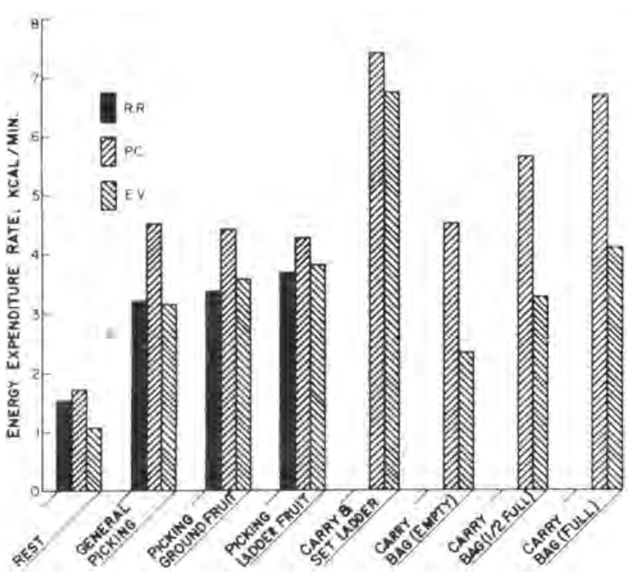
HUMAN ENERGY OF PICKING

Picker shown with mask, respiration meter, and connecting hose as used during orange picking tests with fruit low on the tree in photo above, and from top of ladder in photo to right.

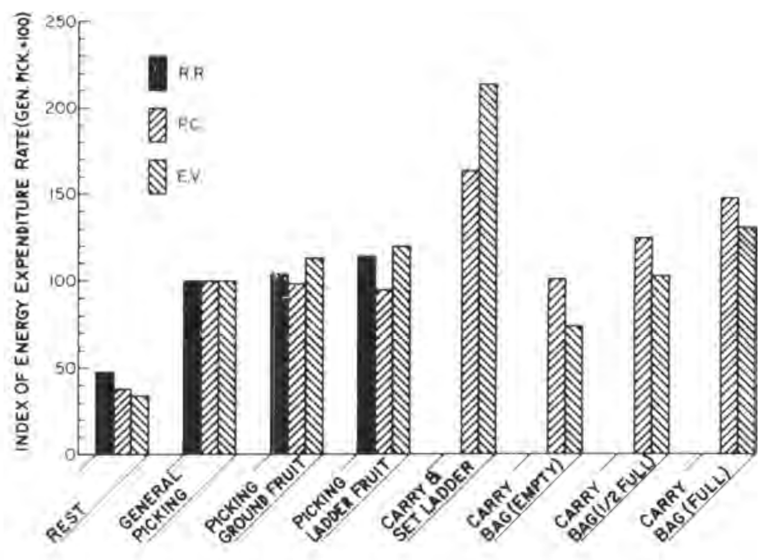
Results of investigations of human energy expended by orange pickers show that pickers are 25% more efficient when picking fruit from the ground than during general picking. Picking fruit from a ladder is not appreciably less efficient than general picking. Ladder-carry and setting require twice the energy per unit of time as general picking.

MOST RESULTS from machine use in citrus picking have been evaluated in terms of product output rate with the inherent assumption that an increase in rate of product output means easier work. This assumption is not necessarily true, however, because the human body has a peak efficiency beyond which productivity is disproportionately lessened. A prime consideration in the development of machines for man's use should be the well-being of the individual, with due regard for the objectives of fulfilling task

Graph 1. Energy expenditure rate for component functions.



Graph 2. Index of energy expenditure rate (general picking for each subject set at 100).



COSTS
ORANGES

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requirements. This should involve a consideration of his well-being, at work and away, as influenced by his working tasks. One method of evaluating task conditions is measurement of the human energy expended. This method has been used by many investigators in evaluating work conditions.

In this study, measurements were made of the energy expended by citrus pickers performing some of the activities of citrus picking. General picking, picking ground-zone fruit, picking ladder-zone fruit, carrying and setting the ladder, and carrying the bag, were studied to determine the physiological costs. The procedure for obtaining the energy expenditure involved indirect calorimetry, sometimes called "respiration calorimetry," in which air breathed by the picker is metered, sampled, and analyzed. The photos show the mask, respiration meter, connecting hose, and other test equipment in place during the tests.

Energy expended

Graph 1 shows the energy expenditure by three individuals performing the tasks of general picking, picking ground fruit, picking fruit obtainable only from a ladder, carrying and setting the ladder, carrying an empty bag, carrying a half-full bag, and carrying a full bag. In addition, the graph shows the energy expenditure while seated and resting, at the start of the day's work. This rest energy expenditure rate is not a true basal metabolism but serves for comparison. The data show that subjects R. R. and E. V. exhibited similar energy expenditure rates, whereas subject P. C. expended energy at a considerably higher rate for all the tasks.

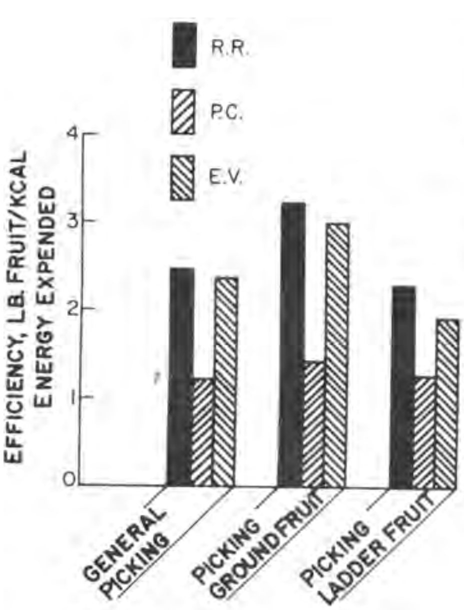
Alternate runs made with and without the sampling equipment showed that the mask and meter slowed the picker by 18% when ladder picking. To determine whether inputs by the individual were comparable for tests with and without the meter, heart rate was measured by telemetering the electrocardiogram, a method which had virtually no influence on the picker (the heart rate was nearly the same from comparisons of the tests without the meter).

Data analysis

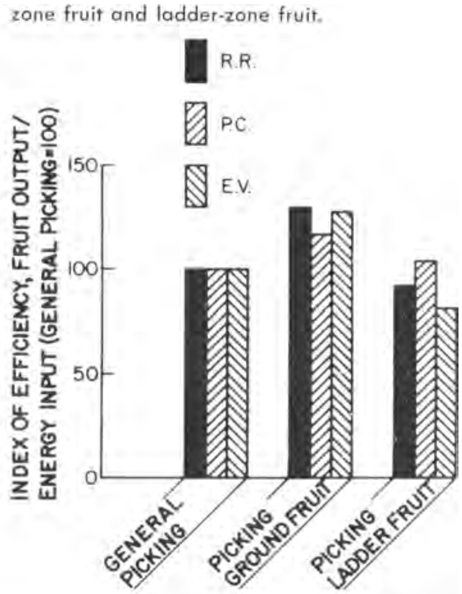
One typical manner of considering data on energy expenditure is to base it on energy rate per unit of body weight, since the man must provide energy to move his own body. In addition, an orange picker must provide energy to move the fruit in his picking bag. Therefore, consideration must be given to the weight of fruit moved. This results in a problem of variable weight, since the amount of fruit in the bag is not constant. The data were analyzed by comparing the energy expenditure for each task with that for the task of general picking. This might be thought of as providing for compensation of energy expended due to body weight and weight of the fruit in his picking bag. The data of graph 2 are the same as graph 1 but based on an index set at 100 for general picking for each subject. The average index for energy expenditure rates is only slightly higher for picking ground fruit and ladder fruit than for general picking. With ladder picking, the average index was 107. The average index for carrying and setting the ladder was 185. The energy required to carry an empty bag averaged only 10% less than for general picking, whereas carrying a full bag required 40% more energy per unit of time than did general picking.

The *efficiency* of the operation in terms of the product output per unit of input was considered of greater concern than the *rate* of energy input. Graph 3 shows efficiency in terms of pounds of fruit picked per kilocalorie of energy input for the three experienced citrus pickers. These data show considerable differences in efficiency between the individuals. Subject R. R. (the most efficient for each consideration), and subject E. V. had nearly equal efficiencies, while P. C. was considerably less efficient. After adjustment of these data to establish an index at 100 for each individual for the efficiency of general picking, the indexes of

Graph 3. Efficiency of general picking, picking ground-zone fruit, and ladder-zone fruit.



Graph 4. Index of efficiency of picking ground-zone fruit and ladder-zone fruit.



efficiency for picking ground fruit and for picking ladder fruit can then be shown (graph 4). This simplifies comparison of the tasks and points out that the significant benefit of picking ground fruit over ladder fruit was in the efficiency of activity rather than in the level of energy input (graphs 1 and 2). Picking ground fruit was 25% more efficient than general picking. Ladder fruit picking was only 7% less efficient than general picking.

When modified tasks or developed devices are to be evaluated on the basis of efficiency, proper consideration must be given to the methods which demand high energy input—and may also afford an opportunity for proportionate productivity analysis. This cannot be done if one evaluates only the rate of energy input, or only the rate of production. The results reported here do not reveal anything contrary to what might be expected by a person with experience in citrus picking. The results do, however, provide a method and a quantitative base with which to compare advantages of proposed alterations in equipment and materials, management practices, tree structure, and fruit-bearing characteristics.

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SUMMARY

1. Pickers are 25% more efficient when picking ground fruit than during general picking.
2. Ladder fruit picking is not considered appreciably less efficient than general picking.
3. Ladder carry and setting require nearly two times the energy per unit of time that general picking requires.
4. The equipment for respiration calorimetry encumbers the subject.
5. There is need for a satisfactory calibration of energy expenditure with heart function or other body function *that can provide data easily,* without encumbering the subject.

Forage and Protein By Subclover-grass Nitrogen-fertilized California

Range grass areas including stands of subclover produced forage yields equal to those from nitrogen-fertilized annual grasslands in a moisture-deficient year in northern California, and more forage was produced in a moisture-adequate year, according to this study. Stands of subclover and grass produced forage yields equal to those from California annual-type grasslands fertilized with 45 to 90 kg of nitrogen (N) per hectare (45 kgN/ha = 40 lb/acre), in a moisture-deficient year (when rains began and ended in March). In a moisture-adequate year (with rains commencing in early October and ending in May), subclover-grass stands produced more forage than did resident grasslands fertilized with 179 kg N per ha. Nitrogen fertilization was found to contribute most to forage production during the winter period. Second- and third-year stands of subclover also showed production increases early in the season, but made the greatest gains in April and May.

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ANNUAL-TYPE GRASSLANDS occupy extensive areas in California. These areas are characterized by a Mediterranean-type climate which is wet during the cool period of the year and dry during the summer months. These grasslands are designated as annual grasslands because winter annual species are the dominant cover. Hardinggrass, *Phalaris tuberosa,* a perennial, has been successfully established in some areas, but even in these areas annual species are generally dominant. A factor which limits production on most of these grasslands is soil nitrogen (N). There are two ways to increase N levels—by fertilization, and by establishing legumes.

Studies

Many studies have been made on the use of commercial N on annual grasslands in California. The effects of increasing rates of N, and of time of application, have been studied on small, ungrazed plots, and extensive work has been done with animals to evaluate the economics of N fertilization. Conclusions were that whether N fertilization is profitable on annual grassland depends upon management, prices, soil type, temperature, and amount and distribution of rainfall. Best results were observed on well-drained annual ranges where the seasonal rainfall was 15 to 25 inches. The price of commercial N has been very favorable in recent years, and its use has been widespread, even in areas of the state which are climatically well adapted for the growth of subclover.

Contribution

The contribution of self-reseeding annual legumes in increasing forage and N production on annual-type grasslands is well recognized. It has been estimated that from 45 to 60 lbs N per acre may be produced each year by annual legumes in California. Subclover, *Trifolium subterraneum* L., pastures in a Mediterranean-type climate at Crookwell, New South Wales, Australia, have reportedly added an average of 42.5 lbs of soil nitrogen per acre each year for periods up to 26 years. Yields have been reported from subclover plots in the north coast region of California of about 13,000 lbs of forage per acre,