Subclover (foreground, above) produced a dense stand and suppressed weeds in a test plot at the University of California, Riverside. Weedy plot in background was untreated. At right, research assistant Doug Holt measures subclover biomass.

Subclovers as living mulches for managing weeds in vegetables

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Subclover mulches, which grow from fall through spring then die back before crop planting, show some potential for suppressing weeds and increasing soil organic matter. Vegetable yields varied in tests, depending on how the mulch was managed.

An increasing number of field and vegetable crop growers are using mulches to control weeds and reduce evaporative water loss. Materials used include black plastic, straw, cardboard, paper, and synthetic materials. Mulches, such as black plastic, that completely block light are the most effective for weed control.

Drawbacks to this practice are the time required to install or place the mulches, difficulty of keeping them in place, and the need to remove and dispose of used materials. Mulches are often installed just before planting, which is one of the busiest times of the year for most growers.

The concept of a "living mulch" has been suggested recently. Living mulches are plants grown in place, which suppress weeds by blocking light, as do other types of mulches. Since they are rooted, they do not blow away. They also may improve soil organic matter content. Living mulches are usually chemically suppressed before crop planting to avoid competition. Because the mulches are grown before the crop is planted, less labor is needed during the crop planting period.

Subclover has been suggested as a possible living mulch plant. This annual legume is well adapted to mild winters in that its vegetative and reproductive growth occurs during the fall through spring, when moisture is usually supplied by rainfall. Seeds deposited in the surface soil in the spring remain dormant until temperatures drop and rainfall or irrigation occurs in the fall. Since the plants die back naturally as temperatures warm in late spring, it is not necessary to suppress subclover chemically before planting the crop. Natural reestablishment in the fall reduces cost and labor in subsequent years.

Subclover has colonized large areas of western and southern Australia under pressure from livestock grazing, and it has a high natural nitrogen-fixing ability. Since this legume can out-compete weeds under heavy grazing pressure, it is thought that management schemes can be designed to suppress weeds and encourage subclover establishment and persistence.

We conducted studies to evaluate the use of subclover living mulches for managing weeds in vegetable crops at the University of California Riverside and Davis research farms and at Salinas. We compared subclover with conventional practices for weed suppression, soil fertility, and crop yield and quality. Several living mulch management strategies were also compared.

Field experiment

Subclover living mulches composed of either a single variety, 'Enfield', or a mixture of 'Geraldton' and 'Dalkeith' were compared with cultivation, herbicide treatment, or an untreated control at the Riverside and Davis locations. The 'Geraldton' and 'Dalkeith' subclover mixture was compared with cultivation plus an herbicide treatment at Salinas. Three subclover management strategies were compared: mowing, desiccation with an herbicide before crop planting, and selective winter-applied herbicide treatments to control weeds.

Subclovers were planted in the fall at each location and received rainfall or were irrigated as needed during establishment. Treatments were replicated four times. Plot size varied among sites; the smallest was 500 square feet. Plantings were seeded at Riverside in October 1986, Davis in November 1987 and October 1988, and Salinas in December 1987. Seed was pellet-inoculated before sowing, and the seeding rate at all locations was 30 pounds per acre. Subclover plots naturally reestablished at the Riverside location in 1987.

Weeds were managed in the Riverside and the 1987 Davis plantings by mowing to a height of 1-1/2 inches, whenever vegetation reached 8 to 10 inches. Mowing began in late December or early January and continued at approximately 4- to 6-week intervals; generally three mowings were required to suppress weeds adequately. Clippings were removed to prevent weed seeds that had matured from germinating in the subclover plots.

At Salinas, subclover stands were allowed to grow without mowing until just before vegetable planting. At that time, glyphosate (Roundup) was applied at the rate of 1 pound per acre to control weeds and subclover.

A combination of mowing and postemergent herbicides was used to control weeds in the Davis subclover stand in 1988. A mixture of sethoxydim (Poast) and 2,4-DB at 0.5 pound and 1 pound per acre, respectively, was applied in February for weed control. Subclover stands were mowed in January and March to eliminate tall weeds.

All nonmulch plots were cultivated to eliminate all vegetation before crop planting. Vegetable crops were direct-seeded into the subclover mulches with a minimum of tillage. A double toolbar setup was used, with a straight shank creating a slit in the mulch and a John Deere flex planter with double disc openers following in the slit. Sweet corn ('Jubilee') was planted at Riverside on April 30, 1987, and April 5, 1988, and at Davis on May 12, 1988. Lettuce ('Salinas') was planted at Salinas on April 29, 1988.

Nitrogen fertilizer was applied before corn planting to the Davis and 1987 Riverside plots, with no nitrogen added to the 1988 Riverside or the Salinas plots. Weeds were removed from cultivation plots as needed to keep the crop weed-free for at least 6 weeks after crop emergence. Study sites received irrigation as required by the

TABLE 1. February weed cover in relation to treatment and planting date at three locations

Treatment	Davis Nov 1987	Davis Oct 1988	Salinas Dec 1987	Riverside Oct 1986	Riverside Oct 1987*
	% weed cover				
Dalkeith & Geraldton subclovers	43.5 a	40.0 b	60.0 a	9.5 b	29.2 a
Enfield subclover	50.8 a	12.3 c	—	6.8 b	25.5 a
Cultivated◊	—	—	20.0 b	—	—
Untreated	42.2 a	80.0 a	—	60.2 a	44.2 a

NOTE: Values in columns followed by the same letter are not significantly different as determined by an LSD test at the 5% level.
* Subclovers reestablished from the previous year's seed set.
◊ Cultivation was not performed at Davis or Riverside until just before corn planting.

TABLE 2. Summer (June or July) weed cover in relation to treatment at three locations

Treatment	Davis 1988	Salinas 1988	Riverside 1987	Riverside 1988*
	% weed cover			
Dalkeith & Geraldton subclovers	77.9 ab	44.4 a	51.7 b	89.8 a
Enfield subclover	95.8 a	—	34.1 bc	91.9 a
Cultivated	45.4 bc	—	1.6 c	21.4 c
Herbicide	34.4 c	6.2 b	14.5 c	60.0 b
Untreated	60.4 abc	—	90.0 a	100.0 a

NOTE: See table 1 NOTE.
* Subclovers reestablished from the previous year's seed set.

TABLE 3. Marketable crop yield relative to treatment at three locations

Treatment	Davis* 1988	Salinas◊ 1988	Riverside* 1987	Riverside* 1988
	% of cultivated			
Geraldton & Dalkeith subclovers	133.3 ab	103. a	83.7 a	43.8 b
Enfield subclover	156.7 a	—	96.5 a	27.5 b
Cultivated	100.0 bc	—	100.0 a	100.0 a
Herbicide	66.7 c	100. a	78.6 a	102.4 a
Untreated	116.7 abc	—	83.3 a	35.4 b

NOTE: See table 1 NOTE.
* Sweet corn ('Jubilee') was used at Davis and Riverside. Yields per acre on cultivated plots equaled 26,400 marketable ears at Davis, and 33,900 and 41,500 marketable ears at Riverside in 1987 and 1988, respectively.
◊ Lettuce ('Salinas') was used at Salinas. Yield on herbicide plots was 34,500 pounds per acre.

TABLE 4. Sweet corn quality at Davis, 1988

Treatment	Ears rated: Good	Disease	Earworm	Marketable*
	% of harvested ears			
Geraldton & Dalkeith subclovers	13 a	60 b	27 ab	40 ab
Enfield subclover	10 a	53 b	37 a	47 a
Cultivated	3 b	69 ab	28 ab	31 bc
Herbicide	6 b	75 ab	19 ab	25 bc
Untreated	4 b	84 a	12 b	16 c

NOTE: See table 1 NOTE.
* Marketable ears are considered to be good ears plus ears with worms.

vegetable crop, by drip at Riverside, furrow at Davis, and sprinkler at Salinas.

Weed cover was evaluated during living mulch growth and during vegetable production. At Riverside, soil samples were taken at 6-month intervals, beginning at subclover planting, so that we could assess long-term nutrient and organic matter changes associated with the treatments. Soils have been submitted to the UC Riverside soils lab for analysis of nitrogen, phosphorus, potassium, and organic matter.

Sweet corn was harvested at Riverside on July 17, 1987, and June 29, 1988, and at Davis on August 1, 1988. Lettuce was harvested on July 13, 1988, at Salinas. All harvests were assessed for yield and quality.

Weed control

Winter weed cover varied in response to planting date and subclover management at the three locations (table 1). Better subclover establishment and growth occurred in an early October planting (Riverside 1986 and Davis 1988), which resulted in less weed invasion than was observed in untreated plots. In November or December subclover plantings (Davis 1987 and Salinas), slow subclover germination and growth gave weeds a competitive advantage over the subclovers, resulting in poor weed suppression.

Subclover was slow to reestablish at Riverside in 1987 because of a lack of rainfall for germination during the fall. Also, soil disturbance during corn planting and harvesting reduced the subclover seed density at the ideal soil depth for germination (1/4 to 1/2 inch). Greater weed invasion than was observed in the previous year (table 1), may have further acted to reduce subclover establishment and growth through competition during the natural reestablishment period.

The combination of mowing and a postemergent herbicide treatment at the 1988 Davis location resulted in a significant reduction in weeds, relative to the untreated plots (table 1). The herbicide treatment coincided with a rapid growth period for subclover, which quickly achieved complete coverage of the plot. Weed growth on the Salinas subclover plots was excessive, partly because there was little competition from the late-planted subclover and no weed control measures were taken during the winter period.

The experimental procedure at Salinas differed from those at the other locations in that subclovers were desiccated with a 2% solution of glyphosate herbicide to eliminate weed and mulch growth before lettuce planting. An unexpected outcome of this treatment was that the weeds were killed, but subclover was only suppressed and was able to complete its life cycle (flowering and setting seed). The drying weeds and dying subclover plants provided good early-season weed suppression but control declined by harvest at Salinas (table 2). The late-planted subclover (December) did not produce enough biomass by vegetable planting to provide an adequate mulch for weed suppression during the vegetable growing season.

TABLE 5. Soil organic matter (June 15, 1988) at the 0 to 24 cm depth among treatments at Riverside

Treatment	Organic matter
	%
Geraldton & Dalkeith subclover	0.86 a
Enfield subclover	0.78 ab
Cultivation	0.66 c
Herbicide	0.70 bc
Untreated control	0.78 ab

NOTE: See table 1 NOTE.

At Davis, cold weather following the late subclover planting resulted in poor establishment and growth, which led to an insufficient mulch cover being produced. Because of the thin mulch cover and lack of cultivation at corn planting to eliminate established weeds, there were as many or more summer weeds in these plots as in untreated plots (table 2).

At Riverside in 1987, summer weed cover on subclover plots was intermediate between untreated plots and herbicide-treated or cultivated plots (table 2). 'Enfield' subclover visually appeared to suppress weed growth better than did the mixture of 'Geraldton' and 'Dalkeith', possibly due to later maturation, although no significant differences were observed. In 1988, weed pressure was much greater on all plots than in 1987; weed cover in the subclover and that in untreated plots were not significantly different. Cultivation provided the best summer weed control during the second season. Poor reestablishment of subclovers in the second year resulted in very little mulch being produced and relatively no summer weed control (table 2).

Marketable sweet corn yield was significantly higher in 'Enfield' subclover plots at Davis than in cultivated and herbicide plots in 1988 (table 3). Cultivated or herbicide plots had fewer weeds than 'Enfield' subclover plots, but disease incidence was much higher, reducing the marketable yield (table 4).

Sweet corn yields at Riverside were equivalent on all plots in 1987. In 1988, sweet corn yields were significantly reduced on subclover plots compared with the cultivated and herbicide plots. Subclover reestablishment was poor in the second year, which allowed weed invasion. Increased weed growth on subclover plots probably used any nitrogen released by subclovers, so that no nitrogen advantage was seen in corn tissue in the absence of nitrogen fertilizer.

Lettuce yields in subclover plots at Salinas were equal to those in herbicide plots (table 3). The large number of weeds at harvest in subclover plots (table 2) failed to affect yield, possibly because of improved nitrogen levels from the subclovers. Desiccating the subclover mulch with Roundup before lettuce planting provided excellent early-season weed control and increased lettuce growth. Improvement of seedling growth on mulch plots has also been observed in several other studies and may be related to improved soil moisture levels, because a reduction in tillage and the presence of a mulch decrease evaporation.

Stand counts indicated significantly denser vegetable crop populations in cultivated, herbicide-treated, and control plots, compared with subclover plots at all locations. Planting directly into mulches, without a no-till planter proved difficult. The use of transplants or a no-till planter could reduce this problem.

Organic matter was significantly increased on subclover plots compared with cultivated plots after 2 years at Riverside (table 5). The increase was small and is at least partially attributable to weeds. Nitrogen at the Riverside site was not increased on subclover plots compared with other treatments, possibly because of utilization by weeds.

Conclusion

Subclover living mulches in these trials have shown some potential to suppress weed growth and increase organic matter. When managed with a combination of mowing and herbicides, subclovers produced dense stands resistant to weed invasion. Mowing alone was effective if subclover stands were dense and weed populations low. Early fall planting appears to be essential for establishing dense subclover stands. Natural reestablishment of a high-density cover also appears to be a problem.

A limitation of using subclover mulches is planting the crop into the mulch. This difficulty would probably be best resolved with a no-till planter. Examination of various types of minimum-tillage equipment is being conducted.

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