POTATO VARIETIES THAT CAN BE PROFITABLY GROWN SPECIFICALLY FOR ALCOHOL PRODUCTION

by
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ABSTRACT

Results of trials conducted across the U.S. in 1980 indicate that potatoes can be profitably grown specifically for ethanol production, especially in the Northwest. Growing potatoes for this purpose will not be as profitable as growing them for human consumption when prices are $100 to $200/T, like in 1980. However, when eating potatoes are selling for normal prices of $40 to $80/T a grower can probably make more on ethanol potatoes, if he grows high-yielding lines like Kennebec, White Rose or Red Pontiac and produces maximum yields. An Idaho line, A503-42, looked especially promising for ethanol production in almost every trial. Since tuber blemishes are of no importance in ethanol production, several cultural practices can be eliminated or altered to reduce production costs. Breeding programs have been initiated to develop high yielding, high solids lines with early dying disease resistance so ethanol and high protein byproducts can be obtained from both tubers and tops.

National Ethanol Trials

Organized in 1980. In 1980 trials were conducted across the U.S. to determine the feasibility of growing potatoes as a biomass crop for ethanol production. These trials were to be funded with a federal alternate fuels grant but the money did not make it through the DOE decision making process. We are grateful to cooperators in the states of Maine, North Dakota, Nebraska, Idaho and Washington who consented to grow trials with this promise of funding and then had to conduct them at their own expense.

Lines Tested. It was decided that all cooperators involved would test a core group of 14 lines and then in each area add other good candidate lines for which only limited seed was available. The core group of lines and sources of seed were: Kennebec (local), Red Pontiac (local), Lemhi (local and Idaho), Crystal (North Dakota), Atlantic (local), Russet Burbank (local), A503-42 (local and Idaho), Wn C 612-13 (Colorado), B6987-201 (Washington- B6987-184 was sent by mistake), Bounty, Neb. S1-3, 210-2, 12.72-2, and A129.69-1 (all from Nebraska).

Growing Season. The growing season in Washington and Idaho was one of the best ever for potatoes, with little heat stress throughout the summer. Yields in Idaho were lower than expected because the trial at Aberdeen happened to fall in a part of the field with poor soils and the trial at Kimberly was injured early in the season by metribuzen herbicide. In North Dakota, Nebraska and Maine the growing season was very hot and dry and the harvest season unusually wet. This resulted in low yields in North Dakota and Maine, where irrigation is not used, and in lower than expected solids.

Results and Discussion. Results indicated that growing potatoes as biomass for ethanol production can be either very profitable or very expensive, depending on which cultivars are grown and where they are grown (Tables 2-10). Results from Nebraska were not available as this was written. The high yields usually obtained in southwest Idaho and up through eastern

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Oregon and eastern Washington could make potato production for ethanol in those areas profitable, if high-yielding cultivars like White Rose, Kennebec and Red Pontiac are grown over a long season (Table 2). Yields of 50 to 70 T/A were obtained in these 1980 small plot trials, which would convert to 1000 to 1300 gallons of ethanol/A, much more than corn or other proposed ethanol crops. The vines of some of the high-yielding, early-dying-resistant lines could also make a significant contribution to the production of ethanol and high protein byproducts. The resistant lines, Wn 708-27 and Wn 705-111, produced 55 to 75 T/A of tops in these single row plots, because they overgrew adjoining plots of commercial cultivars. We estimate that such lines could produce up to 40 T/A of tops in large acreages, which could convert to 300 gallons of ethanol/A and 5 T/A of 20% protein byproduct, paying the cost of extracting ethanol from both tubers and tops.

Nationwide, the leading candidate as an ethanol variety is A503-42 (Tables 2, 5, 7, 8, 9, 11). It is consistently high yielding and has good solids. Other lines that show promise and deserve further testing are Denali, A68113-4, A72545-2, A74595-11, A75708-9, A74771-4, Wn C 612-13, Wn 705-111 and Wn 708-27. Several others showed some promise and probably should be retested. Many new clones were selected in 1980 by breeders interested in this new use of potatoes. These will be screened locally and seed increased of the most promising for wide-scale testing, to determine if they will produce higher yields of fermentable carbohydrates/A than the best lines tested in 1980.

Profitability Factors

Whether potatoes can be profitably grown for ethanol depends to a great extent on the extraction costs of the ethanol and how much of this cost can be recovered by sale of byproducts. This would be particularly true in most areas outside the Columbia Basin area of Oregon and Washington, because the estimated cost of growing the crop in most areas is about the same as the value of the ethanol that might be obtained.

Whether potatoes can be economically used for ethanol also depends on complex supply and demand factors. The high potato prices in 1980, resulting from a short supply, would have made it uneconomical to make ethanol from any potatoes except those not suitable for human consumption. To insure a constant supply of potatoes, ethanol factories must have them grown under contract. The growing of ethanol potatoes will probably be a separate industry from the growing of potatoes for culinary purposes, and will probably involve high yielding varieties not suitable for fresh market or processing.

Ethanol Yield Estimates

We soon found that there was little information available on the production of ethanol from potatoes. It is generally assumed that technology for extracting ethanol from potatoes is available but we were unable to find anyone in the U. S. who had successfully done it on a large scale or over a long period of time. Those who have been trying have encountered various problems in the extracting process or separation of byproducts and are still trying to overcome these problems. None seemed to have good information on how much ethanol can be extracted from potatoes. The literature indicated that from 1 to 1.4 gallons of ethanol could be extracted from a cwt. of potatoes, with 1.25 gallons being the figure most commonly used. Those actually extracting ethanol from potatoes however, agreed that this estimate was too high. There is only about an 85% conversion efficiency of starch to ethanol with the techniques presently used.

I reviewed the literature on the relationships between specific gravity, solids, starch and sugars, and talked with several who had conducted studies on these relationships. From the information collected I developed Table 1 which has many "ifs" connected to it but provides a reasonable estimate of the amount of ethanol that might be extracted from a cwt. of potatoes at various specific gravity levels. Since every cultivar differs in these relationships and environment plays such an important part, it is impossible to come up with exact figures that would hold under all circumstances. The estimates in Table 1 seem to conform fairly closely to actual yields of ethanol which are being obtained by the few ethanol factories trying to use potatoes. The details of how these estimates were computed and used in converting our trial results into gallons of ethanol/A and dollar values are shown in footnotes of Tables 1 and 2.

Important Considerations Before Trying to Raise Potatoes for Ethanol

Not Profitable if Grow Russet Burbank and Obtain Average Yields. Based on 1978-80 reports the average yield of potatoes in Washington increased from 465 up to 505 cwt/A during the past three years, but production costs increased from $1095 up to $1339/A. Thus, the cost of growing a cwt. of potatoes increased from $2.35 up to $2.65 (Table 11). Assuming an ethanol yield of 1.1 gal/cwt. of potatoes, it would have cost $2.09 to $2.41/gal of ethanol just to grow the distillery feedstock, which is about 39¢ to 71¢/gal more than ethanol is selling for in 1981. The picture is even worse in other potato growing areas. In 1978 it required an average expenditure of $795/A in Idaho to produce an average yield of 275 cwt./A (Table 11). Thus, production costs were between $2.89 and $3.30/cwt., depending on which report you read. Ethanol from these Idaho potatoes would have cost about $2.63 to $3/gal in feedstock growing cost, or $1.03 to $1.30/gal more than it is worth. Production costs in Maine and North Dakota also make ethanol production from potatoes appear unfeasible (Table 11). To make the picture even more negative, on top of the cost of feedstock production must be added hauling, storage and ethanol extraction costs. It would be prohibitive to haul potatoes more than short distances or store them in expensive, controlled-atmosphere storages. The cost of extracting 200 proof ethanol from potatoes is currently estimated at 70¢/gal, with only 20¢ to 30¢ of this cost likely to be recovered through sale of distillation byproducts. Therefore, it is obvious that the average grower in Washington and across the nation would lose money raising potatoes specifically for ethanol, unless he was able to greatly increase his yields or decrease his production costs. Fortunately, there appears to be much potential to do both of these.

Potential Cost Savings When Raising Potatoes for Ethanol

Wright, Smith and Hinnman estimated it would cost $1339/A to raise potatoes in the Columbia Basin in 1981 (Table 12). Some of their projected costs, which are required to produce the quality needed for processing or fresh market, would not be required to produce potatoes for ethanol, where internal and external blemishes are of little importance. The main variety in the West, Russet Burbank, is susceptible to almost every potato disease and pest and is very sensitive to water or fertility stresses. It appears that potential ethanol lines could produce high yields without disease control measures and excesses of irrigation and fertilization being used on Russet Burbank. Early-dying resistant vines on ethanol lines will probably be cut like hay before harvest, dried, chopped and added to the tubers as part of the feedstock for ethanol production. Therefore, defoliation before harvest will not be required. Some savings would result from the rougher handling allowable with ethanol potatoes.

Since net necrosis is not important in tubers used for ethanol, more leafroll could be tolerated, as long as yields were not reduced. However, there are some serious implications involved in reducing seed quality for ethanol production. Fields growing ethanol potatoes with minimal aphid control and much leafroll spread would be devastating to adjoining fields of Russet Burbank grown for human consumption. Seed would still have to be raised in seed growing areas and be certified or yield reductions would result. However, lower certification standards would probably be required with resulting lower priced seed.

Total savings could add up to as much as $400 (Table 12). If vines were included as part of the biomass, there would be an estimated cost of $63/A to swath, chop and haul these. The net effect of these estimated changes would be to reduce production costs from $1339/A for culinary use down to $1000/A for ethanol use (Table 12).

Increased Yields of Carbohydrates Feasible

The Effect of Increased Yields. In the Columbia Basin Russet Burbank will yield over 40 T/A in some fields. Small plots of high-yielding cultivars, like White Rose, Kennebec and Red Pontiac, produce yields up to 50 T/A or more under commercial growing conditions, if they are allowed to grow the full season. Very high-yielding clones occasionally appear in breeding programs but are usually discarded because tubers are not the right type, are too large or too rough or have hollow heart or other internal or quality disorders. A high-yielding clone that has been extensively tested in Washington is the Idaho selection A503-42 which looked so good in 1980 across the nation. In 49 trials over a 10 year period throughout the Columbia Basin it has averaged 860 cwt/A with specific gravity of 1.081. If potential ethanol production of such high yielding cultivars or clones is calculated, it becomes evident that potatoes are an economically feasible ethanol feedstock (Tables 2, 3, 6 and 13). As yields are increased to 800 to 1200 cwt/A, which is a reachable goal in much of the Northwest, the feedstock cost is well below the value of the ethanol that could be produced (Table 13). If breeders concentrate on crossing and selecting for yield alone, it is probable that lines yielding 60 T/A can be developed.

The Effect of Increased Solids. In addition to these potential yield increases, there is also potential for increasing the carbohydrate content of potatoes. Russet Burbank when grown in the Columbia Basin averages between 1.075 and 1.085 in specific gravity. The variety Nooksack averages between 1.085 and 1.095. Some advanced test clones average between 1.095 and 1.105 and lines are available that average higher than this. It is questionable whether maximum yields can be combined with maximum solids unless genetic engineering techniques can accomplish it, but major advancements can be made in combining these characteristics. Increasing solids within its potential range will not effect ethanol production or the feedstock cost factor nearly as much as will increasing yields (Tables 13 and 14). However, this is still an important breeding goal because one of the main problems in using potatoes for ethanol production is the relatively low concentration of fermentable carbohydrates compared to grain crops. This results in a low concentration of ethanol in the "beer" entering the distillation columns and an inefficient distillation process. Therefore, corn is usually added to the brew to increase distillation efficiency. Increasing solids would reduce the proportion of corn that needs to be added.

Tops Could Make the Difference

Contribution of Tops. An overlooked ethanol feedstock produced in potato fields is the vines. These grow very large under cultural conditions in the Columbia Basin. The lines being evaluated for ethanol production which are resistant to Verticillium wilt and other early dying diseases have immense vines by harvest time. In 1980 two of these resistant lines, Wn 705-111 and Wn 708-27, were planted in single row plots in competition with Russet Burbank on one side and Norgold on the other. They overgrew these two cultivars and when the vines were harvested on September 5 they had produced 55 and 75 T/A of top growth, respectively (Table 2). Analysis of these tops showed they contained 90% water, 5% carbohydrates and 2.5% protein. If these tops could be solar dried, they would provide a dried product with close to 50% carbohydrate and 25% protein. This might be as good or better than corn as a feedstock for mixing with the high moisture content tubers. Vines could also be harvested from fields of culinary potatoes and used for ethanol production. We estimate that a circle of an early-dying resistant cultivar could yield 40 T/A of tops, which could convert to 260 gal/A of ethanol worth $440 and 5 T/A of 20% protein byproduct worth $750/A, or a total of $1190/A. This would pay all hauling, storage and ethanol extraction costs for both the tops and tubers and still leave some profit. Because of this potential high value of tops, one of our main *breeding goals is early dying resistance. This resistance should also alleviate the yield decline* experienced on fields after repeated cropping to potatoes.

Methods of Harvesting Tops. A week or two before tubers are to be harvested vines could be swathed like hay and, after drying to at least a leathery condition, chopped and stored like sileage or used to cover piles of tubers. Even though drying conditions are not good in the fall during the time of potato harvest, much of the moisture would be gone from a windrow of vines in a week or so. Vines harvested earlier in the fall, when they could be thoroughly dried, could be baled like hay, stored in stacks and later ground for ethanol production. Dried vines could also be chopped and stored like chopped hay. If a hay chopper could be equipped with pea type vine lifters, the vines could be greenchopped immediately before tuber harvest and stored as sileage, probably mixed with straw because they would be very moist. Some means might also be devised to catch vines off the back of the digger so they could be greenchopped later.

Methods of Storing Potatoes for Ethanol

Pit Storage. An economical method of overwintering potatoes was used in earlier days and is still used in some large potato producing areas of the world. A large trench or pit is dug, the potatoes piled in it and covered with soil to prevent freezing. That this method works seems inconceivable today, when so much importance is placed on very refined storage conditions in large, controlled-atmosphere storages. However, this old method would probably work for potatoes to be used for ethanol since the condition of tubers coming from storage is not critical, as long as there are not serious rot losses. Chopped vines could be used instead of dirt to protect from freezing. With a thick covering of chopped vines it would probably be feasible to store potatoes in large piles on top of the ground. Sileage pits or silos would also work, especially if there was a means of collecting juice from rotting tubers. Rotting in storages would not decrease the value of tubers for ethanol production as long as carbohydrates and proteins were not lost in the process.

Natural Dehydrated Potatoes. In some areas or years, potatoes could be left in the ground until spring and then dug. After digging they could be left on the soil surface or spread out in waste land areas to dehydrate. This would markedly increase the concentration of carbohydrates and decrease the bulk to be hauled to the distillery and processed by them. The potatoes might even be dug in the fall and left in the field or spread out in waste areas during the winter to freeze and thaw, to increase the dehydration process, much like South American Indians make chuño. This dehydrated product would make a very good distillery feedstock. Chopped dried vines piled over or under these dehydrating potatoes might also have a good affect and could be mixed with them as they are hauled to the distillery.

How Much Can Ethanol Distilleries Pay for Potatoes?

Distillers comtemplating the use of potatoes as a feedstock differ widely in estimates of prices they can pay for potatoes. Some say they can make a profit only by buying culls at not over $7/T. Others say they can pay $20 to $25/T ($1 to $1.25/cwt) and still make a profit.

If we assume that 1.1 gal of 200 proof ethanol can be obtained from a cwt. of potatoes (Table 1) and that this ethanol can be sold for at least $1.70/gal (a low estimate), then the ethanol from a cwt. is worth $1.87. It has been estimated that it will cost 10¢/cwt. to haul the potatoes, 10¢/cwt. to handle and store them and 77¢/cwt. to extract the ethanol. If these three figures are subtracted from $1.87, it would mean the distiller can pay the grower 90¢/cwt. ($18/T) and break even.

However, as indicated above, there are some possible savings if the tubers are dehydrated before hauling or if they are economically stored in piles. There would probably also be a 20¢/gal savings in ethanol extraction if the ethanol were distilled to only 160 proof and used directly as a fuel rather than distilled to 200 proof and mixed with gasoline to make gasohol. Also, the distiller can sell the high protein byproduct for at least $150/T which recovers 38¢/cwt. from the distilling cost. These savings and return from the byproduct could add about 60¢/cwt. to the value of the potatoes making them worth $1.50/cwt. ($30/T) rather than 90¢/cwt. ($18/T). If the grower can produce 1000 cwt/A at a production cost of $1000/A, it will cost him $1/cwt. ($20/T) to grow the crop. The $10/T difference could be split between the grower and the distiller as profit. If split evenly, this would give $250/A profit for the grower and the distiller. However, if some of the "ifs" above are not satisfied, the ledgers for both the grower and distiller could show a loss rather than a profit at the end of the year.

If vines are added to the biomass, as described above, the picture becomes much brighter, mainly because of the major contribution they make to the quantity of high protein by-product. We estimate that with the tubers and tops combined as much as 7 T/A of high quality, 20% protein byproduct could be produced which is worth at least $150/T. This would be an excellent annual production in itself, even for a crop of alfalfa.

Another factor to be considered is that using potato byproducts for cattle feed is probably its least profitable use. This byproduct could be more profitably used for pet food, protein supplements for humans or as a food base on which to grow fungi and bacteria that produce high value organic chemicals or medicines. Potato dextrose agar for many years has been one of the best media to support the growth of a wide range of such organisms.

As high-yielding, disease-resistant potato cultivars become available that can be profitably grown for ethanol and the systems are developed to handle, store and extract ethanol from them and utilize the byproducts to full advantage, this crop will probably become an important new industry, especially in eastern Oregon and Washington and western Idaho where high yields are possible.

Table 1. Converting Specific Gravity Readings to % Solids, % Starch, % Sugar, % Fermentable Carbohydrates and Gallons of Ethanol/cwt (all estimates, based on review of literature).

Specific Gravity	% 1/ Solids	% 2/ Starch	% 3/ Sugar	% Fermentable 4/ Carbohydrates	Gallons 5/ Ethanol/cwt
1.060	16.8	10.7	3.0	13.7	0.88
1.061	17.0	10.9	2.9	13.8	0.89
1.062	17.2	11.1	2.9	14.0	0.90
1.063	17.4	11.3	2.8	14.1	0.91
1.064	17.6	11.5	2.8	14.3	0.92
1.065	17.8	11.7	2.7	14.4	0.93
1.066	18.0	11.9	2.7	14.6	0.94
1.067	18.2	12.1	2.6	14.7	0.95
1.068	18.4	12.3	2.6	14.9	0.96
1.069	18.6	12.5	2.5	15.0	0.97
1.070	18.8	12.7	2.5	15.2	0.98
1.071	19.0	12.9	2.4	15.3	0.99
1.072	19.2	13.1	2.4	15.5	1.00
1.073	19.4	13.3	2.3	15.6	1.01
1.074	19.6	13.5	2.3	15.8	1.02
1.075	19.8	13.7	2.2	15.9	1.03
1.076	20.0	13.9	2.2	16.1	1.04
1.077	20.2	14.1	2.1	16.2	1.05
1.078	20.4	14.3	2.1	16.4	1.06
1.079	20.6	14.5	2.0	16.5	1.07

Table 1. (Cont'd) Converting Specific Gravity Readings of % Solids, % Starch, % Sugar, % Fermentable Carbohydrates and Gallons of Ethanol/cwt (all estimates, based on review of literature).

Specific Gravity	% 1/ Solids	% 2/ Starch	% 3/ Sugar	% Fermentable 4/ Carbohydrates	Gallons 5/ Ethanol/cwt
1.080	20.8	14.7	2.0	16.7	1.08
1.081	21.0	14.9	1.0	16.8	1.09
1.082	21.2	15.1	1.9	17.0	1.10
1.083	21.4	15.3	1.8	17.1	1.11
1.084	21.6	15.5	1.8	17.3	1.12
1.085	21.8	15.7	1.7	17.4	1.13
1.086	22.0	15.9	1.7	17.6	1.14
1.087	22.2	16.1	1.6	17.7	1.15
1.088	22.4	16.3	1.6	17.9	1.16
1.089	22.6	16.5	1.5	18.0	1.17
1.090	22.8	16.7	1.5	18.2	1.18
1.091	23.0	16.9	1.4	18.3	1.19
1.092	23.2	17.1	1.4	18.5	1.20
1.093	23.4	17.3	1.3	18.6	1.21
1.094	23.6	17.5	1.3	18.8	1.22
1.095	23.8	17.7	1.2	18.9	1.23
1.096	24.0	17.9	1.2	19.1	1.24
1.097	24.2	18.1	1.1	19.2	1.25
1.098	24.4	18.3	1.1	19.4	1.26
1.099	24.6	18.5	1.0	19.5	1.27
1.100	24.8	18.7	1.0	19.7	1.28

1/ Computed by using formula (201.72 x S.G.) - 196.98 = % Solids (Fitzpatrick, et al. 1969, Amer. Pot. J. 46:126).

2/ Computed by multiplying % Solids by a variable ranging from 64% at S.G. 1.060 to 76% at S.G. 1.100. This percentage variable extracted from table in Maercher, M. 1898. Handbook of Alcohol Manufacturing P. Parey, Berlin.

3/ An estimated figure based upon analytical work by Schwimmer et al. 1954. Agr. and Food Chem. 2:1284-1289. These estimates are primarily for % reducing sugars. Sucrose and other sugars are also present. The amount and form of sugar present is influenced by storage temperatures and many other factors but in most cases will make a significant contribution to total % fermentable carbohydrates

4/ Computed by adding estimated % sugar to % starch.

5/ Computed by multiplying % fermentable carbohydrates times 100 lbs to estimate the carbohydrate/cwt. Theoretically 0.5 lb of ethanol will be obtained from each lb of this carbohydrate but in actual practice only about 85% conversion efficiency or 0.425 lbs of ethanol/lb of carbohydrate is attained. Therefore, lbs of carbohydrate/cwt was multiplied by 0.425 to obtain lbs ethanol/cwt and this was divided by 6.6, the weight of a gallon of ethanol to obtain the gallons of ethanol/cwt shown.

Table 2. Trial of potential ethanol lines conducted at Sunheaven Ranch, Prosser, WA - planted Apr. 11, harvested Sept. 10/80 (155 days) - tops harvested Sept. 5/80.

Line	Tubers				Tops		Total	
	Cwt/A 1/	S.G.	% Carbo 2/	Gal Eth/A 2/	Cwt/A	Gal Eth/A 3/	Gal Eth/A 4/	$ Value 5/
White Rose	1311	1.073	15.5	1324	645	207	1531	$ 2603
Kennebec	1360	1.071	15.1	1346	547	176	1522	2587
Red Pontiac	1406	1.069	15.0	1364	311	100	1464	2489
Wn 708-27	985	1.066	14.4	926	1514	487	1413	2402
Wn 705-111	905	1.081	16.8	986	1128	363	1349	2293
Wn C 612-13	1035	1.086	17.5	1180	522	168	1348	2292
A503-42	1109	1.075	15.9	1142	508	163	1305	2219
Lemhi	991	1.081	16.8	1060	406	131	1191	2025
Rus Burbank	922	1.080	16.9	996	491	158	1154	1962
AD73116-1	895	1.069	15.0	868	489	157	1025	1743
B6987-184	823	1.090	18.2	971	166	54	1025	1743
A70365-6	911	1.070	15.2	893	251	81	974	1656
Atlantic	756	1.086	17.5	862	90	29	891	1515

1/ Ave. yield of the Russet Burbank circle in which this trial was grown was 770 cwt/A which is 16% lower than the Russet Burbank yield we obtained on these small plots.

2/ Used Table 1 for converting specific gravity readings to % fermentable carbohydrates and gal ethanol/cwt. Multiplied gal eth/cwt times cwt/A to compute gal eth/A.

3/ Analysis of tops indicates they are 10% dry matter with 50+% of this being carbohydrate or about 5% on a fresh weight basis. Therefore, weight of carobhydrate was computed by multiplying cwt/A by 5 and converting this carbohydrate weight to ethanol weight and gal/A as explained above in 2/ and on Table 1.

4/ Computed by adding ethanol/A from tubers to ethanol/A from tops.

5/ Estimated value of ethanol/A computed by multiplying gal eth/A by $1.70, the current value of 200 proof ethanol. The cost of producing a potato crop for ethanol is estimated to be about $1000/A. It is assumed that the value of the high protein byproduct from the tubers and tops will cover the cost of extracting the ethanol.

Table 3. Lines that can be considered for ethanol production from other trials on Sunheaven Ranch, Prosser, WA - planted Apr. 11, harvested Sept. 10 (155 days).

Line	Cwt/A 1/	S.G.	% Carbo 2/	Gal Eth/A 3/	$ Value 4/
A74708-9	1137	1.078	16.4	1205	$ 2049
Wn C 612-13	1024	1.088	18.0	1188	2020
A74595-11	1051	1.083	17.2	1167	1984
A74771-4	1119	1.075	15.9	1153	1960
Kennebec	977	1.083	17.2	1084	1843
Lemhi	980	1.082	17.0	1078	1833
A68588-16	1023	1.077	16.2	1074	1826
Wn C 521-12	887	1.093	18.7	1073	1824
A74595-15	1004	1.078	16.4	1064	1809
78Ds-50	936	1.084	17.4	1048	1782
AD7377-1	1065	1.070	15.2	1044	1775
A7596-1	855	1.089	18.1	1000	1700
Wn C 672-2	902	1.078	16.4	956	1625
AD7267-1	960	1.070	15.2	941	1600
ADWn 75121-1	996	1.066	14.6	936	1591
Rus Burbank	725	1.081	16.8	776	1319

1/ - 4/ See footnotes below Table 2.

Table 4. Lines from earliness trial at Prior Land Company, Paterson, WA to be considered for early season ethanol production - planted Mar. 27, harvested Jul. 22 (118 days).

Line	Cwt/A	S.G.	% Carbo 1/	Gal Eth/A 2/	$ Value 3/
A74365-2	701	1.072	15.5	701	$ 1192
A7273-3	675	1.072	15.5	675	1148
A7069-7	645	1.076	16.1	671	1141
Wn 775-36	654	1.072	15.5	654	1112
A68588-16	693	1.064	14.3	624	1061
A74117-9	618	1.072	15.5	618	1051
White Rose	689	1.061	13.8	613	1042
Wn C 521-12	535	1.086	17.6	610	1037
Kennebec	625	1.069	15.0	606	1030
A67142-1	631	1.067	14.7	599	1018
Lemhi	604	1.070	15.2	592	1006
Rus Burbank	468	1.073	15.6	473	804

1/ - 3/ See footnotes below Table 2. Cost of production estimated at $900/A, if grown for ethanol.

Table 5. Trial of potential ethanol lines grown at the Research Center, Roza Unit, Prosser, WA - planted May 15, harvested Oct. 8/80 (147 days).

Line	Cwt/A	S.G.	% Carbo 1/	Gal Eth/A 2/	$ Value 3/
A503-42	622	1.079	16.5	708	$ 1204
Crystal	604	1.080	16.7	651	1108
Kennebec	565	1.080	16.7	610	1037
Wn 705-111	491	1.093	18.6	594	1010
White Rose	567	1.076	16.1	590	1003
Neb. S1-3	585	1.072	15.5	585	995
A70365-6	567	1.075	15.9	584	993
Rus Burbank	521	1.083	17.1	578	983
Lemhi	477	1.090	18.2	563	957
Bounty	565	1.071	15.3	559	950
Wn C 612-13	466	1.089	18.0	545	927
B6987-184	415	1.100	19.7	531	903
Atlantic	378	1.096	19.1	469	797
Neb. 12.72-2	461	1.070	15.2	452	768
Red Pontiac	454	1.068	14.9	436	741
Neb. 210-2	383	1.076	16.1	398	677

1/ - 3/ See footnotes below Table 2. Cost of production estimated at $900/A, if grown for ethanol.

Table 6. Lines from Regional Trial, Othello, to be considered for ethanol production - planted Apr. 17, harvested Sept. 17/80 (154 days).

Line	Cwt/A	S.G.	% Carbo 1/	Gal Eth/A 2/	$ Value 3/
Wn C 612-13	930	1.095	18.9	1144	$ 1945
A72545-2	930	1.083	17.1	1032	1754
Rus Burbank	854	1.089	18.0	999	1698
AD7377-1	912	1.079	16.5	976	1659
Lemhi	822	1.090	18.2	970	1649
Wn C 672-2	812	1.091	18.3	966	1642

1/ - 3/ See footnotes below Table 2. Cost of production estimated at $900/A, if grown for ethanol.

Table 7. Trial at Aberdeen, ID of potato lines that might be considered for use as biomass for ethanol production - 1980.

Line	Cwt/A	% Solids	Gal Eth/A 1/	$ Value 2/
A503-42	542	21.9	618	$ 1051
A681113-4	563	21.3	625	1063
Red Pontiac	570	18.5	553	940
Wn C 612-13	464	22.5	543	923
Neb. 12-72-2	472	19.3	477	811
Atlantic	348	23.5	468	796
Bounty	421	20.5	450	765
Neb. S1-3	450	18.7	441	750
Crystal	407	20.5	435	740
Kennebec	395	19.9	411	699
Lemhi	358	21.9	408	694
Rus Burbank	358	20.5	383	651
B6987-184	260	24.1	325	553
Neb. 210-2	282	19.9	293	498
LSD (.05)	57	0.8		

1/ - 2/ See footnotes below Table 2. Cost of production estimated at $800/A, if grown for ethanol.

Table 8. Trials in southcentral and southwest Idaho of potato lines that might be considered for use as biomass for ethanol production - 1980.

Line	Cwt/A	% Solids	Gal Eth/A 1/	$ Value 2/
		Southwest Idaho		
A503-42	874	22.9	1040	$ 1768
Lemhi	757	24.0	939	1596
Butte	710	25.4	930	1581
Bintje	945	18.8	926	1574
Wn C 612-13	633	24.9	810	1377
A68113-4	684	22.7	807	1372
A67142-1	626	21.6	701	1192
Atlantic	586	21.6	656	1115
Rus Burbank	481	22.9	572	972
		Kimberly, Idaho		
Kennebec	645	22.9	768	1306
B6987-201	624	21.6	699	1188
A68113-4	632	19.7	651	1107
Lemhi	509	21.4	565	961
Atlantic	437	21.6	489	831
Wn C 612-13	443	20.7	478	813
Rus Burbank	461	19.4	466	792
Crystal	447	18.8	438	745
A503-42	447	18.6	434	738

1/ - 2/ See footnotes below Table 2. Cost of production estimated at $900/A, if grown for ethanol.

Table 9. Trial of potential ethanol lines conducted in Aroostook, ME - 1980 (120 days growing season).

Line	Tubers				Tops		Total	
	Cwt/A	S.G.	% Carbo 1/	Gal Eth/A 2/	Cwt/A	Gal Eth/A 3/	Gal Eth/A 4/	Value 5/
A503-42	501	1.087	17.7	576	334	107	683	$ 1161
Denali	424	1.098	19.4	534	248	80	614	1044
Red Pontiac	533	1.071	15.3	528	236	76	604	1027
Lemhi	435	1.081	16.8	465	352	113	578	983
Crystal	470	1.073	15.6	475	316	102	577	981
Kennebec	456	1.076	16.1	474	274	88	562	955
Atlantic	426	1.090	18.2	503	134	43	546	928
Wn C 612-13	384	1.090	18.2	453	264	85	538	915
B6987-184	351	1.095	18.9	432	224	72	504	857
Norchip	422	1.081	16.8	452	148	48	500	850
Rus Burbank	391	1.080	16.7	422	222	71	493	838
B6987-201	327	1.094	18.8	399	158	51	450	765
				Second Trial				
Atlantic	438	1.092	18.5	526	168	54	580	986
Bounty	498	1.074	15.8	508	170	54	562	955
Neb. S1-3	457	1.071	15.3	452	300	97	549	933
Neb. 210.2	414	1.080	16.7	447	142	46	493	838
Neb. 12.72-2	405	1.071	15.3	401	220	71	472	802
Neb. A129.69-1	364	1.074	15.8	371	236	76	447	760

1/ - 5/ See footnotes below Table 2. Cost of production estimated at $600/A, if grown for ethanol.

Table 10. Trial of potential ethanol lines grown at Grand Forks, ND - planted May 12 and 19/80, harvested Sept. 22 and 23/80 (133 days).

Line	Cwt/A	S.G.	% Carbo 1/	Gal Eth/A 2/	$ Value 3/
Bounty	266	1.079	16.5	285	$ 485
A503-42	238	1.084	17.3	267	454
Neb. 210-2	222	1.074	15.8	226	384
Wn C 612-13	189	1.090	18.2	223	379
Neb. 12.72-2	237	1.064	14.3	218	371
Red Pontiac	216	1.069	15.0	210	357
Lemhi	171	1.085	17.4	193	328
Neb. A129.69-1	193	1.072	15.5	193	328
Kennebec	186	1.073	15.6	188	320
Crystal	168	1.083	17.1	186	316
Neb. S1-3	166	1.063	14.1	151	257
B6987-201	70	1.088	17.9	81	138

1/ - 3/ See footnotes below Table 2. Cost of production estimated at $500/A, if grown for ethanol.

Table 11. The breakeven prices of ethanol produced from average yields of potatoes at average production costs during 1978-80 (not considering hauling, storage and ethanol-extraction costs).

State	Year	Ave. Cwt/A 1/	Ave. Cost/A 1/	Cost/cwt 1/	Ethanol Cost/gal 2/
Washington	1978	465	$1095	$2.30 (2.35)	$2.09 (2.14)
	1979	475	1175	(2.47)	(2.25)
	1980	505	1339	(2.65)	(2.41)
Idaho	1978	275	795	3.30 (2.89)	3.00 (2.63)
Maine	1978	220	673	2.78 (3.06)	2.53 (2.78)
North Dakota	1978	175	371	2.75 (2.12)	2.50 (1.93)

1/ From various reports prepared by the USDA and economists from other agencies. Numbers in parenthesis computed by dividing cwt/A into cost/A.

2/ Obtained by assuming 1.1 gal eth/cwt and then dividing 1.1 into cost/cwt. Numbers in parenthesis obtained by dividing 1.1 into cost/cwt in parenthesis. The present value of 200 proof ethanol is between $1.70 and $1.80/gal.

Table 12. Possible reductions in production costs when using potatoes for ethanol.

Washington Potato Production Cost Analysis for 1981 1/		Variable Costs	$1006/A
		Total Costs	1339/A
Possible Cost Reductions:			
Elimination of fumigation for nematode and disease control		$175	
Potash reduced from 300 to 100 lb/A		30	
Nitrogen reduced from 400 to 300 lb/A		30	
Elimination of disease control chemicals and application		37	
Elimination of aphidicides and application		60	
Irrigation can be reduced on non-sandy soils		10	
Elimination of defoliants before digging		18	
Faster digging and rougher handling allowed		12	
Lower quality, lower cost seed allowable		30	
	Potential Savings	$402/A	
Additional Costs:			
Swathing, chopping and hauling vines		63	
Estimated Cost of Raising Potatoes for Ethanol			$1000/A

1/ Figures taken from "1981 Estimated Production Costs in the Columbia Basin" prepared by M. A. Wright, T. J. Smith and H. Hinman. Based on costs of growing two center-pivot irrigated circles (250 A) of potatoes on a 750 A farm.

Table 13. Effect of increasing potato yields on cost of ethanol production.

Cwt/A	Production Cost/A	Cost/cwt	Ethanol [1/] Cost/gal
200	$ 1000	$ 4.00	$ 3.64
400	1000	2.50	2.27
600	1000	1.67	1.52
800	1000	1.25	1.14
1000	1000	1.00	0.91
1200	1000	0.83	0.75

1/ Obtained by assuming 1.1 gal eth/cwt and then dividing 1.1 into cost/cwt. This is the portion of ethanol cost attributable to feedstock production only and does not include cost of hauling, storage, or ethanol extraction. Current value of 200 proof ethanol is $ 1.70 to $ 1.80/gal.

Table 14. Effect of carbohydrate content on ethanol production.

Specific Gravity	% Carbohydrates [1/]	Ethanol [1/] Gal/cwt	Cost/gal [2/] @ 600 cwt/A	Cost/gal [2/] @1000 cwt/A
1.060	13.7	0.88	$ 1.90	$ 1.14
1.070	15.2	0.98	1.70	1.02
1.080	16.7	1.08	1.55	0.93
1.090	18.2	1.18	1.42	0.85
1.100	19.7	1.28	1.30	0.78
1.110	21.2	1.38	1.21	0.72
1.120	22.7	1.48	1.13	0.68

1/ Taken from Table 1.

2/ Assuming a yield of 600 or 1000 cwt/A at a production cost of $1000/A which would equate to $ 1.67 or $1/cwt. The estimated gal/cwt was divided into this $ 1.67 or $1/cwt production cost to obtain cost/gal. This is the portion of ethanol cost attributable to feedstock production only and does not include cost of hauling, storage or ethanol extraction. Current value of 200 proof ethanol is $ 1.70 to $ 1.80/gal.