DROUGHT RISK MANAGEMENT FOR IRRIGATED POTATO PRODUCTION IN IDAHO

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ABSTRACT

Streamflow in much of the western United States originates as snowfall that has accumulated in the mountains during the winter and early spring. During periods of drought, the water supply for a large portion of irrigated cropland in Idaho is at risk of depletion before the growing season ends. In the case of irrigated potato production, early depletion or limited availability of irrigation water can result in substantial financial loss to a producer due to reduced yield and quality and difficulty in harvesting, handling and storing the raw product. Basin wide estimates of available water supply are provided by Federal and State agencies, however, a given producer's irrigation water supply can be vastly different due to water rights based on the Doctrine of Prior Appropriation, which allocates water according to a priority date. To minimize financial risk under drought conditions, potato producers need realistic estimates of available water supply well in advance of the growing season and production management guidelines for economical potato production under limited water supply. To address this need, a methodology for estimating the probability of a water supply shortage that incorporates water right based allocation was developed to assist producers with drought risk management planning. Additionally, the drought tolerance of six commercial potato varieties was evaluated for four widely varying seasonal drought management patterns simulated by irrigation management. The methodology developed to estimate probability of a water shortage on an irrigation district basis is described and results of an economic risk analysis for the six potato varieties subjected to the four drought management patterns is presented. The results show that the probability of a water shortage can vary widely among irrigation districts due to differences in water priority dates. The results of the economic risk analysis show that potato variety selection and

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irrigation management strategy can substantially reduce economic loss in potato production systems during drought.

INTRODUCTION

Annual streamflow in much of the western United States originates as snowfall that has accumulated in the mountains during the winter and early spring. Runoff from snowmelt in combination with reservoir storage provides the surface water supply for nearly 1.2 million acres of cropland in southern Idaho. However, certainty of the quantity of snowmelt runoff and river basin reservoir storage isn't available until the first of July when snowmelt is complete and the growing season is 2-3 months along. A shortage in the surface water supply affects long season crops the most (e.g. potatoes, sugar beets, corn) as the water supply is exhausted in early to mid-August in drought years. A producer's ability to manage drought risk is largely dependent upon knowledge of the water supply prior to the growing season. This knowledge can have a substantial influence on the crops and varieties to be grown, the number of acres to be planted and the estimated operating capital requirements. Water supply information needs to be available promptly so that production management decisions can be made without delay to minimize financial risk.

Water rights in Idaho and most western states are based upon the Doctrine of Prior Appropriation, which in essence means, "First in Time is First in Right." As plans for irrigated areas developed, water rights were sought and granted once water was actually applied to the land. As storage reservoirs were planned, water rights were applied for and granted once the dams were completed. Concurrently, reservoir storage space was sold with storage water rights assigned priority according to the water rights of the storage reservoir. The result of over 100 years of water resource development is a multitude of water diversion and storage rights based on a myriad of priority dates. Thus, the allocation of water during drought years depends upon water right priority dates as much as the available supply. An irrigation district's total water supply availability depends upon its natural stream flow priority date(s) and its water storage priority date(s) in relation to other water right holders, be they agricultural, municipal, industrial or environmental uses.

The objective of this project was to develop a methodology for estimating risk of a water supply shortage for irrigation districts and evaluate drought tolerance of common potato varieties for use in making production management decisions that minimize financial risk in potato production systems. The methodology used to estimate risk of a water supply shortage for an irrigation district and results of potato drought tolerance evaluations are described.

Evaluating Water Supply Risk for an Irrigation District

The USDA NRCS in western states publishes monthly basin outlook reports January through June based on data collected from federal-state-private cooperative snow surveys (www.wcc.nrcs.usda.gov/cgibin/bor.pl). The snow survey data are used by hydrologists to estimate monthly runoff flows that will occur when the snow pack melts. These forecasts are coordinated between hydrologists in the USDA NRCS and NOAA National Weather Service. These forecasts are an important part of risk management planning as they define water availability basin wide but they do not account for the differences in water allocation between irrigation districts due to water rights.

River Basin Reservoir Storage: In a river basin with snowmelt hydrology and reservoir storage, the reservoirs capture base flow and snow melt runoff above minimum stream flow requirements or until reservoir storage water diversion rights are filled. This is also subject to storage space required to safely pass peak snowmelt runoff events. Under drought conditions, partially filled reservoirs are managed to capture as much water as allowed by the reservoir storage water right. Thus, reservoir storage for the coming irrigation season is a function of flow and snowmelt runoff, which for Idaho is normally completed by July. This storage is called initial storage to denote it from storage that occurs after the irrigation season and before Oct 31st. Total storage for the irrigation season is the sum of initial storage and carryover from the previous year defined as reservoir storage on October 31st of the prior year.

Under drought conditions, initial storage is largely a function of April through September basin runoff or streamflow. As an example, initial storage for drought years in the Upper Snake River Basin of Idaho is shown in figure 1 as a function of April through September basin runoff volume. The data shown in figure 1 represents nine years during the period of 1980 through 2003 that basin reservoir storage did not fill to capacity. The relationship between initial storage and April through September basin runoff volume is well represented by a linear function having a correlation index (r^2) of 0.911. Thus, total basin storage can be reasonably well estimated as a function of April through September basin runoff plus carryover storage from the previous year. If the sum is greater than total basin reservoir storage, then the reservoirs should fill and the irrigation water supply will be sufficient.

The linear relationship shown in figure 1 provides a good estimate of initial storage on average; however, there is still uncertainty about the actual value of initial storage for a given level of basin runoff. The uncertainty in initial basin storage volume is due to uncertainty in how much snowmelt will enter streams; which depends upon the rate of snowmelt, soil moisture conditions, and spring precipitation. This uncertainty needs to be quantified in order to measure risk related to the available water supply. One approach to quantify this uncertainty is to use the prediction interval for the linear relationship (Lott 1984). The prediction interval for initial basin storage using a 95% confidence interval is shown in figure 1. As an example, if April through September runoff volume is 4.2 million ac ft, then initial basin storage is between 2 and 3 million ac ft with 95% confidence.

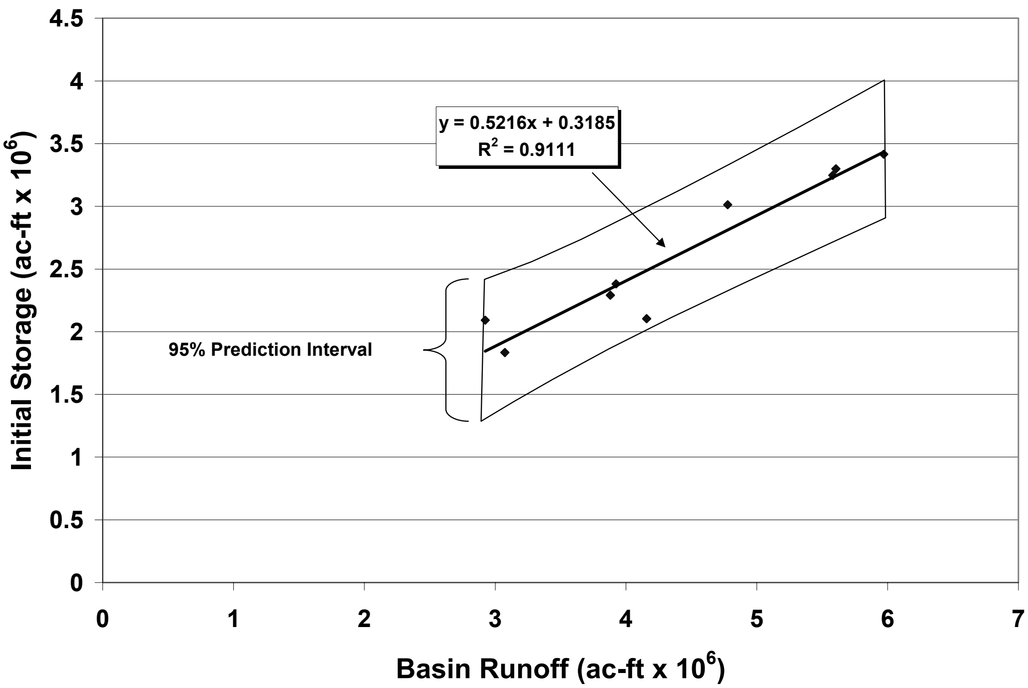

Figure 1. Basin initial storage as a function of basin runoff for 9 of the 24 years (1980 – 2003) river basin storage did not fill to capacity along with 95% prediction interval.

Irrigation District Storage Allocation: Water allocated to an irrigation district depends upon the initial storage captured in the reservoir(s) in which it has purchased storage right(s) plus any unused storage from the previous year subject to the upper limit of the storage space purchased. Initial storage captured in a particular reservoir is dependent upon the storage water rights of the reservoir and the rate at which snowmelt occurs. This uncertainty is considered small in relation to the uncertainty in total basin storage. Thus, irrigation district storage allocation is considered to be a deterministic linear function of total basin storage only and is irrigation district specific.

Irrigation District Storage Requirement: Storage water required by an irrigation district to fulfill its irrigation demand after their natural flow water right is cutoff depends upon several factors. The most important factors are the priority date(s) of the natural flow water right(s), natural flow in the river (basin runoff), and crop water requirements for the season. The primary factor is basin runoff. The storage water requirement for the Aberdeen-Springfield Canal Co. as a function of basin runoff is shown in figure 2 as an example of irrigation district storage requirements. The linear relationship represents district storage requirements as a function of basin runoff reasonably well with a correlation index (r^2) of 0.85. The randomness about the linear regression line is due to randomness in seasonal water requirements due to crop mix, climatic conditions and snow pack melt

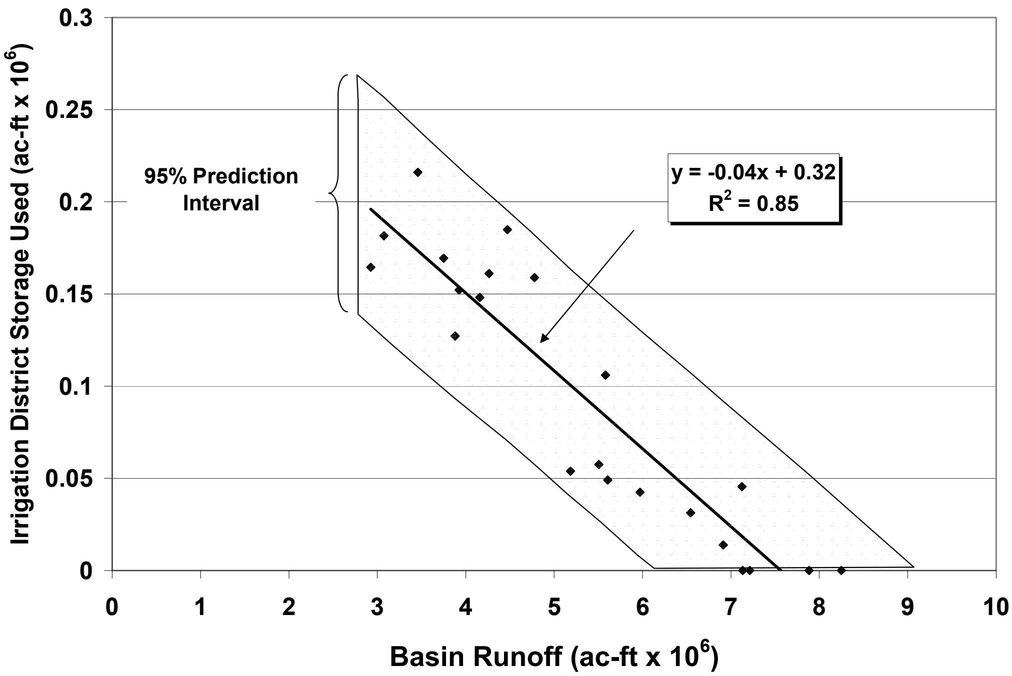

Figure 2. Storage water requirement and associated 95% prediction interval of the Aberdeen Springfield Canal Co. as a function of April through September basin runoff based 24 years of record.

pattern, which is also dependent upon climatic conditions. For example, if the spring is cool and wet, the snow pack will melt slowly and irrigation requirements will be delayed and reduced for the season. A slow snowmelt means natural flow will exceed irrigation demand longer into the growing season, delaying the time the irrigation district needs storage water and hence reducing storage water requirements. A warm/dry spring causes the opposite effect in terms of district storage water requirements. This uncertainty in storage water requirements is demonstrated in figure 2 using a 95% prediction interval for a linear regression relationship that is specific to the Aberdeen Springfield Canal Company.

<u>Calculating Water Supply Risk:</u> The risk of a water supply shortage, i.e. probability that water storage requirements will exceed allocation, is numerically calculated as the probability that an irrigation district's storage water allocation minus their storage water requirement will be less than zero. This representation of water supply shortage risk for a specific realization of basin runoff (conditional probability) is numerically calculated using the linear relationships and associated prediction intervals for irrigation district allocated storage and storage

requirement. At the lowest expected runoff volume, the probability of a water shortage is 1.0 or certain. At the highest expected runoff volume, the probability of a water shortage is zero. The cumulative risk of a water supply shortage is calculated by integrating the product of the conditional probability of a water supply shortage and the probability of the runoff event over the range of possible

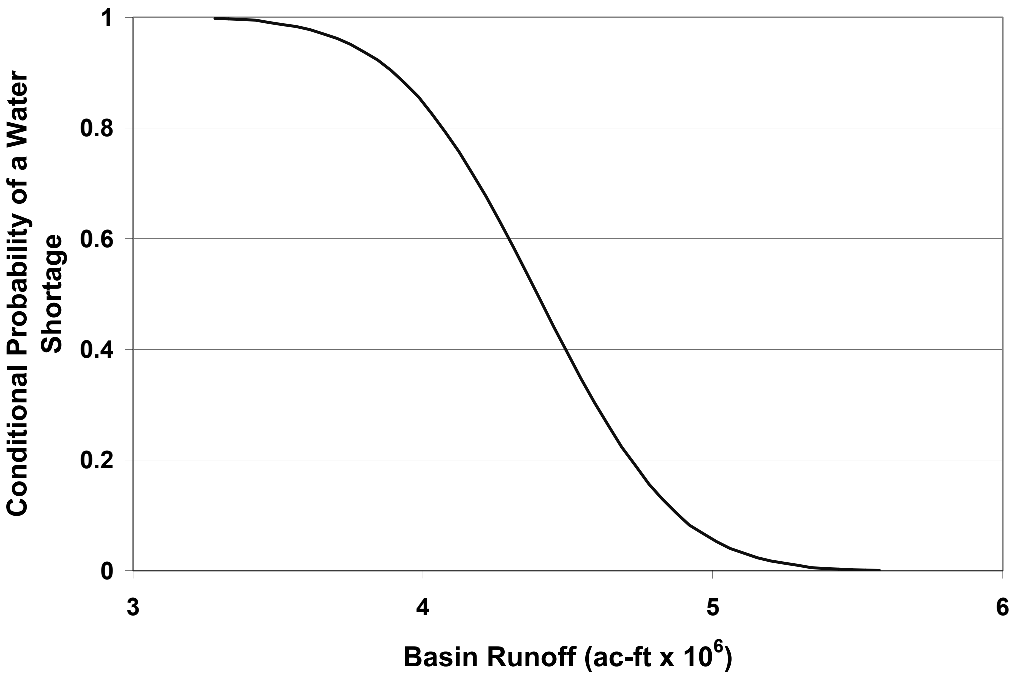

Figure 3. Conditional probability of a water shortage for Aberdeen Springfield Canal Co for February 2003.

basin runoff values. The probability of a specific runoff event is derived from the USDA NRCS April through September stream flow forecasts. An example of the computed conditional probability distribution function for the Aberdeen-Springfield Canal Co. is shown in figure 3. It assumes a basin storage carryover of 300,000 ac ft and February 2003 range in basin runoff forecast.

Potential Water Shortage Severity: Beyond quantifying the probability of a water shortage, the potential severity of the shortage also needs to be quantified. The potential severity of a water shortage is estimated as the maximum difference between the irrigation district's storage water allocation and storage water requirement regression lines. This maximum difference occurs at the minimum expected basin runoff estimate. This difference is then expressed as a percentage of the irrigation district's average annual total diversion to scale the potential water shortage severity to the particular district circumstances. Since the difference in regression lines or mean expected value is used to quantify severity of a water shortage, there can be a finite probability of a water shortage while the severity is zero. This results from using the prediction intervals about the regression lines to compute probability of a shortage and mean values for computing severity of a shortage.

Examples of computed water supply risk and severity for a few select irrigation districts in Eastern Idaho for April 2004 basin runoff estimates and 2003 basin storage carryover are presented in Table 1. While all the irrigation districts have the same water source, there is a wide disparity in the probability of a water shortage and potential severity. This disparity is the result of water right priority dates, which determines allocation of natural river flow every day throughout the irrigation season. This disparity among irrigation districts demonstrates that the location of a producer's operation can have a substantial impact on water supply availability. The results emphasize the importance of including irrigation water rights in assessing the risk in water supply availability under drought conditions

Table 1. Computed water shortage probabilities and associated water shortage severity relative to average annual diversion for select irrigation districts.

Irrigation District	Probability of Shortage (%)	Severity (%)
Blackfoot	8	0
Burgess	71	10
Butte & Market Lake	33	38
Consolidated Farmers	63	20
Corbett	0	0
E. Labelle	22	0
Egin	21	0
Farmers Own	97	57
Harrison	52	12
Sunnydell	70	16

Estimating the probability of a water shortage is needed information, but it alone does not reduce risk. Production management decisions must be made accordingly to account for the possibility of a water shortage. One possible production management decision is to not plant potatoes if the possibility of water shortage exists. However, such a decision represents a financial loss (opportunity cost) if the water supply actually is sufficient for potato production. In this event, choosing not to plant potatoes does not maximize net return. Besides not planting potatoes, one possible management option is to choose a potato variety that is drought tolerant and will provide a reasonable yield and net return with reduced water application. Information for selecting potato varieties based on yield response to reduced water application is limited. For this reason a field study was conducted to evaluate yield response of six common potato varieties to reduced water application under Idaho climatic conditions.

Evaluating Potato Drought Risk

Six potato varieties were grown under five imposed widely varying seasonal drought patterns simulated by irrigation management in 2002 and 2003 to identify specific potato management systems that will minimize exposure to drought risk. The irrigation management schemes included: 1) application of irrigation water to provide 100% evapotranspiration (ET) replacement for the full season (100% Full Season), 2) providing 100% ET replacement until Aug 10 with no application thereafter (100% Early Cut Off), 3) providing 75% of ET replacement for the full season (75% Full Season), 4) providing 75% of ET replacement until Aug 10 with no application thereafter (75% Early Cut Off), or 5) providing 100% of ET replacement until July 20 with a reduction to 75% of ET until Aug 10 and then decreasing to 50% ET replacement until vine kill (Step Down). Irrigation was applied with a solid-set sprinkler system, while ET was estimated with the modified Penman method used by the U.S. Bureau of Reclamation AgriMet system (www.usbr.gov/pn/agrimet/). Each irrigation management scheme was applied to four 36 ft x 80 ft main plots comprised of six 12 ft (4 rows) by 40 ft variety subplots. The six varieties included in the study are Russet Burbank, Russet Norkotah, Alturas, Summit Russet, Ranger Russet and GemStar Russet.

An economic analysis was conducted to evaluate economic risk associated with each drought management scheme on the six commercial potato varieties. The specific budget used for evaluating the economic impact of drought as measured by the various drought management schemes are those constructed for Southeastern Idaho (University of Idaho 2003 Costs and Returns Estimates (Patterson and Smathers, 2003)). The costs and returns estimates used in the economic analysis are based on a model 1,500-acre farm with 500 acres in potatoes. The typical crop rotation is one year of potatoes followed by two years of grain. Corn may substitute for grain, while sugar beets and alfalfa are grown in longer rotations. The farm uses a center pivot irrigation system and surface water delivered from an irrigation district. The irrigation district charges a flat fee per acre for water.

The results of the economic analysis are summarized in figure 4 which shows the return to risk for each potato variety under each drought management scheme. For three varieties (Russet Burbank, Alturas, and Ranger Russet) a gradual reduction in water application as the season progressed was the best option. Russet Norkotah, an early maturing variety, had the smallest relative yield losses and highest returns to risk when irrigation was cut-off in early August (100% Early Cutoff), but showed significant drought susceptibility and lower returns when stressed throughout the growing season. GemStar Russet and Ranger Russet exhibited the highest degree of drought tolerance and highest returns to risk overall. By comparison, Russet Burbank showed a relatively high susceptibility to drought and low returns to risk in most limited irrigation management schemes, while Summit Russet and Alturas exhibited moderate drought susceptibility and would not be good choices for reducing drought risk. These data show that management options are available in terms of potato variety selection to reduce risk of economic loss in different drought management schemes.

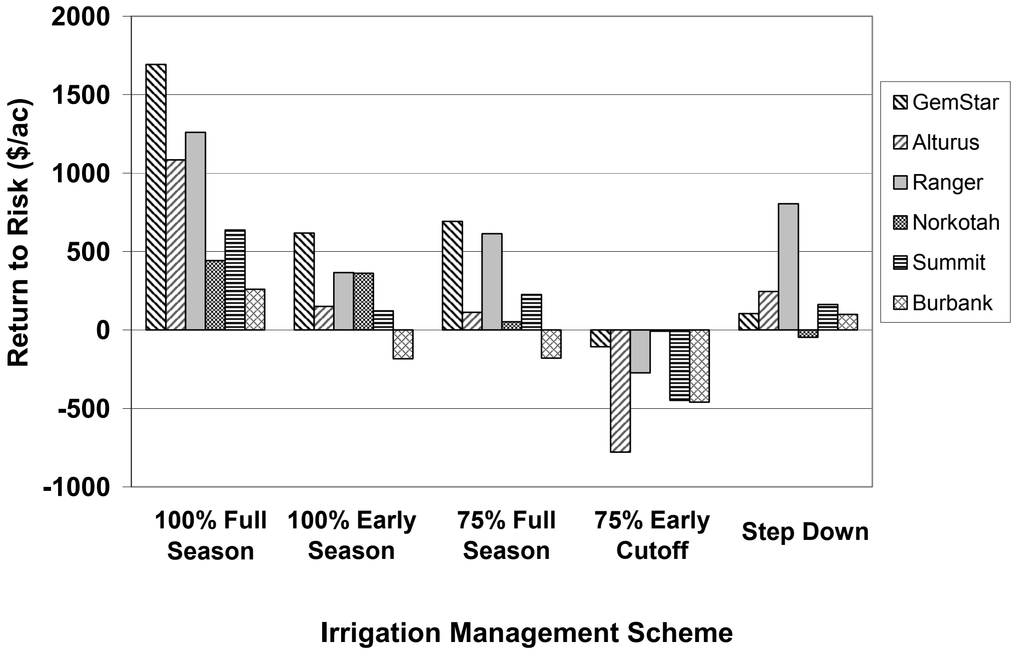

Figure 4. Calculated return to risk of six potato varieties under four imposed seasonal drought patterns compared to irrigation management to meet seasonal crop evapotranspiration requirements.

Dissemination of Potato Drought Management Information

Drought management information for potatoes is disseminated through the website: http://extension.ag.uidaho.edu/droughtpredict/. The information includes risk assessment of an irrigation water supply shortage on an irrigation district basis that is updated monthly January through April, potato variety drought tolerance comparisons, guidelines for irrigation and nitrogen management with limited water supply, and economic comparisons of water management strategies. Risk assessment for over 80 irrigation districts in the Upper Snake River basin and Boise River basin combined is provided on the website. These two river basins represent about 90% of potato production in Idaho irrigated by surface water supplies.

SUMMARY

Irrigation is required for the profitable commercial production of potatoes in Idaho. However, periodic drought is a fact of life, and can force producers to adopt sub-optimal irrigation practices due to restrictions on water availability.

Potatoes have a relatively shallow root zone and a lower tolerance for water stress than most other crops grown in Idaho. Drought management planning is necessary to minimize financial loss that can result from water supply shortages. Thus, producers need information on water availability for their production location and decision aids for adjusting agronomic practices under drought conditions.

An approach for estimating the risk of a water shortage and associated potential severity on an irrigation district basis was developed to assist producers with drought management planning. The approach requires a minimum amount of hydrologic information and incorporates an irrigation district's water rights into the estimates using historical water allocation and use data. Relative drought tolerances of six commercial potato varieties were evaluated under four different water restrictive irrigation management schemes. An economic analysis of yields for each potato variety under each irrigation management scheme used to simulate drought demonstrates the potential financial impact variety selection can have under drought conditions. These results show that choosing appropriate potato varieties and irrigation management strategies can substantially reduce risk of economic loss in potato production systems during drought.

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