

**Return of Investment in the
Northwest Potato Breeding Program**

by

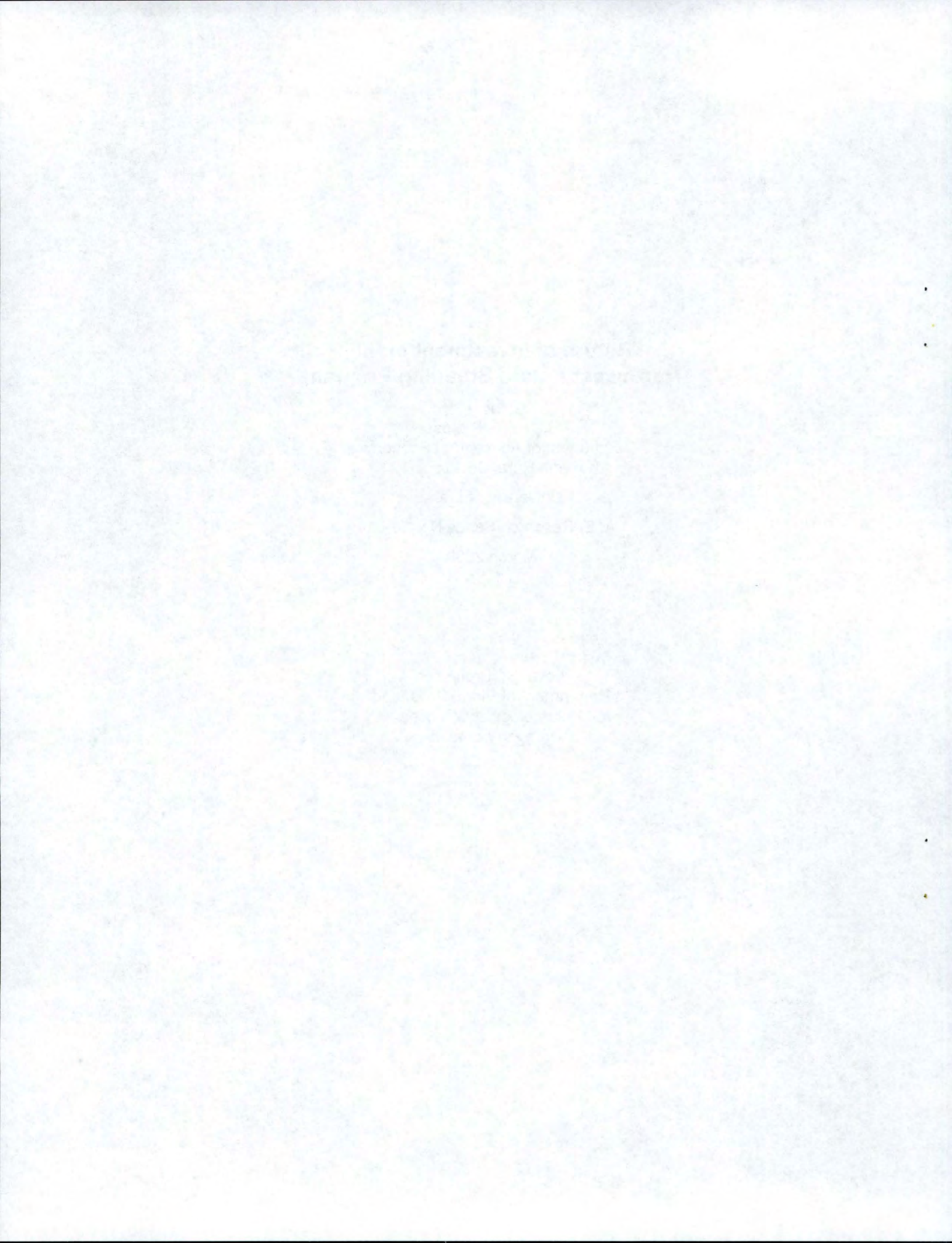
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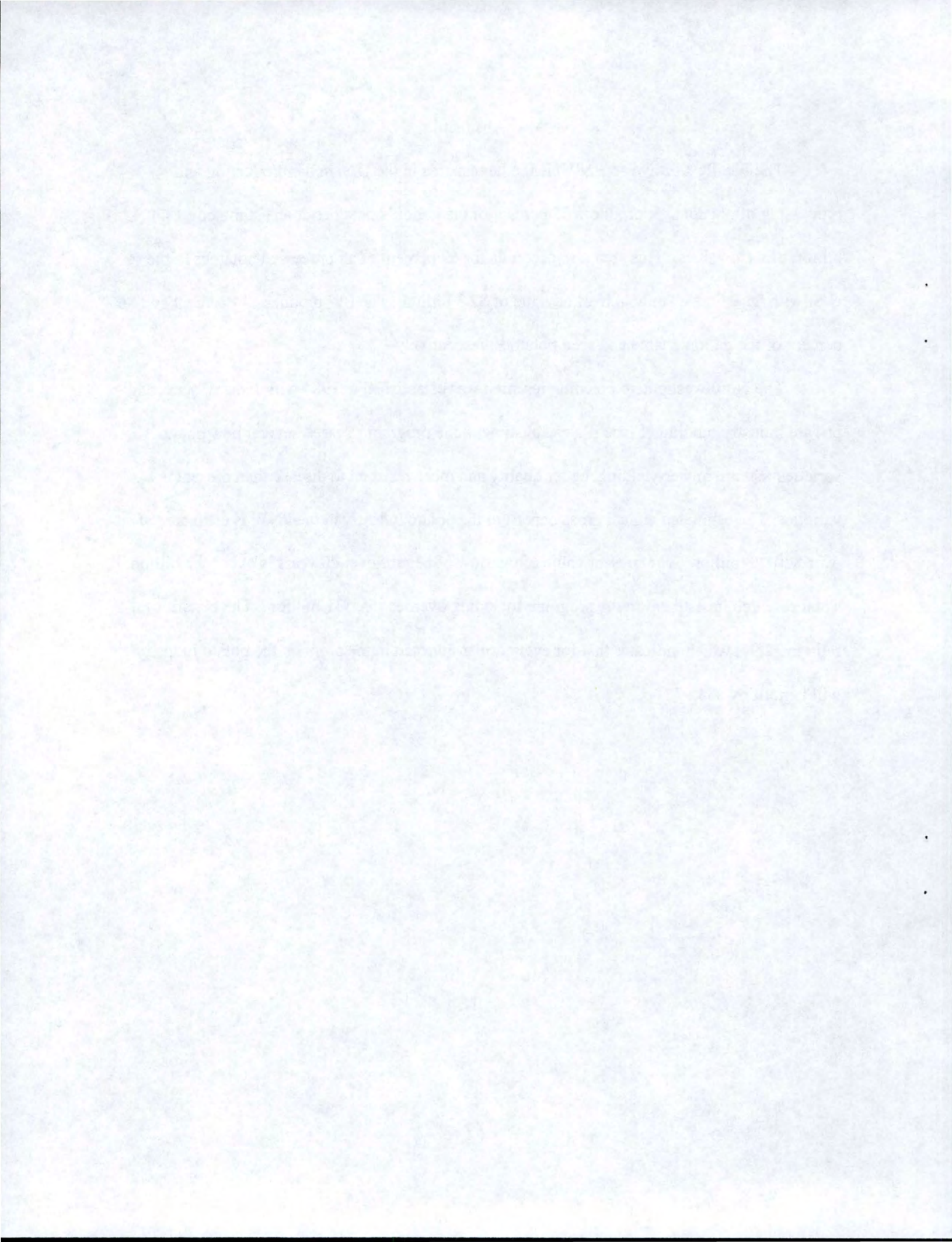
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Abstract

The Pacific Northwest (PNW) is the largest area in the U.S. in the production and processing of potatoes. It produces 55 percent of the nation's potatoes at an estimated \$1.44 billion of farm values. This area also accounts for 69 percent of all processed potatoes in the U.S. with an estimated annual market value of \$2.3 billion. The PNW produces 44 percent and 36 percent of the nation's table and seed potatoes, respectively.

The Northwest potato breeding research was established in 1984 with federal, state, and private industry funding. Since its establishment, the program released several new potato varieties that are higher yielding, better quality and more resistant to disease than present varieties. The estimated annual gross benefit to the potato industry in the PNW is estimated at over \$201.5 million. The present value of the flow of benefit over 20 years is over \$1.2 billion. Total research investment in the program, including overhead is, \$31 million. The benefit cost ratio is 38.97, which indicates that for every dollar invested in the program the potato industry will benefit by \$38.97.



RETURN TO INVESTMENT IN THE NORTHWEST POTATO BREEDING PROGRAM

Introduction

Agricultural research in the United States has evolved into a decentralized federal/state system. The system has responded with considerable flexibility to changing circumstances and has developed local, appropriate technologies. The Northwest Potato Breeding Program is a success example of the decentralized federal/state research system. The program was initiated in 1984 as a cooperative research between the United States Department of Agriculture (USDA) and the State Agriculture Experiment Station in the three Pacific Northwest (PNW) States, and the private potato industry. The objective of this study is to evaluate the benefits of public and private investments in the Northwest Potato Breeding research to producers and processors in Idaho, Oregon, and Washington.

Potato is an important agricultural commodity in the United States (U.S.). Annual U.S. potato production exceeds 477 million cwt. with annual farm value of over \$2.62 billion and a processed value of about \$3.4 billion. The Pacific Northwest is the largest sub-region in the U.S. in the production and processing of potatoes. It produces about 55 percent of the potatoes in the U.S. and accounts for over 46 percent of its farm values. Idaho is the largest potato producing state accounting for about 30 percent of the U.S. potato production and 25 percent of its farm values. Washington is second to Idaho in potato production accounting for 19 percent of the U.S. potato production and 16 percent of its farm value (National Potato Council).

An estimated 59 percent of all potatoes produced in the U.S. is processed annually. The Pacific Northwest accounts for 69 percent of all potato processed in the U.S. with an estimated annual market value of \$2.3 billion. Idaho's processing plants accounts for 34 percent of the

total U.S. processed potato, while Washington and Oregon represent 27 percent and 8 percent, respectively.

An estimated 129 million cwt of potatoes is produced for the fresh market in the U.S. annually. The Pacific Northwest accounts for over 44 percent of the fresh potato market. Idaho is the largest producer of the potato in the fresh market, representing about 32 percent of the total U.S. production of potatoes. Oregon and Washington account for 3 percent and 9.5 percent, respectively.

An estimated 60 million cwt. of seed potatoes are produced in the U.S. annually. The Pacific Northwest accounts for over 36 percent of this production. Idaho accounts 29.5 percent of the total U.S. seed potato production while Oregon and Washington represent 2.2 percent and 4.4 percent respectively. Less than 1 percent of the potato acreage in this sub-region is in chip potatoes (National Potato Council).

In general, the PNW sub-region is the most important area in the U.S. in the production of potatoes for processing, the fresh market, and seed potatoes. This sub-region also processes the major segment of potatoes and accounts for about 69 percent of all processed potatoes in the nation. The future competitive position of this area in the domestic and international markets for fresh, processed, and seed potatoes will depend significantly upon new technologies to enhance the productivity and the quality of potatoes.

Major Potato Varieties Planted in the Pacific Northwest

Russet Burbank is the major variety of potato produced for the fresh market and for processing in the PNW (Table 1). In Idaho, Russet Burbank accounted for over 96 percent of the potato acreage in 1984. It gradually declined to 77.9 percent of the acreage in 1998. Shepody was introduced in 1985 and reached a maximum of 10 percent of the Idaho acreage in 1996, but

declined to 5.6 percent of the acreage in 1998. Russet Norkotah, a fresh market variety, accounted for 4.8 percent of the potato acreage, and Ranger Russet, a variety developed by the Northwest Potato Breeding program and released in 1991 represented 6.6 percent of 1998 acreage.

Russet Burbank was the dominant potato variety in Oregon in the late 1980's. It accounted for over 82 percent of the potato acreage in 1986 and gradually declined to 39.5 percent of the acreage in 1998. The percentage of Oregon potato acreage planted in Shepody increased to 27.2 percent in 1995 and declined to 17.2 percent in 1998. Russet Norkotah acreage increased to 38.8 percent of the acreage in 1997 and declined to 24.8 percent of the acreage in 1998. Ranger Russet is the new variety that showed significant adoption of 10.3 percent of the potato acreage in 1998.

Russet Burbank also dominates Washington potato acreage. In 1987, about 87 percent of the potato acreage were planted with Russet Burbank. Since then the percentage of potato acreage planted with Russet Burbank declined rapidly, reaching 58 percent of the acreage in 1998. The percentage of potato acreage planted with Shapody and Russet Norkotah did not change significantly over time, standing at 8.9 percent and 13.2 percent of the acreage, respectively. Ranger Russet adoption increased since its release in 1991, reaching 11.4 percent of the potato acreage in 1998.

Russet Burbank and Shepody still dominate the production of potato for processing in the Pacific Northwest. These two variations are susceptible to disease, have low percentage of U.S. No. 1 tuber, and have low processing yield. As a table potato, Russet Burbank also has short shelf life and lack the smooth appearance desired by consumers. To maintain and/or improve the

PNW competitive position in the production and processing of potatoes; new varieties that are higher yielding, better quality with a higher processing yield need to be developed.

Potato Breeding Research Program for the Northwest

Because of the national importance of the PNW in the production and processing of potatoes, the United States Department of Agriculture supported the establishment of a potato breeding research program located in Idaho to serve the potato industry in the three PNW States of Idaho, Oregon, and Washington. The objective of the program is to develop new potato varieties to replace or upgrade the present two dominant processing varieties, Russet Burbank and Shepody; the two dominant fresh market varieties, Russet Burbank and Russet Norkotah; and the two major chip varieties, Gemchip and Norchip.

The distribution of potato acreage by market channel for Idaho, Oregon and Washington is shown in table 2. About 12.2 percent of the potato acreage in Idaho is in seed potato production; 30 percent is in fresh potato market production; 57 percent is processing potato production; and 0.8 percent is in chip potato production. About 2.2 percent of the potato acreage in Washington is in seed potato production; 14 percent is in fresh potato market production; 82 percent is in processing potato production; and 0.8 percent is in chip potato production. About 4 percent of the acreage in Oregon is in seed potato production, 15 percent is in fresh potato market production, 80 percent is processing potato production, and 0.8 percent is in chip potato production.

Since its establishment in 1984, the potato breeding research for the Northwest released, or are in the process of releasing, the following potato varieties:

Gemchip

Gemchip was released by the Northwest Breeding program in 1989, and quickly became the dominant chip variety in Idaho and the Northwest. However, acreage declined with the release of Chipeta. Gemchip is a round, white potato with thin skin. In comparison with Norchip, the variety it replaced in the Northwest, Gemchip produces 16 percent higher yield and 31 percent higher U.S. No. 1 tuber. On average the tubers have 0.6 percent higher solids than Norchip and return a higher chip yield. Gemchip tubers maintain physical integrity and chip color for a longer period of storage than does Norchip, allowing growers to market for 1 to 2 additional months into the spring. Gemchip is resistant to early die, does not require soil fumigation to control this problem, and requires about 20 percent less nitrogen than Norchip.

Frontier Russet

Released by the Northwest Breeding program in 1990. Frontier Russet was never widely adopted but has been grown on small acreage in both the Northwest and Northeast. It produces tubers that have excellent appearance and are generally free from both external and internal defects. Frontier Russet typically produces a total yield that is about 10 percent less than that of Russet Burbank, but has the advantage of producing 20 percent higher U.S. No. 1 tubers. It has similar storage and processing characteristics to Russet Burbank. Frontier Russet has established itself in a niche market for the production of skin-on fried products.

Chipeta

Chipeta is a 1993 Colorado release of a selection that originated with the Northwest Breeding program. Chipeta is currently the most widely grown chipping variety in the Northwest. Compared with Norchip, it produces 18 percent higher total yield and 32 percent higher U.S. No. 1 tuber. Like Gemchip, Chipeta has excellent storage characteristics and has the

ability to extend the marketing of potatoes for an additional one to two months. Chipeta has tuber solids that are 3 percent higher than that of Norchip and consequently can produce a higher yield of higher quality chips. Chipeta is resistant to most field diseases, does not require soil fumigation (except for control of nematodes), nor treatment for early blight, and uses about 20 percent less nitrogen than Norchip.

Ranger Russet

Released in 1991 by the Northwest Breeding program. Ranger Russet has been widely adopted as a processing variety, both from field delivery and storage situations. Ranger Russet produces 5 percent higher total yield and 29 percent higher U.S. No. 1 tuber than does Russet Burbank. It has about a 10 percent advantage in total yield and U.S. No. 1 tuber over Shepody.

Ranger Russet does not store well over 6 months and has a fairly serious problem with susceptibility to blackspot bruise, but is almost completely free of other external and internal defects. A combination of suitable tuber shape, freedom from defects and high solids gives Ranger Russet a high level of processing efficiency, with about 70 percent finished product derived from raw tubers. Russet Burbank typically returns around 50 percent. Ranger Russet also gives better processing efficiency than Shepody due to its 3 percent higher solids content. Ranger Russet has better resistance to early blight, net necrosis caused by leafroll virus, (PVY), and early die. It does not require soil fumigation (except to control nematodes) nor control measures for any of these diseases. It is estimated that replacing Russet Burbank and Shepody with Ranger Russet will eliminate up to two chemical applications at \$15-20 each to control green peach aphid and two chemical applications at \$20 each to control early blight.

Umatilla Russet

Released in 1998 by the Northwest Breeding program. Umatilla Russet is similar in many respects to Ranger Russet including appearance and resistance to internal defects. It is almost identical in yield potential and processing quantity. It does not have the severe blackspot bruise problem expressed by Ranger Russet. Umatilla Russet is expected to have the same yield and processing advantages over Russet Burbank as does Ranger Russet, with the added advantage that it will store for a longer period of time, up to 8 months. Ranger Russet and Umatilla Russet are expected to replace Russet Burbank and Shepody as processed potatoes.

Russet Legend

Released in 1998 by the Northwest Breeding program. Russet Legend is only moderate in yield potential but has an extremely high percentage of U.S. No. 1's (Figure 3). It produces oblong shaped tubers with heavy russet skin and is superior to Russet Burbank in its appearance and grade. Russet Legend produces about 7 percent lower total yields, but 23 percent higher U.S. No. 1 tubers in comparison with Russet Burbank. It is estimated that each 1-percent increase in U.S. No. 1 above 60 percent will increase price to growers by \$0.01 per cwt. Russet Legend has one flaw that will limit its utility: the development of stem-end discoloration after two to three months' storage. However, Russet Legend will likely replace some of the Russet Burbank in the fresh market during the first two months of the storage season. It is resistant to early die, will not require soil fumigation for this problem, and will use 10 to 20 percent less nitrogen than Russet Burbank.

Gem Russet (A8495-1)

This new variety was released in 1999. It has Russet Norkotah's appearance and superior processing quality to Russet Burbank. Gem Russet's total yield potential is similar to that of

Russet Burbank, but it produces about 21 percent higher yield of U.S. No. 1's. Gem Russet has about 3 percent higher solids and larger tuber size, which should give it, better processing efficiency (almost as good as Ranger Russet). Gem Russet has excellent storage characteristics and should be marketable for 10-12 months of the year. It is resistant to net necrosis caused by leafroll virus and will usually not require treatment for green peach aphid. It is estimated that at least two chemical applications to control green peach aphid, at a cost of \$15-20 per application will be eliminated with the adoption of Gem Russet. Russet Legend and Gem Russet are expected to replace Russet Norkotah and Russet Burbank as fresh market potatoes.

ND01496-1 (unnamed)

This unnamed selection is a round, white chipper. It produces good yield, but its appeal comes from its outstanding chip quality following storage at colder- than-normal temperatures. It produces 9 percent higher yields than Norchip and about 9 percent less than Chipeta. Its U.S. No. 1 yield is higher than Norchip by 18 percent. Because ND01496-1 is a cold chipper, it can be stored at cooler temperatures and still maintain quality. This should reduce the amount of shrinkage in storage by as much as half, and extend the market season by one to four months.

IdaRose

This selection was released in 1999. It has round tubers with bright red skin. It combines high yield with excellent appearance and outstanding eating quality. It exceeds the yield of Dark Red Norland by as much as 20 percent. IdaRose has long storage potential, an unusual trait for a red-skinned variety.

This should allow it to be used in the rapidly expanding red storage market. This is a market that the northwest has not yet capitalized on.

Bannock Russet (A81473-2)

This selection was being released in 1999. It has oblong tubers with heavy, dark russet skin. It combines excellent disease resistance with high yield and good appearance. It has shown the ability to produce 2 percent higher total yield and 29 percent higher U.S. No. 1 yield than does Russet Burbank. It produces very few undersized potatoes, combined with one-percent higher solids, which should give it processing efficiency approaching that of Ranger Russet. Bannock Russet has good storage characteristics and will be capable of supplying high quality potatoes for 10-12 months of the year. Additionally, Bannock Russet is resistant to all diseases associated with early die and will not require soil fumigation. It is also immune to PVY and resistant to net necrosis caused by leafroll virus. Bannock Russet also uses about 40 percent less nitrogen than Russet Burbank. It is expected that this variety will replace Russet Burbank, Shepody, and Russet Norkotah.

The Benefits of Investments in the Northwest Potato Breeding Research

The flow of benefits from each variety developed by the Northwest Breeding program is estimated by the following equation:

$$\beta_{jt} = A_{jt} \left\{ \left(\Delta P_{jt} V_t - V_o \right) - C_{jt} \right\} \quad (1)$$

Where:

β_{jt} = the benefits accruing to the j^{th} variety in year t

A_{jt} = the expected total production or acreage affected by the J^{th} variety in year t

ΔP_{jt} = the expected change in net productivity and or quality of potato due to the J^{th} variety in year t

V_t = the expected price received per cwt of raw potato or pound of processed potatoes in year t

$$V_t = \left\{ V_o + V_o (f \Delta P_t) \right\}$$

where f is the flexibility ratio and V_o is the price per unit in the base year

B_{jt} is the benefit that accrues to potato producers and processors as a result of adopting and implementing the new variety. The outcome B_{jt} is probabilistic because it depends on the probability of successful development of the j^{th} variety, $(P(S))$, and the probability of adopting the J^{th} variety $(P(A))$. The expected value of β_{jt} is defined as:

$$E(\beta_{jt}) = \sum_{t=1}^N \beta_{jt} \{P(A) \cap P(S)\} \quad (2)$$

The present value of the expected flow of benefits from variety J^{th} is calculated by "discounting" the right-hand side of equation (2) as shown in equation (3) below.

$$E(\beta_{jt}) = \frac{\sum_{t=1}^N \beta_{jt} \{P(A) \cap (S)\}}{(1+r)^t} \quad (3)$$

Where:

r = the social discount rate.

N = number of years for which the J^{th} variety affects productivity, quality, and/or cost.

A 6 percent social discount rate was used to discount the flow of future return. The present value of the flow of costs is expressed as:

$$C_{jt} = \sum_{t=1}^N \left\{ \left(R_{jt} + T_{jt} + I_{jt} + M_{jt} \right) \right\} / \left\{ (1+r)^t \right\} \quad (4)$$

Where:

C_{jt} = the present value of total costs associated with the development of the J^{th} variety.

R_{jt} = research investment in the development of the J^{th} variety

T_{jt} = technology transfer cost of the J^{th} variety

I_{jt} = implementation cost to adopt the J^{th} variety

M_{jt} = the cost of maintenance research required to sustain the productivity of the

J^{th} = variety at its potential level

Expenditure in the development, transfer, implementation, and maintenance of the J^{th} variety prior to 1998 were compounded at 6 percent to bring it to the 1998 level. The flow of expenditure after 1998 was discounted by 6 percent to bring it to the 1998 level. The 1997-98 average acreage, production, and prices shown in table 2 were used to calculate the expected value of the flow of benefit.

Results

The flow of benefits, cost, and return associated with the development and transfer of the new potato varieties developed by the Northwest Breeding program are analyzed in this section.

Benefit

Five major areas of expected benefits from the development of new potato varieties are analyzed. These areas are: (1) development of high yielding and high quality potato varieties for processing, (2) development of high yielding and high quality potato varieties for the fresh market, (3) development of disease resistant potato varieties for all market channels, (4) development of new potato varieties with a high percentage of processing yield, and (5) development of high quality and high yielding varieties of chip potatoes. The benefit from each area is analyzed in the following sections.

Development of high yielding processed potato varieties

The estimated benefit of improved yield of Ranger Russet and Umatilla to growers producing potatoes for processing is shown in table 3. The release and adoption of the higher

yielding Ranger Russet and Umatilla as the two processing varieties to replace 35 percent of Russet Burbank acreage and all of Shapody acreage will yield an annual gross value of about \$18 million. The present value of the flow of return over the next 20 years to the PNW potato producers for processing will exceed \$108 million at an annual rate of \$5.4 million.

Development of High Quality Potato Varieties for the Fresh Market

The two fresh market varieties developed by the Northwest Potato breeding program are Russet Legend and Gem Russet. Russet Legend was released in 1998 and Gem Russet is being released in 1999. The estimated gross annual benefits to the PNW producers of potato for the fresh market is \$5.9 million. This benefit is based on replacing 35 percent of Russet Burbank and 50 percent of Russet Norkotah fresh market potato acreage with these to new varieties. The estimated present value of the flow of benefits over the next 20 years is \$27.6 million at an annual rate of \$1.35 million (Table 4). Growers in Idaho producing table potatoes will gain the most as Idaho has a larger proportion of its potato acreage planted in table potatoes than Oregon and Washington. It is estimated that Idaho growers of table potatoes will benefit by over \$1 million annually compared to \$242 thousand for Washington and \$72.8 thousand for Oregon.

Development of disease resistant potato varieties

Russet Burbank, Shepody, and Russet Norkotah are highly susceptible to net necrosis, early blight, and late blight. Ranger Russet, Umatilla, Legend, and Gem Russet are more resistant to PLRV and early blight. The results of this study indicate that the adoption of the new varieties will eliminate 2 sprays per year to control green peach aphid at \$15-20 per spray and 2 sprays to control early blight at \$20 per spray. The annual savings to potato producers in the PNW by replacing 35 percent of Russet Burbank acreage all of Shepody acreage with the new varieties is estimated at over \$17 million (Table 5). This is based on eliminating one spray for

green peach aphid and one spray for late blight. The present value of the flow of future benefit over the net 20 years is estimated at \$77.13 million. Idaho potato growers will benefit by \$2.4 million annually while Washington and Oregon growers will benefit by \$1 million and \$380 thousand, respectively. The adoption of the new disease resistant varieties will eliminate an estimated 1224 chemical spray per year from the Pacific Northwest environment.

Development of new Potato Varieties with High Processing Yield

Before the release of Ranger Russet, an estimated 83 percent of Idaho potato acreage was planted with Russet Burbank and 7.1 percent with Shepody for a total of 90.1 percent. Washington had 65.7 percent of its potato acreage planted with Russet Burbank and 7.6 percent with Shepody, for a total of 73.3 percent. Oregon had 30.9 percent of its potato acreage planted with Russet Burbank and 18.2 percent with Shepody, for a total of 49.1 percent.

Ranger Russet and Umatilla Russet produce 70 percent finished processed potatoes from raw potatoes. This is 20 percent more finished processed potatoes than that produced from Russet Burbank and Shepody. Average price for finished processed potatoes is \$0.25 per pound. The annual gross benefits, using 10 percent increase in processing yield, to the potato processing industry in the PNW is estimated at over \$158.5 million (Table 6). This is based on replacing 35 percent of Russet Burbank and all Shapody acreage with the new varieties over the next 20 years. The present value of the future flow of benefit over the next 20 years will exceed \$976.7 million at an annual rate of about \$48.8 million. Idaho potato processors will capture about 52 percent of this benefit while Washington and Oregon potato processor will capture 37 percent and 11 percent, respectively.

Development of High Yield Chip Potato Varieties

The two main varieties of chip potatoes planted in the Pacific Northwest are Norchip and Gemchip. These varieties, however, are low yielding. The Chipeta variety is projected to replace 70 percent of Norchip and Gemchip acreage over the next 20 years with 20 percent higher yield. The annual gross benefit to chip potato producers in the PNW will exceed \$2 million. The present value of the flow of future benefits will exceed \$14 million over a 20-year period at an annual rate of \$703,639 (Table 7).

Total Benefits

The total annual gross benefit to the potato industry in the Northwest from investments in the Potato Breeding program is estimated at over \$201.5 million. The present value of the flow of future benefits over the next 20 years will be over 1.2 billion at an annual rate of over \$60 million (Table 8). The present value of the flow of benefits over the next twenty years to Idaho potato growers and processors is over \$658 million. The Idaho potato industry will capture 54 percent of the expected flow of benefit due to its acreage and processing capacity.

Total Costs

Since its inception in 1984, the Northwest Breeding Program received funding from the federal, the state, and the potato industry. The United States Department of Agriculture (USDA) has been the primary source of funding. The USDA contribution is in two ways. First, the USDA/ARS potato-breeding program, located at Aberdeen, plays an integral role in potato variety development and supplies of germplasm to the three Universities programs in the Northwest. This program also assists with early generation selection and supplies materials for initial seed increases for new varieties. Direct research budget in this portion of the federal contribution ranged from \$188,816 in 1984 to \$401,805 in 1999. Direct investment during the

1984-1999 period totaled \$4,856,229. Second, the USDA contribution through cooperative agreements with the three land grant Universities in the PNW ranged from \$192,300 in 1984 to \$633,600 in 1998. Total USDA contribution to cooperative agreements was \$8,021,125 during the 1984-1998 period. The three land grant Universities in the PNW directly contributed a total of \$4,231,599 in state funds to the potato-breeding program during the 1984-1998 period. The potato industry during this period contributed a total of \$2,202,220 (Table 9).

All investments from 1984 to 1998 were compounded by 6 percent. Research expenditures for 1999 until the expected release of the last varieties in 2005 are estimated at the 1998 level and are projected to be \$9,854,898. Total research investments from 1984 until the release of the final varieties under development will be \$30,877,026.

Return to Investment

Total gross annual benefit to investments in the Northwest breeding program is estimated at over \$201.5 million. The flow of annual benefit discounted by 6 percent over 20 years will yield present value of over \$1.2 billion. Direct research expenditure plus overhead since the inception of the program in 1984 to 2005 will total \$30,877,026. The benefit-cost ratio is 38.97. The benefit-cost ratio indicates that for every \$1 of investment in the Northwest Breeding program, the potato industry in Idaho, Oregon, and Washington will benefit by \$38.97. In addition to its economic benefits, the program has significant environmental benefit and will enhance the economic viability of the industry and its competitive position in the national and international markets.

Summary

Potatoes are an important U.S. agricultural commodity with an annual farm value of over \$2.62 billion and a processed value of about \$3.4 billion. The Pacific Northwest is the major

region in the production and processing of potatoes. It accounts for 55 percent of the total U.S. potato production and 69 percent of the total processed potato.

Russet Burbank and Shepody were the two dominant varieties of potatoes produced for processing in the Pacific Northwest. Russet Burbank and Russet Norkotah are the two main varieties of table potatoes and Norchip was the main chip variety. These varieties are low yielding, susceptible to diseases, have low percentage of U.S. No. 1, have low processing yield, have low shelf life, lack the smooth appearance desired by consumers, and have low chip yield.

Since its inception in 1984, the Northwest Breeding program released 10 new varieties of potatoes. They are Gemchip, Chipeta, Frontier Russet, Ranger Russet, Umatilla Russet, Russet Legend, Gem Russet, ND01496-1, IdaRose, and Bannock Russet. These ten varieties are expected to replace a portion of the present acreage planted with Russet Burbank, Shepody, Russet Norkotah, and Norchip. Compared to the present varieties, the new varieties are resistant to diseases, higher yielding, better quality, and have higher processing yield.

The USDA, the three Pacific Northwest states, and the potato industry founded the Northwest Breeding program. About 67 percent of the investments in the breeding program are from federal sources, 22 percent from the three states, and 11 percent from the potato industry. During the 1984-1998 period an estimated \$21 million was invested in the program. It is projected that \$9.8 million will be invested between 1999-2005 to complete the release of several varieties being developed. Total investments in the breeding program is expected to reach \$30,877,026.

Several sectors of the potato industry in the PNW will directly benefit from the breeding program. The present value of the flow of benefits to potato growers producing potatoes for processing is estimated at over \$108 million, and benefits to growers producing potatoes for the

fresh market is estimated at \$27.6 million. Potato producers will also benefit by an estimated \$77.2 by eliminating one spray for late blight. In addition to the economic benefits, an estimated 1224 chemical sprays will be eliminated from the PNW environment.

The benefits to the PNW potato processors from the development and adoption of the new varieties with high processed yield will exceed \$976.68 million. The growers of chip potatoes are expected to benefit by an estimated \$14 million. In general, the PNW potato industry is expected to benefit by a total of 1.2 billion over 20 years. The Idaho potato industry will capture 54 percent of this benefit. The Washington and Oregon potato industries will capture 36 percent and 10 percent, respectively.

The benefit cost ratio of investment in the Northwest Breeding Program is estimated at 38.97. It indicates that for every \$1 invested in the breeding program, the PNW potato industry will benefit by an estimated \$38.97 excluding the environmental benefit.

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Table 1: Percent of major varieties of fall potatoes planted in the Pacific Northwest, 1998

State	Percent of Major Varieties				Other
	Russet Burbank	Shapody	Russet Norkotah	Ranger Russet	
Idaho	77.9	5.6	4.8	6.6	5.1
Oregon	39.5	17.2	24.8	10.3	9.2
Washington	58.1	8.9	13.2	11.4	9.4

Source: National Potato Council, Potato Statistical Yearbook, Englewood, Colorado

Table 2: Potato acreage, production, prices, and planting by market channel for Idaho, Oregon, and Washington, average, 1995-1997.

State	Acres harvested (1000)	Production (1000 Cwt)	Price (\$/Cwt)	Percent processed	Percent fresh	Percent seed	Percent chip
Idaho	402	136,963	5.03	57	30	12.2	0.8
Oregon	57	27,355	5.38	80	15	4.2	0.8
Washington	153	87,967	5.46	82	14	2.2	0.8

Source: National Potato Council, Potato Statistical Yearbook, Englewood, Colorado

Table 3: Benefit to potato growers producing high yield potatoes for processing

State	Gross Annual Benefit (\$)	Present Value (\$)	Annual Present Value (\$)
Idaho	10,511,255	63,397,969	3,169,898
Oregon	1,515,753	9,142,168	457,108
Washington	5,959,461	35,944,117	1,797,208
Pacific Northwest	17,986,467	108,190,203	5,424,212

Table 4: Benefit to Potato growers producing potatoes for the fresh market

State	Gross Annual Benefit (\$)	Present Value (\$)	Annual Present Value (\$)
Idaho	4,503,342	20,710,460	1,035,523
Oregon	316,606	1,456,043	72,802
Washington	1,052,703	4,841,287	242,064
Pacific Northwest	5,872,851	27,607,790	1,350,389

Table 5: Benefit to potato growers by adopting new disease resistant varieties

State	Acres Harvested (1000)	Percent Affected	Annual Gross Benefit (\$)	Present Value (\$)	Annual Present Value (\$)
Idaho	402	95.1	11,469,060	48,400,035	2,420,001
Oregon	57	87.9	1,503,090	7,616,067	380,803
Washington	153	90.8	4,167,720	21,117,590	1,055,879
Pacific Northwest	612		17,139,870	77,133,692	3,856,684

Table 6: Benefit to the Potato Processing Industry in the Pacific Northwest from the Development and Adoption of Varieties with high processing yield

State	Total Production (1000 cwt)	Percent Processed	Percent in Russet Burbank and Shepody	Annual Gross Value (\$)	Present Value (\$)	Annual Present Value (\$)
Idaho	136,963	58	90.1	83,972,015	517,621,267	25,881,063
Oregon	27,355	80	61.2	15,017,895	92,573,482	4,628,674
Washington	87,967	82	73.3	59,482,625	366,663,685	18,333,184
Pacific Northwest	252,285			158,472,535	976,683,374	48,834,168

Table 7: Benefit to Pacific Northwest Growers of Chip Potatoes from the development and adoption of Chipeta

State	Production (1000 cwt)	Percent in Chip	Annual Gross Benefit (\$1)	Present Value (\$1)	Annual Present Value (\$1)
Idaho	136,963	.8	1,102,272	8,103,217	405,160
Oregon	87,967	.8	707,955	1,416,018	227,677
Washington	27,355	.8	220,153	4,553,547	70,800
Pacific Northwest	252,285		2,030,380	14,072,782	703,639

Table 9: Total funding for the Northwest Potato Breeding Research, 1984-1998

State	Source of Funds			
	Federal ^{a)}	State ^{a)}	Private	Total
Idaho	4,721,696	867,977	306,280	5,895,953
Oregon	4,721,696	2,227,500	707,000	7,656,196
Washington	4,721,696	1,559,282	1,189,000	7,469,978
Total	14,165,089	4,654,759	2,202,280	21,022,128

^{a)} Direct research expenditures including 10 percent overhead cost

Table 8: Total benefit to the Pacific Northwest Potato producers and processors from the development, transfer, and adoption of the new potato varieties.

State	Annual Gross Benefit (\$)	Present Value (\$)	Annual Present Value (\$)
Idaho	111,557,944	658,232,948	32,911,647
Oregon	19,061,299	112,203,778	5,610,188
Washington	70,882,662	433,120,226	21,656,011
Pacific Northwest	201,501,905	1,203,556,952	60,177,847

