and 81°F day. They were irrigated with 1/4 concentration Hoagland nutrient solution three times a week. After 3 weeks, growth recovery was measured as a percentage of the control treatment in which tillers were collected from the field and not given a cold or freezing treatment.

After 8 weeks of cold treatment, all the buffalograsses resumed growth. The Mexican collections showed only a slight reduction in growth recovery after 14 weeks' cold treatment. The Texas native and Colorado Common buffalograsses showed no reduced growth recovery, even after 14 weeks of cold treatment (table 2).

The Texas native and Colorado Common buffalograsses fully resumed growth after 2 weeks of freezing treatment and had 80% growth recovery after 4 weeks of treatment. Plants of the two Mexican buffalograsses did not resume their growth after 2 weeks of freezing (table 2). These studies indicate a substantial genetic variation in both winter color retention and cold resistance among buffalograss collections. Plants used in the test may be used for buffalograss turf improvement.

Vegetative propagation

Most commercial warm-season turfgrass cultivars are vegetatively propagated, but no vegetatively propagated buffalograss is available commercially. At both UC Davis and the UC Deciduous Fruit Field Station in Santa Clara, vegetatively propagated clones are being observed for differences in rate of spreading and turf quality under reduced mowing, irrigation, and fertilization.

Buffalograss clones have shown considerable differences in rate of turf establishment through vegetative propagation. Some clones selected from the natural buffalograss populations have formed a solid turf within 6 weeks, starting from 1-inch plugs planted 12 inches apart. Turf established from selected female clones remains under 4 inches in height without mowing. Flower heads of female clones are inconspicuous, because they are short and under the turf canopy. Reasonable turf color and density are being maintained with 1 pound nitrogen per 1,000 square feet per year and irrigation once a week during the summer.

Selected clones have been planted in the field in Davis, Santa Clara, and southern California. Vegetatively propagated cultivars from these trials may be available to the public within the next 3 to 4 years.

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Field-drying rice using modified swath harvesting

Bryan M. Jenkins

A technique for drying rice in windrows by covering them with stubble has been developed and field-tested. Modified swath harvesting reduces drying costs, and it protects the crop from dew, improving yield of head rice.

In the last 50 years, combine harvesting has completely replaced swath harvesting in California. To achieve the potential of combines for better quality and higher yields, however, growers of the rice varieties used in California have had to harvest at fairly high moisture. Because field-drying couldn't be used to reduce moisture to safe levels for storage, the grain had to be dried at a high cost after harvest. Rising energy costs over the last two decades have caused some growers to take another look at swath harvesting as a way to cut drying costs. Complete drying by traditional swathing doesn't work, because rice left for more than a day in a windrow loses quality rapidly.

TABLE 1. Head rice yields, grain moisture content, and total milled rice for standing crop, open windrows, and modified windrows of 1987

Days after swathing	Standing Head	Standing Moisture	Standing Total	Open Head	Open Moisture	Open Total	Modified Head	Modified Moisture	Modified Total
	%								
0		27.9			27.9			27.9	
1	—	—	—	64.7	22.7	68.9	64.4	23.5	67.7
3	—	—	—	48.8	13.7	69.7	58.9	14.4	69.2
5	65.0	25.6	68.6	—	—	—	—	—	—
6	—	—	—	36.5	14.0	67.8	46.6	13.9	68.9
8*	—	—	—	38.8	13.3	68.2	51.4	13.0	69.6
12	—	—	—	34.5	10.8	69.1	45.0	10.3	70.9
17	—	—	—	24.1	9.8	68.6	42.9	10.2	70.6
18	42.0	16.5	69.7	—	—	—	—	—	—

*Cylinder speed reduced from 775 to 600 rpm.

TABLE 2. Costs and revenues for modified swath and direct-harvest methods

Category	Harvest* Direct	Harvest* Swath	Difference (swath relative to direct)
	$/cwt	$/cwt	%
Costs:			
Drying	0.698	0.250	-64.2
Harvesting	0.233	0.350	+50.1
Transportation	0.049	0.045	-7.5
Total	0.980	0.645	-34.2
Gross revenue	6.580	6.735	+2.4
Net revenue	5.600	6.090	+8.8

*Grain at 14% moisture content, wet basis.

The value of rice is largely based on the yield of whole-kernel grain, or head rice, at the mill. The moisture content of the grain at harvest is an indicator of the expected head rice yield. Rice kernels crack if rewetted when below a critical moisture content of 13% to 16%. Since the distribution of individual kernel moisture in the panicle is nonuniform, cracking or fissuring of some kernels on the standing crop will begin when the average grain moisture drops below 25% for medium grain varieties. In the field, rewetting results from changes in relative humidity and from heavy dew. Both the standing crop and swathed grain at the surface of a conventional windrow can be damaged. Not much can be done to protect the standing crop once the moisture content has begun to decline. For swathing, however, the technique developed in this project protects the grain from rewetting by dew and significantly improves head rice yields.

The new technique consists of placing a layer of stubble over the windrow, covering the grain. Dew may still form on the cover but generally not on the grain underneath. Even a light cover of chopped stubble is enough to significantly reduce damage to grain in the windrow during prolonged exposure. The greater yields obtained from covered windrows are thought to be the result of reduced exposure to dew.

The covering can be done mechanically, and is superior to inverting the windrow, which leads to excessive shatter loss.

Harvesting experiment

Two ways to modify the environment of grain in windrows were tested. In the first, in 1985, the windrow was folded to place the grain between an upper and lower layer of straw. This proved difficult to do mechanically. It also slowed the drying of the grain and generated narrow, dense windrows that were difficult to thresh. In the second method, in 1986 and 1987, stubble was cut from the side of the windrow with a flail chopper and distributed on top of the windrow. A spreader was built to distribute a uniform layer 1 to 2 inches (25 to 50 mm) deep over the windrow. The 1986 field trial included 9 days of exposure for M-9 rice; the 1987 trial allowed 17 days of exposure for M-202 rice.

Head rice, total milled rice, grain and straw moisture, yield, and harvesting losses were monitored for both open and covered windrows in both trials. Standing grain samples were taken at days 5 and 18 in 1987. Weather data and drying rate data for the grain were recorded continuously during the trials.

Head rice yields from covered windrows during the 1986 trial did not change significantly. Yields from open windrows began to drop after day 5 (fig. 1). There was essentially no difference in the drying rate for grain in either type of windrow.

Changes in head rice yield during the 1987 trial were more dramatic (table 1). They were similar to results obtained in the folded windrow trials of 1985 using M-201 rice, at least for the first 4 days. Differences between the 1986 and 1987 trials are probably due to the time of year the trial was conducted (October 1986; September 1987), and perhaps also to the variety of rice. The weather was cooler throughout the 1986 trial, and dew was lighter on the windrows. A light rain on day 8 of the 1986 trial apparently had little more effect than a heavy dew.

By the third day of the 1987 trial, grain moisture had reached 14%, and again there was no apparent difference in the drying rates for open and covered windrows. An increase in head rice yields seen at day 8 resulted from slowing the threshing cylinder to avoid cracking the drying grain. The data show that the cylinder speed should actually have been reduced earlier, probably before harvesting on day 3.

Threshing losses (measured by rethreshing the windrows after additional drying in the field) were not significantly different between the two windrow treatments, and remained at about 1%. Nor did slowing the cylinder speed after the grain reached a low moisture level increase threshing loss. The threshing loss did not include gathering or separator loss, but inspection of the soil surface following harvest showed these losses to be similar for both types of windrows and for direct-harvested crop.

Earlier studies indicated that the amount of milled rice drops as the head rice yield declines, because more flour is produced during milling. In these experiments, total milled rice did not change substantially as the grain dried and head rice declined (table 1). Standing grain harvested directly at day 5 had a moisture content of 26% and yielded 65% head rice. By day 18, at 16.5% moisture content, the head rice yield was only 42%, or somewhat lower than the yield of covered windrows left for 17 days and harvested at a moisture content of 10%. While such long exposures for windrowed rice are not recommended, the potential for stabilizing grain quality by modifying the windrow environment is clear.

On day 3, at 14% moisture content, the head rice yield of grain in the modified windrows was 59%, compared with 49% for grain in the open windrows. The main difference in the environment of the grain between the open and covered windrows appears to be exposure to dew. Dew formed on the surface of the windrows on every night of the 1987 trial. It did not penetrate the stubble layer. This is supported by the difference in rates of head rice decline seen past day 8 (table 1). Grain in open windrows shows an accelerating rate of decline; in covered windrows, the rate of decline decreases with time. The leveling of head rice yields for covered windrows is consistent with less rewetting of the grain by atmospheric vapor and dew as the soil dried.

Economic analysis

A comparison of the three major operations occurring after grain ripens shows that modified swath harvesting has a potential for improving net revenue (table 2). This is based on a swath harvest begun at 28% moisture compared with a direct harvest begun at 24.5% moisture under the assumption of a moisture limitation imposed by the receiving dryer. The costs in table 2 are for grain at 14% moisture.

Although harvesting costs may be about 50% greater because of the additional swathing operation, drying costs are 64% lower. Drying costs are based on actual schedules from a major cooperative. Higher head rice yields from the swath harvest resulted in slightly higher gross revenues. Transportation costs are less for the swath harvesting system because of the lower moisture content of the grain, which means more grain per truckload. The overall effect is 34% lower costs and 9% higher net revenue. As the moisture content for direct harvesting declines, the relative advantage to swath harvesting improves because of better grain quality (fig. 2).

The size of the operation also affects the cost difference between direct harvest and modified swath harvest. When only a small acreage is harvested, improved grain revenues and lower drying costs will not offset the increased capital cost of equipment if the grower allocates the full cost of equipment against the harvesting operation. On larger acreages, net revenue from the swathing system exceeds that of direct harvest, because equipment costs are lower than the benefits from higher grain quality and lower drying cost (fig. 3). The costs shown are based on a grain yield of 83 cwt per acre at 14% moisture. At about 300 acres (120 ha), swath harvest breaks even with direct harvest and generates superior revenues above this point. On smaller farms, contracting the harvest could achieve results similar to those for larger acreages for swath harvesting.

Commercial energy savings

Modified swath harvesting may also reduce the total amount of energy needed to process the rice. Drying in the field could reduce drying energy 4 to 6 therms per ton of rough rice (500 to 700 kJ/kg), depending on the efficiency of the dryer handling direct harvested rice (fig. 4). These savings are less when natural air drying is used to remove final moisture.

Transportation energy is also reduced as a result of transporting lower moisture rice. Savings in transportation energy, however, amount to a difference of only 0.06 gallon (0.2 L) of diesel fuel per ton of rough rice (10 kJ/kg) for a 25-mile (40 km) haul. The lower moisture for swath harvest eliminates one truckload out of every eight needed for direct harvest at 24.5% moisture.

Energy for harvesting is increased by 0.2 gallon (0.8 L) of diesel fuel per ton of rough rice (36 kJ/kg) in modified swath harvesting, primarily because of increased fuel consumption by the swather. Overall, however, modified swath harvesting substantially reduces commercial energy consumption because of large savings in drying.

Summary and conclusions

Modified swath harvesting improved head rice yields when compared with open windrows or direct-harvested grain at low moistures. Drying rates for grain in modified windrows are not significantly different than for open windrows. Adequate stubble is available to provide sufficient cover for the windrows. Apparently, only light covers are needed to obtain significant gains in head rice compared with open windrows. Reduced drying costs improve net revenue over direct-harvesting grain for larger scale operations. At smaller scales, increased harvesting costs may offset the marginal gains obtained by higher quality and field drying, if the equipment is fully allocated to the small acreage harvested.

Swath harvesting permits earlier entry into the field, and can improve timing of harvest and possibly equipment utilization, leading to cost savings not included here.

The modified swath method may also have potential for straw harvesting. Because it removes stubble from the tracks of equipment moving in the field, more straw is available for collection, and there would be less of a problem with overwintering stem rot. The method also allows straw to dry before harvest, making total harvest systems feasible. Straw harvesting could generate additional income not included in the economic analysis reported here.

The technique has so far been tested only in relatively good weather. Further evaluation is needed under more adverse weather and crop conditions. Modified swath harvesting will not be suitable under all conditions; lodged and late-season crops may prove difficult to harvest in this manner. The method has not yet been tested in long grain varieties, and the advantages, if any, over direct harvest are uncertain. However, as growers in California shift to earlier maturing rice varieties, modified swath harvesting does appear to have good potential for at least a part of the crop.

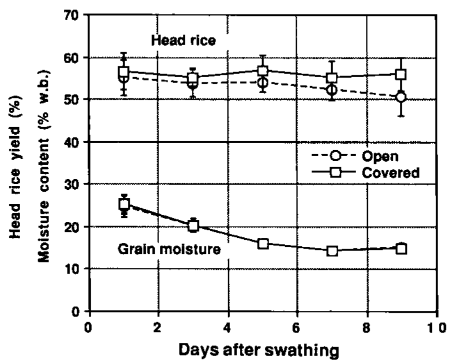

Fig. 1. Head rice yields and grain moisture, M-9 rice, 1986. Yields from covered windrows changed little but in open windrows began to drop after day 5.

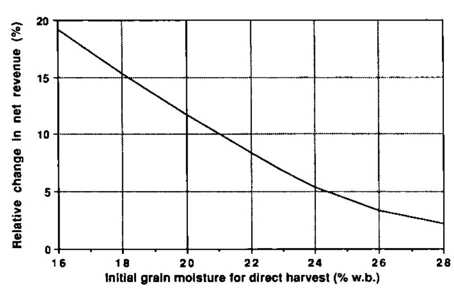

Fig. 2. At lower moisture content, the relative advantage in net revenue of swath harvesting over direct harvesting increases because of quality differences.

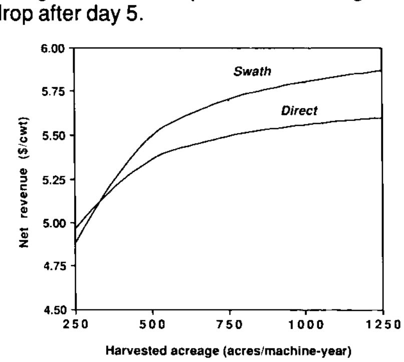

Fig. 3. On small acreages with low equipment utilization, equipment costs for swathing may exceed the benefits, up to a break-even point of about 300 acres.

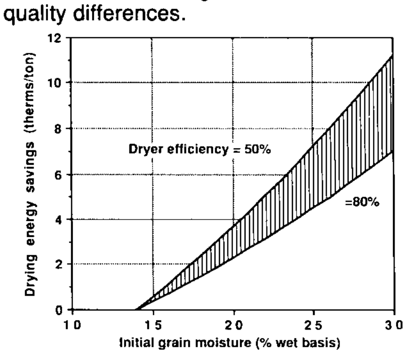

Fig. 4. Field-drying to 14% moisture could save 4 to 6 therms of energy per ton, depending on efficiency of dryer handling direct-harvested rice.

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