Influence of Date of Planting on Emergence of Cultivars of *Trifolium hirtum* All. and *T. subterraneum* L.

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Highlight: *Emergence by seven cultivars of rose clover (*Trifolium hirtum *All.) and eight cultivars of subclover (*T. subterraneum *L.) was studied in relation to date of planting in a plant community on cismontane California annual range. Numerous dates of planting were used in each of three growing seasons, from 2 months before to 2 months after the first rain in the fall. The temperature in the seedbed was monitored hourly from the first planting date through clover emergence. The seeded clovers, including seeds of all previous plantings, germinated at the time of the first effective rains. Where seeds were exposed to high soil temperatures (30–50°C), early fall planting generally reduced seedling emergence in cultivars of rose clover, but enhanced or did not affect emergence in subclover. In 2 of the 3 years, seeding after the first rain gave significantly lower emergence. Maximum seedbed temperatures below 10°C allowed only very limited emergence.*

On Annual-dominated ranges in cismontane (west of the mountains) California, desirable forage species are seeded in the fall. The annual grasses and the broadleaf plants of resident plant communities germinate with the first substantial rain after the summer drought. Since the date of the first substantial rain varies from September to December, the sequence of moisture-temperature relations after the first rain also varies. These different moisture-temperature relations after the first rain also vary. These different moisture-temperature regimes in relation to rose clover (*Trifolium hirtum* All.) and subclover (*T. subterraneum* L.) germination would seem to be important in determining the use of different types of weed-control seeding systems. The germination characteristics of a number of cultivars of rose and subclover in relation to temperature are known from laboratory studies (Young et al., 1970).

A study was made to: (a) determine the dates of planting that gave best establishment of cultivars of rose clover and subclover; and (b) interpret success of establishment at different planting dates in relation to date of the first effective rainfall and to seedbed temperature before and after this rainfall.

Materials and Methods

Date of planting was studied for three fall and winter growing seasons, 1970 through 1972, at the Sierra Foothill Range Field Station near Marysville, Calif. The site supports a sparse blue oak (*Quercus douglasii* Hook and Arn.) / digger pine (*Pinus sabiniana* Dougl.) woodland, with an understory dominated by annual grasses. Average annual precipitation (1961–72) at the field station approximated 75 cm. Rainfall there is largely restricted to late fall, winter, and early spring, typifying a Mediterranean climate. Soil at the study site is classified in the Sobrante and closely associated Auburn series. The Sobrante series is a member of the fine-loamy, mixed, thermic family of Mollic Haploxeralfs (formerly classified as Noncalcic Brown soils). Sobrante soils have reddish-brown, medium-acid, silt loam A horizons (0 to 12 cm) and yellowish-red, slightly acid, clay loam B horizons (12 to 60 cm) underlain by weathered schist. Planted each experiment were 100 seeds of each cultivar in each of six replications at each

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Table 1. Species and cultivars used in date-of-planting studies from 1970 through 1972.

Species and cultivars	Years planted		
	1970	1971	1972
Rose clover			
Wilton	X	X	X
Kondinin	X	X	
Hykon	X	X	X
Sirint	X	X	
S-6[1]	X	X	
T. O. 2648[1]	X	X	
Olympus	X	X	X
Subclover			
Mount Barker		X	X
Woogenellup		X	
Clare		X	
Yarloop		X	X
Dwalganup		X	
Geraldton	X	X	X
Daliack		X	
Seaton Park		X	

[1] Unnamed selections.

planting date. Two seeds were planted per 2.5 cm of row and covered with 1 cm of soil. The seeds were inoculated with peat inoculum (*Rhizobium*) and pelleted in calcium carbonate (Holland et al., 1969). The germinated seedlings were pulled and counted as soon as they emerged.

Different cultivars of the two species were studied in the three seasons (Table 1). In the 1970-71 season, the seed used had been harvested and mechanically threshed from plants grown in 1969 in a replicated common garden at Davis, Calif. The planting dates were September 25, October 7 and 21, November 9, and December 15, 1970, and January 8, 1971.

In 1971-72, the seed used was of cultivars of rose clover grown in 1970 at Davis and threshed by hand. Seed of cultivars of subclover was obtained from the 1969 garden at Davis. Planting dates were September 28, October 13 and 26, November 9 and 23, and December 7, 1971.

Also planted was seed of cultivars of rose clover obtained from the same source used for the previous year's plantings.

The seed used in 1972-73 was from the 1970 source but was mechanically scarified for 30 seconds before planting. Planting dates were August 17, September 6 and 20, October 4 and 25, and November 25, 1972.

In all 3 years, air and soil temperatures in the planting gardens were monitored hourly from the times of planting to the times of sampling. Temperature was measured 1 cm below the soil surface and 3 cm above with thermistors with a base resistance of 3,000 ohms at 25°C. Soil and air temperatures were similar, so only the soil temperatures are presented. Seedbed temperatures were monitored with the same recorder used in another study (Evans et al., 1975). Precipitation was measured weekly with a standard rain gauge or after each storm.

Results

The seeded clovers germinated at the time of the first effective rains, including seeds of all previous plantings. The time of the first effective rains in the 3 years varied from the last of September to the middle of December.

First Growing Season (1970-71)

Emergence of all cultivars was best when seeding took place 2 weeks before the first effective rain (3.2 cm on October 23) (Table 2). Rose clover seeded a month before the first rain showed markedly lower emergence than the seedings made 2 weeks before rain. Reduced the least by early planting was emergence of cultivars 'Hykon' and 'Sirint.' Emergence of 'Geraldton' subclover was not significantly lowered by seeding a month before the first rain. The earliest seeding endured 2 weeks in dry soil with maximum soil temperatures of 30 to 35°C; the next seeding (giving optimum emergence) had spent 2 weeks in dry soil with maxima of 15 to 20°C (Fig. 1).

The planting after the first effective rain germinated when temperatures were only slightly lower than before. With planting 3 weeks after the first effective rain, seedbed temperatures were still in the optimum range for germination of the cultivars of annual clovers (Fig. 1) (Young et al., 1973; 1970). Some germination probably occurred during this period, but emergence was extremely limited, and in early December soil temperatures dropped dramatically, limiting emergence further. Emergence of 'Geraldton' subclover also dropped during the cold winter months, though not as much as in cultivars of rose clover (Table 2).

Mid-December plantings gave minimum emergence of all cultivars, even after seedbed temperatures rose in the spring (Table 2). The mid-December temperatures were low (3 to 10°C), but germination of the rose clover cultivars had been optimum in this range in the laboratory (Young et al., 1973). A later planting in January 1971 gave lower winter mortality and increased emergence of some cultivars (Table 2). In studies of the development of subclover seedlings, Raguse et al (1970) found that full emergence of the cotyledons required about 56 days at 10°C. During mid-December, daytime maximum temperatures did not often exceed 10°C (Fig. 1). Why the December plantings did not emerge in the spring, as did the January plantings, is not known.

Second Growing Season (1971-72)

The first effective rains were very late in 1971. Five plantings preceded the first rains (three separate storms of 1.9, 1.6, and 1.8 cm from November 11 to 30) (Table 3).

Table 2. Emergence (%) of cultivars of rose and 'Geraldton' subclover in relation to planting dates during the growing season 1970-71.[1] The first effective rain was October 23.

Date planted	Cultivars								Date last count
	Rose clover							Subclover	
	Wilton	Kondinin	Hykon	Sirint	S-6	T. O. 2648	Olympus	Geraldton	
Sept. 25	34c x	38c x	56a x	46b x	27c y	39b x	51a x	69a w	Nov. 18
Oct. 7	72 w	80 w	82 w	67 w	65 w	75 w	81 w	79 w	Nov. 18
Oct. 21	47b x	69a w	72a w	63a w	45b x	68a w	68a x	74a w	Nov. 18
Nov. 9	4c y	5bc y	5bc y	4c y	3c y	1c y	8b y	35a x	Dec. 23
Dec. 15	4 y	4 y	8 y	3 y	6 z	6 y	7 y	3 y	Apr. 22
Jan. 8	7b y	10b y	7b y	12b y	8b z	25a x	10b y	13b y	Apr. 22

[1] Means within each planting date (rows) followed by the same letter (a through c) or within each cultivar (columns) (w through z) do not differ significantly at the 0.05 probability level, as determined by Duncan's multiple range test. No letters in a row or column means no significant difference among values.

Table 3. Emergence (%) of cultivars of rose clover in relation to planting dates during the growing season 1971–72. Seed source was the same as used in 1970–71.[1] The first effective rain was during the November 11–30 period.

Date planted	Cultivars of rose clover							Date last count
	Wilton	Kondinin	Hykon	Sirint	S-6	T. O. 2648	Olympus	
Sept. 28	49a	30b	44a	40ab	37ab	38ab	46a	May 7
Dec. 7	6b	14b	23a	5b	30a	21ab	5b	May 7

[1] Means within each planting date followed by the same letter do not differ significantly at the 0.05 probability level, as determined by Duncan's multiple range test.

Unfortunately, the seed used for the six 1971–72 plantings was hand-harvested and hand-threshed rose clover. This was naturally hard-coated seed, with a maximum germination of 5% for any cultivar at any date of planting. In the first and last plantings, however, mechanically harvested rose clover seed was also used. These plantings produced emergence comparable to that of the previous year (Table 2). Obviously no information on optimum germination was available, so we could not determine whether the early planting date depressed germination as it had in 1970–71. The one post-rain planting had much lower germination except in the two numbered cultivars.

Of the eight cultivars of subclover tested, emergence was consistently best in 'Mt. Barker,' the much-used late-season cultivar in California; 'Yarloop,' the large-white seeded subspecies (Young et al., 1970); and 'Geraldton,' the subclover tested in 1970 (Table 4). Emergence of six cultivars of subclover was greatest for the first planting in early fall (September 28), and emergence of the other two cultivars was not affected by date of planting when the five dates before and during the first effective rain are compared. The first planting also had a high percentage of total observed germination in the cold winter after December 7 (Table 5). Most of the planting made shortly before the first effective rain (November 9) emerged nearly simultaneously when the moisture came, though a low percentage of additional germination occurred in the cold winter. Many species of annuals exhibit both simultaneous and continuous germination (Newman, 1963), and the conversion from simultaneous to continuous germination is conditioned by exposure to the seedbed environment.

In 1971, the very long dry fall had wide diurnal fluctuations in soil temperature, with maxima of 35°C between the first and second plantings (Fig. 2). Seeding done after the unusually late first fall rain gave a winter mortality that was almost complete; only a slight additional emergence was observed in the spring (Table 4).

Third Growing Season (1972–73)

In 1972, the first effective rain (3.9 cm) was early in the fall (September 26). Continuously wet warm weather then prevailed in October (Fig. 3), and seedbed temperatures did not drop to the range of 5 to 10°C until late October. Germination was optimum for the first planting after the first rain (Table 6). Seeds of the first fall planting lay in the seedbed for almost 2 months before the first rain, exposed to

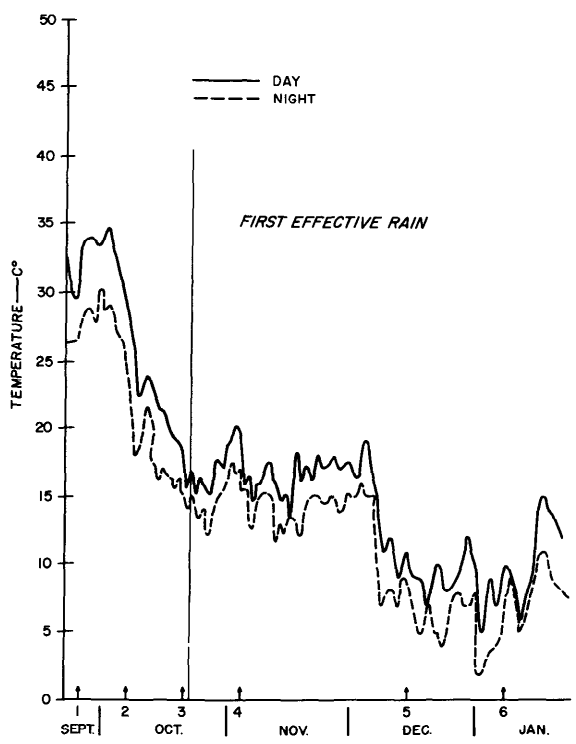

Fig. 1. *Daily mean day (8 am-7 pm) and night (8 pm-7 am) soil temperatures at planting depth (1 cm below surface) during times of planting of clovers in 1970-71. Numbered arrows on the abscissa indicate planting dates.*

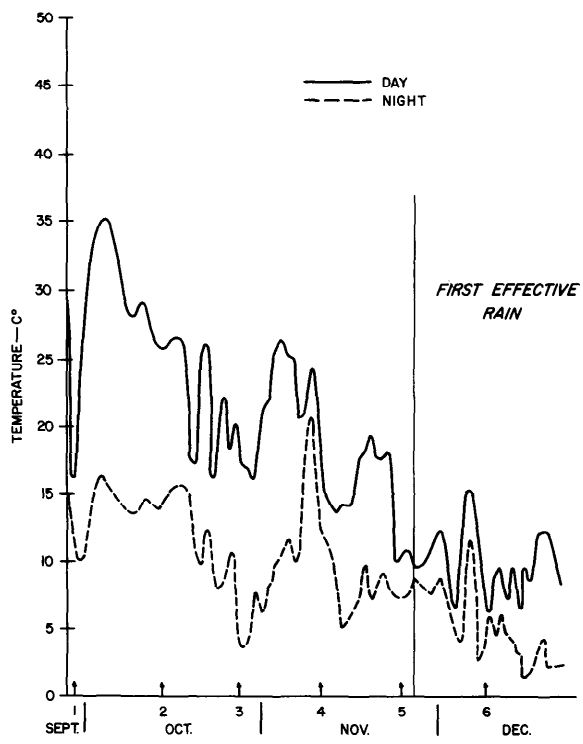

Fig. 2. *Daily mean day (8 am-7 pm) and night (8 pm-7 am) soil temperatures at planting depth (1 cm below surface) during times of planting of clover in 1971-72. Numbered arrows on the abscissa indicate planting dates.*

Table 4. Emergence (%) of cultivars of subclover in relation to planting dates during the growing season 1971–72.[1] The first effective rain was during the November 11–30 period.

Date planted	Cultivars of subclover								Date last count
	Mt. Barker	Woogenellup	Clare	Yarloop	Dwalganup	Geraldton	Daliak	Seaton Park	
Sept. 28	71a w	47ab w	38b w	61a w	48ab w	70a w	45b w	40b w	May 7
Oct. 13	58a wx	37ab w	27b wx	39ab wx	29b wx	46ab x	45ab w	48ab w	May 7
Oct. 26	61a wx	42ac w	28c wx	45ab wx	36bc wx	37bc x	42ac w	36bc w	May 7
Nov. 9	57a wx	40ab w	34bc w	47ab wx	23c x	37bc x	35bc w	38bc w	May 7
Nov. 23	42a x	29b w	14c xy	31ab x	22bc x	31ab x	29b w	24b x	May 7
Dec. 7	1 y	2 x	1 y	1 y	2 y	1 y	1 x	1 y	May 7

[1] Means within each planting date (rows) followed by the same letter (a through c) or within each cultivar (columns) (w through y) do not differ significantly at the 0.05 probability level, as determined by Duncan's multiple range test. No letters in a row or column means no significant difference among values.

Table 5. Percentage of total emergence (%) during the winter (after December 7) for cultivars of subclover planted in September and early November of the 1971–72 growing season.

Date planted	Cultivars of subclover							
	Mt. Barker	Woogenellup	Clare	Yarloop	Dwalganup	Geraldton	Daliak	Seaton Park
Sept. 28	48	28	58	27	50	49	49	30
Nov. 9	22	20	20	17	26	45	6	26

temperatures as high as 50°C. Seedling emergence of two of three rose clover cultivars was lower from the first planting than from the last before the rain. Planting after the rain did not increase emergence of these cultivars. One of three cultivars of subclover (Yarloop) had lower germination from planting before the rain (at all three dates) than from planting after. Emergence was greater from the first planting than from the later plantings before the rain. Emergence of the other cultivars was unaffected by date of planting.

November and December 1972 were exceptionally cold, and all the clover seedlings were killed. The few seedings that emerged from the October 25 and November 21 seedlings were destroyed by frost heaving in the seedbed before they could be counted.

Discussion

The recommended optimum time for seeding annual clovers is October before the first fall rains (Murphy et al., 1973; Williams et al., 1957). Additionally, initial establishment is often benefited by weed control to reduce competition from other annual species, particularly if late rains and low temperatures create conditions more favorable to grass growth (Kay and Owen, 1970; Murphy et al., 1973). Clovers can be planted following a grain crop, or competition can be reduced by the use of herbicides or light disking. Any soil disturbance, however, may result in excessive frost heaving of seedlings. In 2 of the 3 years of this study, seeding after the initial rain gave a very low emergence of all cultivars of rose and subclovers because the seedbed was cold. This phenomenon has been observed generally, and efforts have been made to select cultivars that will germinate at low temperatures (Young et al., 1970). From this study and that of Jones et al. (1971) it is apparent that when weed control depends on weed emergence (spraying or cultivation), a clover cultivar is usually needed that has an inherent capacity for germination and rapid juvenile seedling growth at relatively low temperatures. In the year (1972–73) when the rains came early, all cultivars planted after the initial rain emerged as well as or better than those planted before. Certainly the paraquat-direct-seeding technique (Kay and Owen, 1970) would be effective under these conditions. However, favorable temperatures prevailed only for a short time after the initial rain (Fig. 3), so that even in a year of early precipitation any weed-control seeding method dependent on emergence of the resident annuals would be difficult to time.

If a cultivar could be found that had superior cold-temperature germination and growth, what would be the possibilities for persistence in the annual communities? We must remember that these legumes are annuals. If they are not to be at a competitive disadvantage in the year after their first

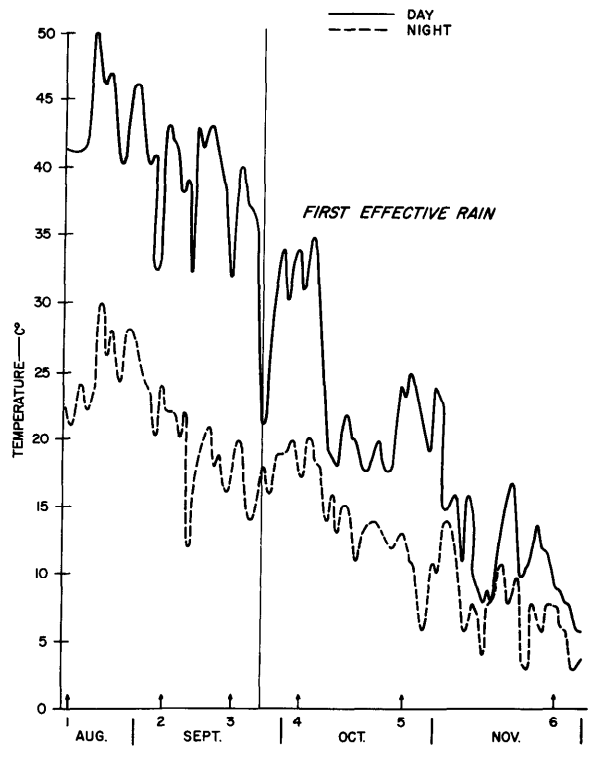

Fig. 3. *Daily mean day (8 am-7 pm) and night (8 pm-7 am) soil temperatures at planting depth (1 cm below surface) during times of planting of clovers in 1972-73. Numbered arrows on the abscissa indicate planting dates.*

Table 6. Emergence (%) of cultivars of rose and subclover in relation to planting dates during the growing season 1972–73.[1] The first effective rain was September 26.

Date planted	Cultivars						Date last count
	Rose clover			Subclover			
	Wilton	Hykon	Olympus	Mt. Barker	Yarloop	Geraldton	
Aug. 17	34 x	39	39 x	40	32 x	34	Oct. 25
Sept. 6	37bc x	51a	45ab w	46ab	28c y	41ab	Oct. 25
Sept. 20	49a w	38ab	48a w	48a	29b y	36ab	Oct. 25
Oct. 4	55ab w	53ab	60a w	55ab	46ab w	40b	Oct. 25

[1] Means within each planting date (rows) followed by the same letter (a through c) or within each cultivar (columns) (w through y) do not differ significantly at the 0.05 level of probability, as determined by Duncan's multiple range test. No letters in the row or column means no significant differences among values. No data are presented from the plantings of October 25 and November 21 because the plants were killed before counts could be made.

establishment, they must germinate at an optimum level with the initial flush of germination, at the time of the first effective rain. Studies of naturalized populations of rose clover have indicated that these natural selections tend to germinate at higher temperature (Young et al., 1973). Thus, selective advantage for persistence is in the direction opposite from that needed for initial establishment by artificial revegetation techniques that can be used only after germination of the annual grasses and broadleaf plants. It would seem better to design and develop new weed-control seeding systems that would be more compatible with the ecology of the annual clovers. Development of a selective herbicide or fallow weed-control method (Eckert and Evans, 1967) would be viable alternatives to following a grain crop for control of plant competition with pre-rain planting of clovers.

Our results also indicate that high seedbed temperatures experienced in early fall (30–50°C) before the rains harmed seeds of rose clover but not subclover. Emergence of Geraldton subclover, a cultivar planted in all 3 years of the study, and Mt. Barker subclover, planted in 2 years, was either enhanced or unaffected by early fall planting. Rose clover cultivars, in contrast, generally had a lower emergence with seeding in early fall than with later seeding. Thus timing of seeding prior to effective rains in relation to species and cultivar of annual clover is important, and should be incorporated into any weed-control seeding system.

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