other treatments. Subclover produced more than did rose clover, bur clover, and the annual grasses. In the spring harvest following September irrigation, yields of the early-flowering subclover, annual grasses, bur clover and indigenous species were lower than those of mid and late-flowering subclovers and rose clover.

August irrigation of winter annual range species exposed these plants to summer insect infestations. The most serious insect pest was the beet armyworm (*Spodoptera exigua* Hübner), which appeared the last week in August. The adult moth was more attracted to bur clover than to the other legumes. The worms caused extensive damage to bur clover and minor damage to rose clovers and subclovers. Leaves of subclovers had the smallest amounts of eggs and larvae. A fungus damaged rose clover plants in well-formed canopies in the 1972 August and September planting dates. The epiphytotic was possibly related to the high humidity and temperature from warm days and ample moisture from irrigation. This problem did not appear in the 1973-74 season because the irrigation requirements were different. The moisture requirements were more critical for the 1972-73 season because seed germination of a new planting was required every two weeks. The 1973 August irrigations could be further apart once the plants were established, therefore, canopy humidity was lower.

Growth rate of the winter annual legumes was greater in the fall of 1972 than in the fall of 1973. This was probably due to soil disturbance during planting of the experiment. This disturbance made water penetration easier and the fertilizer more readily available to the seedling. The total forage yields were about two times higher in the 1973-1974 season than the 1972-1973 season. This difference can probably be attributed to temperature. Small temperature differences can result in significant growth differences when the temperature is near threshold levels for uptake of nutrients. After planting date 6 in the 1972-73 season, mean temperatures of 10 C or below occurred for 2 months. Assuming favorable soil and air temperatures, a subclover or rose clover plant will be well established and have functioning nodules at the seven-leaf stage. Gibson (1) reported nodule formation when the ambient root temperatures ranged between 7 and 33 C. Gibson (2) also reported that below 12 C, established nodules would not fix N for plant use.

Under climatic conditions similar to those in the present experiment, early fall irrigation will ensure vigorous plant growth at temperatures under which maximum root development and nodulation of legumes can occur. The mean soil temperature at the Sierra Foothill Range Field Station usually ranges downward between 33 and 12 C during the months of August, September, and October. Using supplemental irrigation to germinate these annual legumes in the fall allows an adequate supply of nutrients to move into the plant for rapid fall establishment and growth. This increase in plant material in early fall allows earlier and longer grazing periods, and allows 6,000 to 7,500 kg/ha of high quality forage to be produced.

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