Consumptive Water-Use Efficiency of Alfalfa Grown Under Three Irrigation Regimes

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Alfalfa is the most important forage crop in Arizona. Over 200,000 acres in Arizona are devoted to alfalfa hay-production. Alfalfa accounts for over 90 percent of total hay-production and 85 percent of the total hay acreage in the state. Yields are high and alfalfa does require a lot of water during one growing season because of the amount of leaf area produced.

Water is our most important natural resource. Competition for water in Arizona is keen. The demand for water by agriculture, industry, and urban users is depleting our underground aquifers. The cost of water is increasing as the supply diminishes, making the conservation and efficient use of water of prime importance.

Since alfalfa is a major irrigated-crop in Arizona, emphasis should be given to increased efficiency of water use in alfalfa production. This study was initiated to determine the most efficient use of water in alfalfa production under field conditions. When designing this experiment, the following questions were asked:

1. Do alfalfa cultivars** differ in their ability to use water efficiently?
2. Does consumptive water-use efficiency of alfalfa change with different irrigation regimes?
3. At what time during the growing season is the alfalfa plant most efficient?
4. At what time during the growing season does alfalfa forage contain the most leaves per unit of dry matter?

Plots of Mesa-Sirsa, Moapa, Sonora, and El-Unico were established at the Soil Conservation Service Plant Materials Center at Tucson and were used to evaluate consumptive water-use efficiency of these cultivars grown under three irrigation regimes. Efficiency of consumptive water-use was determined by dividing total water applied in kilogram per plot by total kilograms dry weight of forage per plot. The resulting value was the kilograms (kg)of water used to produce 1 kg of dry forage.

Irrigation treatments were established by surface irrigating when approximately 30, 60 and 90 percent of the available soil moisture had been removed to a depth of three feet (Figure 1). These irrigation regimes were designated as high, medium and low, respectively. All cultivars grown under each of the irrigation regimes received the same amount of water at each irrigation.

The forage was harvested from plots that were 0.91 M (meters) (3 ft.) by 7.6 M (25 ft.) for two complete growing seasons. Plants were cut approximately the one-tenth bloom stage. At each harvest during the second growing season, replicated samples of individual cultivars were separated into leaves and stems to obtain the leaf to stem ratio.***

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***Cultivars means varieties.*

****Leaf to stem ratio was obtained by dividing the dry weight of leaves by the dry weight of stems.*

Figure 1. Irrigation treatments used in this study were applications of water when 30 percent (high), 60 percent (medium), and 90 percent (low) of the available soil moisture had been depleted.

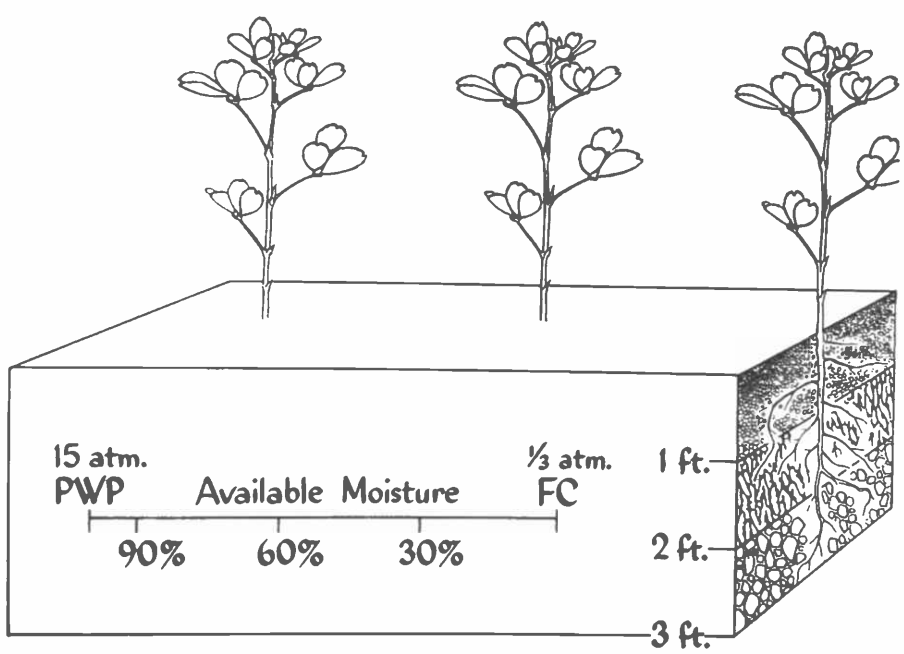
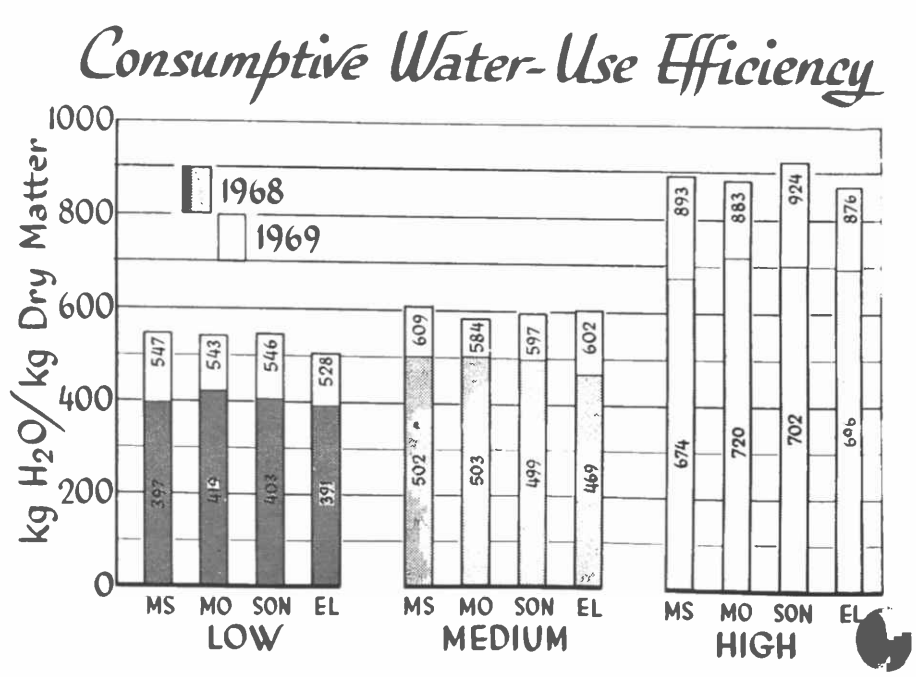


Figure 2. The units of water required to produce a unit of dry matter for Mesa-Sirsa (MS), Moapa (MO), Sonora (SON) and El-Unico (El) cultivars of alfalfa grown with three irrigation regimes during 1968 and 1969.



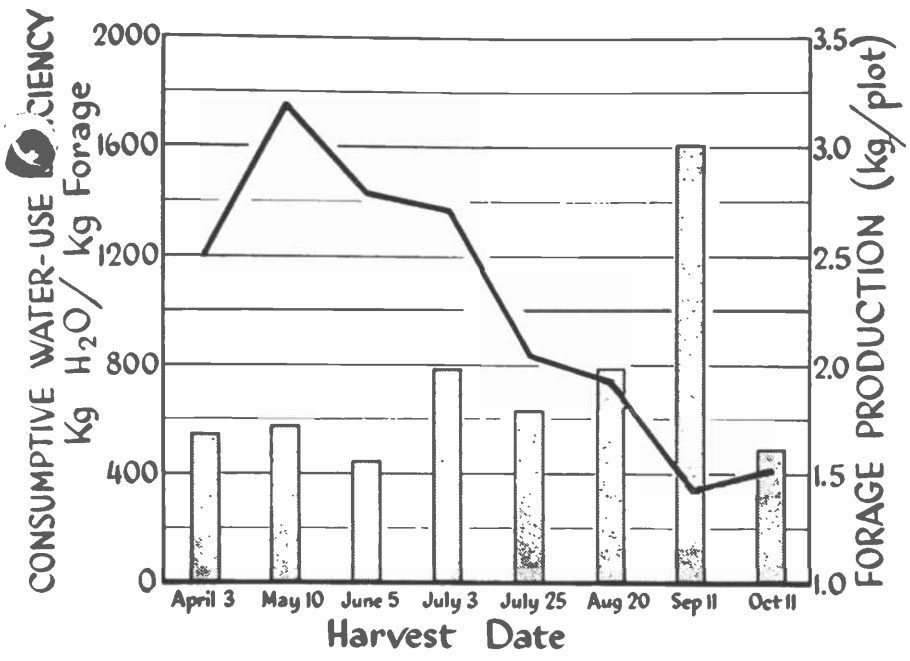


Figure 3. Average consumptive water-use efficiency (bars) and dry forage production (black line) at eight harvests of four alfalfa cultivars grown under three irrigation regimes in 1969.

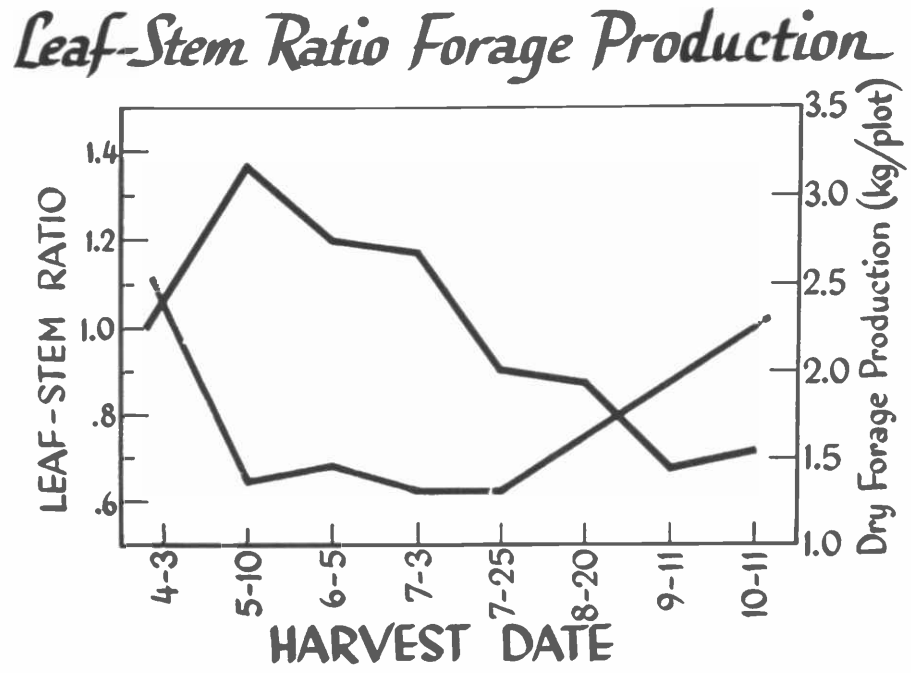


Figure 4. Average leaf to stem ratio (bottom line) and dry forage production (top line) of four alfalfa cultivars grown under three irrigation regimes in 1969.

Cultivars Differ in Consumptive Water-Use Efficiency

A statistical comparison of cultivars within soil moisture regimes showed that in 1968 El-Unico was significantly more efficient than Moapa under the low moisture regime. Under the medium regime El-Unico was more efficient than Mesa-Sirsa, Sonora and Moapa. Mesa-Sirsa was the most efficient cultivar under the high regime during the 1968 season (Figure 2).

El-Unico was significantly more efficient than Sonora but not significantly different than Moapa or Mesa-Sirsa under the high soil moisture regime in 1969. Cultivars were not signigicantly different under the low and medium moisture regimes in 1969.

Irrigation Regimes Affect Consumptive Water-Use Efficiency

Plants grown under the low soil moisture regime were the most efficient in water-use while plants grown under the high moisture regime were the least efficient (Figure 2).

Consumptive use was successively greater from the low to the high soil moisture regimes which was partially due to increased evaporation. However, differences in consumptive water-use efficiency among irrigation regimes were due mainly to differences in irrigation efficiency. Irrigation efficiency was higher on the low and medium soil moisture regimes than on the high regime. To attain maximum irrigation efficiency of approximately 90 percent, the irrigation system was designed for water applications of more than twice the 400 gpm (gallons per minute) used in this experiment. It was necessary to apply an average minimum irrigation of 5 acre-inches in order to adequately irrigate all plots under the high moisture regime. This was more than that needed to refill the plant root zone and water was lost through deep percolation. Irrigation efficiency of the low and medium soil moisture regimes was believed to more nearly approach maximum because larger quantities of water were required to refill the plant root zone at each irrigation.

Total rainfall plus irrigation water applied to alfalfa grown under the low, medium and high soil moisture regimes in 1968 was 45, 55 and 75 acre-inches, respectively. In 1969 the low, medium and high regimes received 50, 54 and 83 acre-inches of water, respectively.

Alfalfa Plants Most Efficient at Period of Highest Production

Cultivars varied significantly in consumptive water-use efficiency among harvests. In general efficiency was greatest when alfalfa production was highest. The consumptive water-use efficiency values shown in Figure 3 are based on the amount of water applied prior to each harvest. In 1969 plants harvested in June were the most efficient while the least efficient harvest occurred in September. Although the October harvest yielded only 23 kg of forage per plot more than the September harvest, it was the second most efficient harvest with a value of 489. This occurred because no irrigations were applied after September. When harvested in October, the plants were using moisture supplied to the soil prior to the September harvest.

Leafiness of Alfalfa

The leaf to stem ratio and dry forage production averaged over cultivars and irrigation regimes for each harvest are shown in Figure 4. The alfalfa plants had more leaves per unit of dry matter at the first and last harvests and more stems during the period of peak forage production. The average leaf to stem ratio dropped sharply from the April to the May harvests, remained low through July and increased with the fall harvests. Temperature influenced the leaf to stem ratio of alfalfa. Reference to temperature data for 1969 showed that the averaged leaf to stem ratio was generally highest during the coolest months and lowest when temperatures were high.

Conclusions

Alfalfa cultivars with the highest forage production were the most efficient in consumptive water-use. Water was wasted when more was applied than that amount removed from the plant root zone by evapotranspiration. This illustrated the importance of operating irrigation systems at maximum efficiency. Increases in consumptive water-use efficiency achieved by growers through more efficient alfalfa cultivars would be nullified if the plants were grown under an inefficient irrigation system.