Use of Polyethylene Mulch and Drip Irrigation on Olympus Strawberries

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USE OF POLYETHYLENE MULCH AND DRIP IRRIGATION ON OLYMPUS STRAWBERRIES

A. Richard Renquist
Department of Horticulture
Oregon State University

Lloyd W. Martin
North Willamette Experiment Station
Oregon State University

Patrick J. Breen
Department of Horticulture
Oregon State University

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ABSTRACT

A series of studies during six years examined vegetative growth and fruit yield of the 'Olympus' strawberry when grown with black polyethylene mulch and drip irrigation. In some studies, plants were grown with or without mulch and irrigated at low, medium, or high levels for one or two months in the summer. Improved summer irrigation greatly increased the number of crowns and leaves during the first season. Mulching gave additional benefits at each irrigation level, probably because of an increase in soil temperature. Both mulch and increased summer irrigation also improved flower production, but these treatments were less effective in increasing the number of fruit or fruit yield. First season yields of a mulched, well-irrigated planting with a 12-inch in-row spacing were 19 tons per acre for single rows (13,100 plants per acre) and 24 tons per acre for double rows (26,200 plants per acre). In other plantings on a 15-inch spacing (about 10,000 plants per acre), the best treatments yielded 14 to 15 tons per acre in the first season. Low summer irrigation reduced yields from 10 to 22 percent. Mulching diminished the amount of irrigation water needed to produce a given amount of fruit. When irrigation and mulch treatments were continued for a second season, large differences in plant size were visible by the end of summer, but flower production and fruit yield were similar in all treatments the following spring.

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INTRODUCTION

Two horticultural practices which can benefit Oregon strawberry production are the use of polyethylene mulch and drip irrigation.

The 'Olympus' strawberry, which has the highest demonstrated yield of any Pacific Northwest cultivar (Martin, 1976), lends itself to a mulched hill planting system because of its low runnering tendency. The high yield of 'Olympus' may be caused by its rapid crown branching, which forms a large central plant.

Drip irrigation, as described in previous reports (Oregon Agricultural Experiment Station, Special Reports 412 (1974) and 444 (1975)), is a useful complement to polyethylene mulch. It allows frequent, precision irrigation and fertilization under the mulch, and perhaps improves yield in its own right.

Both polyethylene mulch and drip irrigation, either separately or in combination, may save water and produce high yields in situations where water is limited. Other advantages include easier weed control, because of the black poly mulch in the row and the absense of irrigation in the aisles. In addition, problem soils may compact less under mulch, and irrigation and fruit harvest can be done simultaneously.

To test how 'Olympus' responds to a poly mulch and drip irrigation system, a series of studies was carried out between 1974 and 1980 at the North Willamette Experiment Station near Aurora, Oregon, and at the Department of Horticulture Farm at Corvallis, Oregon. In 1974, a study showed the high yield potential of 'Olympus' at two plant spacings using raised soil beds, black polyethylene mulch, and drip irrigation. In 1977 and 1978, additional plantings compared mulched and unmulched plants as well as three rates of summer irrigation. Although strawberries are most sensitive to water shortages in the spring at planting time and again during fruit development, we focused on summertime, when irrigation water is most apt to be in short supply. During this period, rainfall is less likely to interfere with the control of soil moisture. A 1979 planting compared two rates of summer irrigation, and provided additional fruit size and yield data to allow a broader appraisal of seasonal effects.

PROCEDURES

All plantings used shaped soil beds 2 feet wide and 5 inches high, with row lengths ranging from 30 to 60 feet. Viaflow drip irrigation tubing was placed on the bed surface and covered with 4-mil black polyethylene, which was buried along the edges. 'Olympus' plants were set through slits in the poly, 12 inches apart in 1974 and 15 inches in all other years. Rows in the 1974 planting were 40 inches apart (center to center), giving a plant population of about 13,100 plants per acre. Double rows (26,200 plants per acre) were also used in that year. In 1977, 1978, and 1979, the rows were separated by 80 inches to prevent interference between irrigation treatments, but per acre yields were calculated by assuming the rows were 42 inches apart, resulting in 10,000 plants per acre. To allow a mulch versus no mulch comparison in the 1977 and 1978 plantings, poly mulch was removed from half the length of each bed in early July, when plants were well established. During the treatment period, irrigation was supplied every two to three days at levels of 0, 23 percent, and 70 percent of the depth of water evaporated from a Class A weather pan (referred to as low, medium, and high regimes). Rainfall supplied additional known amounts of water. The 1974 and 1979 plantings were watered frequently, based on soil moisture levels.

In 1977, the different rates of irrigation were only maintained for one month, since rainy weather began in late August (Table 1). The values given in Table 1 are not acre-inches, since irrigation wet only a 24-inch-wide band along each row. In the 1978 planting, the irrigation treatment was lengthened to two months, but only with the aid of clear polyethylene rain-shelters which were placed over the low and medium irrigation rows during rainy of threatening weather. Before irrigation treatments began, and in the following spring (before and during fruiting), water was applied equally to all rows. In 1979, irrigation was witheld from half the rows from July 21 to September 22, and rainshelters were again utilized.

Table 1. Amount or irrigation plus rainfall (inches) received by two 'Olympus' strawberry plantings during treatment periods

Irrigation	July 21-Aug. 22, 1977	July 7-Sept. 7, 1978
Low	0	1.3
Medium	2.0	5.4
High	6.1	11.5

Soil temperature was recorded continuously during the 1978 treatment period at a depth of four inches in rows with low and high irrigation levels. Soil moisture was monitored five days a week in the 1974, 1977, and 1978 plantings using tensiometers and gypsum blocks. The blocks were needed when soil suction exceeded the 80 centibar (cb) range of the tensiometers. Measurements were made at 8-, 24-, and 36-inch depths, but little or no moisture depletion occurred at 24 or 36 inches. Soil suctions at eight inches increased to high levels in August in all rows with low irrigation, as well as unmulched rows with medium irrigation (Table 2). Note that rainfall caused the soil suction in all treatments to rapidly drop to low values by August 31, 1977, but suction declined more slowly when rain shelters were used in 1978.

Table 2. Soil suction at a depth of eight inches in 1977 and 1978 plantings of 'Olympus' strawberries with three levels of irrigation, with or without polyethylene mulch. Suction increases as soil dries. 100 centibars equals approximately 15 psi. Gypsum blocks were used in plots with high suction

1977

		Soil suction (centibars)				
Irrigation	Mulch	July 15	Aug 1	Aug 15	Aug 22	Aug 31
Low	no	8	100	960	1160	3
	yes	2	37	670	840	9
Medium	no	1	65	95	470	1
	yes	1	13	45	45	2
High	no	1	19	20	7	3
	yes	1	7	5	3	1

1978

		Soil suction (centibars)				
Irrigation	Mulch	July 11	Aug 1	Aug 10	Aug 25	Sept 5
Low	no	60	540	1170	550	630
	yes	30	530	1250	730	930
Medium	no	43	280	580	200	190
	yes	24	100	860	190	220
High	no	2	46	50	2	2
	yes	3	21	32	3	3

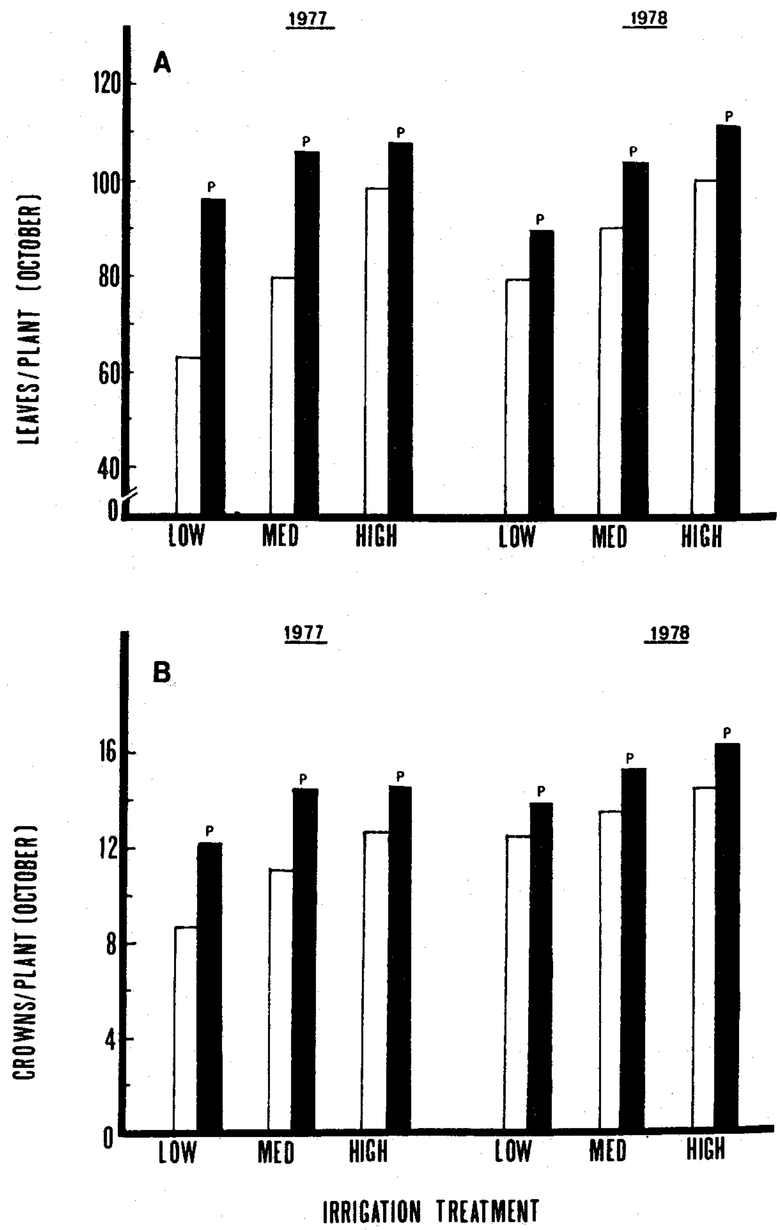
Growth measurements in the 1977 and 1978 plantings included the numbers of crowns, leaves, and fruit. To determine in detail how leaf growth was affected by mulch and irrigation, the rates of leaf enlargement were compared for eight individually tagged leaflets in each treatment in 1978. Leaf enlargement was calculated from the length of leaflets, measured one or two times a day. First-year fruit yield was recorded for all plantings and the second-year yield was also measured for the 1974 and 1977 plantings. The 1974 planting was also harvested a third year.

RESULTS AND DISCUSSION

The 1974 planting of 'Olympus' with raised beds, black polyethylene mulch, and drip irrigation produced record yields for strawberries in the Pacific Northwest, with 18.6 and 23.5 tons/acre in single and double rows, respectively (Martin, 1976). The studies that followed examined both vegetative growth and fruiting in detail, and sought to determine what contributions the poly mulch made to the high yields. Drip irrigation was not compared to sprinklers but was applied at three levels during the summers of 1977 and 1978 to identify the most desirable level for growth and production.

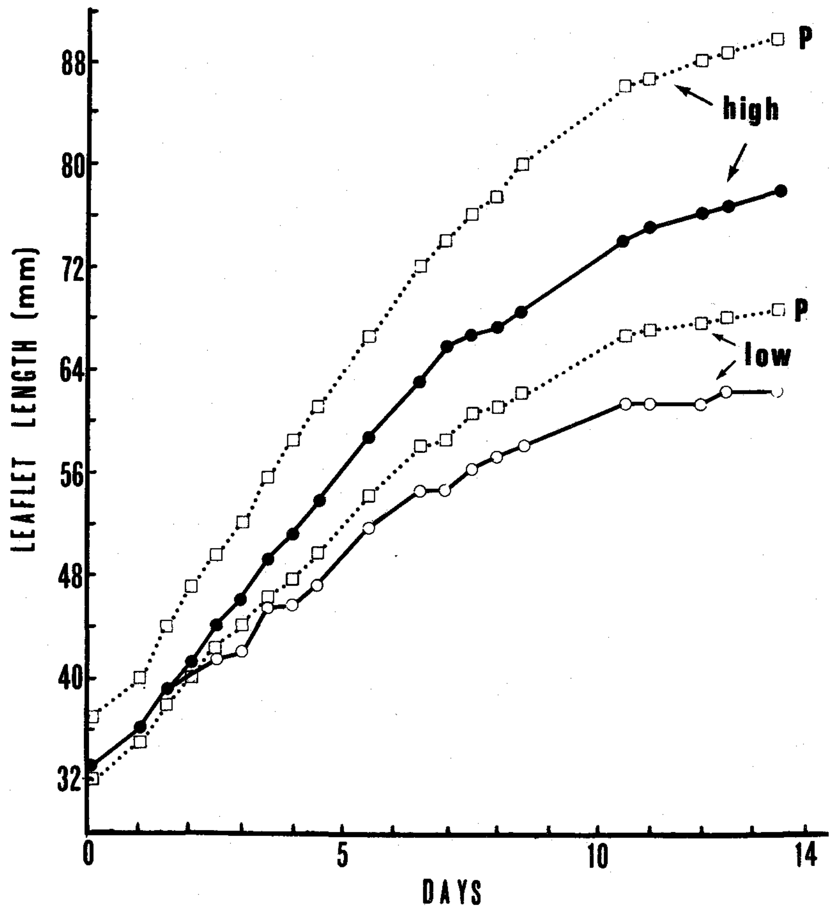
First year effects. Irrigation during the 1977 and 1978 summer treatment period greatly increased vegetative growth (number of crowns and leaves, see Figure 1), with the greatest growth at the highest level of irrigation. Mulching gave additional increases at each irrigation level. Individual leaf size also was increased by both irrigation and mulch so the total leaf area per plant was increased to an even greater degree than the number of leaves.

Figure 1. Effect of irrigation regime (low, medium, high) and polyethylene mulch (dark bars with P) on the number of leaves and crowns per 'Olympus' strawberry plant five months after planting in both 1977 and 1978



During July and August 1978, the growth rates of newly unfolded leaves on well-irrigated plants (high regime) were compared to those on plants which had not been irrigated for 13 days before the start of leaf measurements (low regime). Comparing the two unmulched irrigation levels at the end of two weeks (Figure 2, solid lines with filled (high) or empty (low) circles), showed that leaves were 20 percent longer in the high regime, which equals an 85

Figure 2. The rate of leaf growth (length of center leaflet) in 'Olympus strawberry after 13 days without irrigation (low regime, empty circles), with frequent irrigation (high regime, filled circles), and with each of these regimes plus polyethylene mulch (labeled P); measurements were started July 28, 1978, using leaves which had just unfolded



percent greater leaf area. Leaves on unirrigated plants (low regime) were able to compensate somewhat by continuing to extend for a longer period so irrigated leaves were only 35 percent larger by the end of four weeks. The belated leaf growth on unirrigated plants occurred largely during a period of cloudy cooler weather. This shows that weather conditions such as evaporative demand can be important along with soil moisture in controlling strawberry leaf growth.

Black polyethylene mulch increased the rate of leaf growth in both irrigated and unirrigated strawberries (Figure 2). The mulch did not greatly affect the amount of soil moisture in 1978, so its beneficial effect probably was caused by its ability to increase soil temperature. On a warm sunny day, mulched soil at a depth of four inches averaged five degrees warmer than unmulched soil during a 24-hour period. Such an increase is known to increase growth of several crop species. The time of greatest warming by mulch was in the evening, which may help maintain rapid leaf growth despite the falling air temperature. The cool summer night temperatures in western Oregon are presumed to inhibit strawberry leaf growth, since leaf expansion at night is extremely slow even in the absense of water stress. The enhancement of soil temperature by black poly mulch was greater on hot days than in the cooler weather of late summer. This can be seen from the weekly averages of daily maximum and minimum soil temperatures (Table 3). For example, compare the six degree increase from mulch the week of August 5 to the two to four degree effect during the week of September 2.

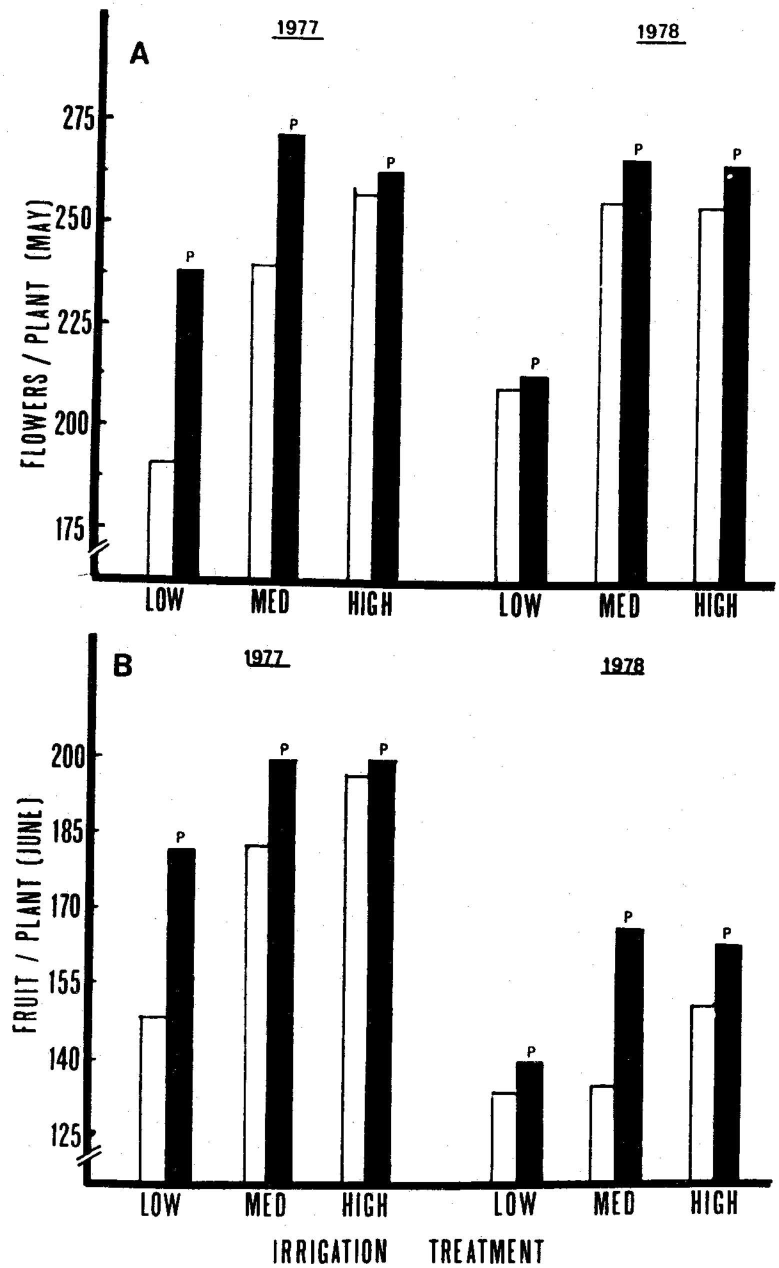
Summer irrigation and mulch had little effect on the weight of the root system at the time of the first fruit harvest. This is an example of why the normal growth cycle of a crop must be known before the effects of cultural practices can be properly interpreted. In strawberries, most root growth occurs in the fall, which in this study was after irrigation treatments were terminated. Soil moisture differences in the fall or early spring would be more likely to influence root growth than those in summer.

Table 3. Weekly means of the daily maximum and minimum soil temperatures (°F) at four inches depth below strawberries at the high level of irrigation, with or without black polyethylene mulch; measurements were begun July 22, 1978.

	Soil temperature (°F)			
Starting date of each week	Daily maximum		Daily minimum	
	-mulch	+mulch	-mulch	+mulch
July 22	82	86	70	78
July 29	82	89	69	74
August 5	83	89	70	76
August 12	70	74	64	68
August 19	65	67	61	64
August 26	71	75	62	66
September 2	64	66	59	63

The number of flowers on one-year-old plants was closely related to the number of crowns in the previous October. Therefore, increased summer irrigation and mulch, which led to more crowns, also increased flowers (Figure 3A). The number of fruit per plant also was higher on mulched and summer-irrigated strawberries (Figure 3B). The increases in fruit number because of irrigation (18 percent) and mulch (11 percent) were smaller than the increases in crowns (24 percent and 20 percent for irrigation and mulch), probably because of equalizing effects of root growth during autumn and top growth in the spring, when all treatments were irrigated equally.

Figure 3. Effect of summer irrigation regime (low, medium, high) and polyethylene (P) mulch on the number of flowers and fruit per plant in the first crop of 'Olympus' strawberries planted in 1977 and 1978



Average fruit size (weighted according to the total yield at each picking) was altered little by mulch or previous summer irrigation. Large differences, as much as 2.3 fold, occurred between years, however (Table 4). The small fruit size in 1977 (5.8 g) and 1978 (6.0 g) was partly caused by frosts in early May which damaged flowers. Many primary berries were absent in 1978, and the average fruit size was further reduced by picking fruit too small for commercial harvest in the last two of five pickings. The small size in 1977, the third year of the 1974 planting, also may have been caused by the tendency of fruit size to decline as plantings age.

First year fruit yields from the 1977 and 1978 plantings were increased both by mulch and greater summer irrigation during the one- or two-month treatment periods after plant establishment (Table 5). Mulch was more beneficial at the two lower rates of irrigation. Yield was closely related to the number of fruit per plant, but not fruit size, when comparing treatments in a given year. It is likely that inadequate irrigation would have reduced yield more dramatically if it had occurred during plant establishment or fruit development in the spring. A more elaborate system of sheltering research plots from rainfall would be required to study those phases of the growth cycle. Considering the high yield potential of 'Olympus', the 13 percent loss from low summer irrigation regime is still quite important.

Table 4. Fruit size and yield of 'Olympus' strawberries grown under black polyethylene mulch and drip irrigation, with adequate rates, during six years (1975 to 1980)

Year of planting	1974*				1977**	1978**	1979***
Year of harvest	1975	1976	1977	1978	1979	1979	1980
Weighted average fruit size (grams)	10.2	10.0	5.8	6.0	7.3	10.4	13.3
Fruit yield (tons/acre)	18.6	16.5	5.0	13.6	9.2	14.2	14.6

*Only data from the single rows given
**Values from medium irrigation regime
***This planting was not mulched

Withholding irrigation for two months during the drier summer of 1979 caused a 22 percent yield loss (equivalent to 3.1 tons per acre). In addition to getting plants off to a good start and watering during fruit development, it is also necessary to irrigate throughout the summer of the planting year to insure adequate plant size.

Table 5. Effects of irrigation level and polyethylene mulch on the fruit yield of 'Olympus' strawberries in the 1977 and 1978 plantings (tons per acre)

		1977 planting		1978 planting
Irrigation	Mulch	1st year	2nd year	1st year
Low	no	10.4	9.7	11.2
	yes	12.1	8.3	13.0
Medium	no	12.0	9.8	11.7
	yes	13.6	9.2	14.2
High	no	11.9	9.8	13.3
	yes	12.6	9.2	13.3

Second year effects. The 1977 planting was given the same irrigation treatments for a second summer. Soluble 30-10-10 fertilizer was applied through the drip system in July 1978 at the rate or 40 pounds per acre of actual nitrogen. The enhancement of vegetative growth from irrigation and mulching in the first year was accentuated in the second year. For example, at the end of the second summer the average number of leaves per plant was 105, 145, and 191 for the low, medium, and high regimes, respectively. Despite large differences in plant size, however, plants in all treatments produced essentially the same number of flowers the next spring, averaging more than 300 per plant. Likewise, the fruit yield did not differ significantly in the second year, although mulched pots tended to yield slightly lower (Table 5). The immediate cause of the reduced yield compared to the first crop was the much lower fruit set (the percentage of flowers which develop into harvestable fruit). An average of only 44 percent of the flowers in the 2-year-old plants was able to develop, compared to 61 percent and 76 percent in the first crop of the 1977 and 1978 plantings. The number of crowns on a single root system may have been too great by the second year of a hill system with poly mulch, so fewer flowers in each cluster were able to set. Perhaps fewer, more vigorous crowns are preferable to a greater number of "weaker" crowns. With standard irrigation and no mulch it may take three or more years for plants to reach this condition, and new runner plants also may offset this tendency. Poly mulch, runner removal, and optimum irrigation may lead to an earlier excess in crowns per plant. The record yielding 1974 planting also declined in yield with age (Table 4). An earlier planting of 'Olympus' at the North Willamette Experiment Station, with standard culture, increased from 9.1 to 12.3 tons per acre from the first to second crop.

SUMMARY

The studies in 1977 to 1979 did serve to confirm the high yield potential of 'Olympus,' which even at 15-inch spacing in 42-inch-wide rows produced up to 14.6 tons per acre. This is three times the average Oregon yield and about three tons more than 'Olympus' has produced with standard cultural methods. In both the 1978 and 1979 plantings the first year fruit weight per plant exceeded that in the record 1974 planting. The higher yields in the 1974 trial were because of closer spacing (12 inches by 40 inches), which resulted in a 30 percent higher plant population in single rows and 160 percent more plants per acre for double rows. The yield response to different populations of 'Olympus' is being studied at the North Willamette Experiment Station. The

preliminary results for 42-inch-wide rows indicate that yield increases as within-row spacing decreases, even down to eight inches between plants.

The studies of black polyethylene mulch and irrigation level showed that mulch increases first-year yields of 'Olympus', especially at lower levels of irrigation. If irrigation during plant establishment or fruit development is inadequate, it is possible that even greater yield gains could be realized with mulch. The efficiency of water use with respect to yield (fruit yield vs. amount of water applied) was improved by mulch. Considering only unmulched treatments, the highest irrigation regime produced the top yield in 1978 and nearly so in the 1977 planting. However, this treatment was out-yielded in both plantings by the medium treatment plus mulch, even though it received only one third as much irrigation water. The fruit yield of mulched rows was increased slightly by the medium and high summer irrigation regimes. Although 'Olympus' plants grown under drip or sprinkler irrigation may have similar requirements, a direct comparison between these methods was not made. However, the aisles make up more than 40 percent of the surface area when rows are 42 inches apart. Since the aisles were not wet, it is likely that drip irrigation conserves at least that fraction of the water used with sprinklers.

FUTURE OUTLOOK

Additional studies would be useful before drip irrigation and polyethylene mulch are adapted on a commercial scale in Oregon. The experiments most needed are:

1. A comparison of drip and sprinkler irrigation on several major strawberry cultivars without mulch.
    a. If the drip system proves advantageous, then different drip systems should be investigated.
    b. If there is no yield increase from drip irrigation, then additional trials should determine how well mulched plants produce with sprinkler irrigation.

2. A production cost analysis, with trials to estimate the labor

requirements for mulching, planting through mulch, and runner removal; costs for other cultural practices (e.g., weed control) also may differ from current methods.

Results with mulched strawberries in Norway offer clues as to what to expect in Oregon. One study found that sprinkler-irrigated, poly-mulched plants did not require supplemental nitrogen, even on five-year-old plants (Ystass, 1971). Presumably the warmer mulched soil had a more rapid rate of nitrogen release from organic matter. This may be inadequate for the higher-yielding 'Olympus' cultivar, however. In another study (Krakevik, 1978), with data from 77 small commercial fields, the total labor requirement was reduced for mulched rows. Establishment took 61 percent longer, but picking time for a given weight of fruit was 17 percent shorter than on a matted row. The improved efficiency of harvest (the major labor input), along with increased yield, may outweigh the cost of mulch.

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