POTATO PRODUCTION WITH LIMITED WATER SUPPLIES

Brad King, Jeff Stark and Stephen Love

INTRODUCTION

Potatoes have a relatively shallow root zone and a lower tolerance for water stress than most other crops grown in Idaho. The preference for producing this drought sensitive crop in coarse textured soils with limited water holding capacities makes precise irrigation management a necessity to obtain optimum yield and quality. Therefore, when restricted water availability reduces potato production potential, options for optimizing water use efficiency need to be considered to minimize the potential effects of drought.

IRRIGATION MANAGEMENT EFFICIENCY

The first step in optimizing the efficiency of any irrigation management program is to make sure the irrigation system is designed, maintained, and managed properly. Increasing irrigation efficiency to derive the most crop yield from every increment of water available will generally produce greater economic return than any other change in management.

Irrigation scheduling and irrigation uniformity are two key management factors affecting irrigation efficiency. Irrigation scheduling involves determining the correct timing and amount of water necessary to maintain root zone moisture within the optimal range for the crop growth. Irrigation uniformity is related to how evenly water is distributed over the field area.

An additional course of action is to evaluate possibilities for increasing the amount of available water per acre of potatoes produced. Potential courses of action include reducing potato acreage, purchasing additional water from surrounding water users, and selecting other crops that are drought tolerant or reducing acreage of other crops and transferring the water to the potato crop.

POTATO RESPONSE TO DROUGHT

The extent tuber yield and quality are adversely affected by drought will depend upon the severity, timing, and duration of water stress during the growing season. It is critical to have an understanding of how water stress at each growth stage influences tuber yield and quality if a grower is to balance water supply with potential returns. Specific irrigation management guidelines for each growth stage are presented below.

Presented at the Idaho Potato Conference on January 22, 2003.

Vegetative Growth - The vegetative growth stage begins at seed piece sprouting and extends to stolon formation. Water stress during the vegetative growth stage tends to acclimate (harden) the plant to water stress, potentially reducing the effect of water stress in later growth stages. Water stress during the vegetative growth stage reduces leaf area, vine and root expansion, plant height, and delays canopy development. Water deficits during vegetative growth have also been shown to decrease the number of tubers set per plant, which then results in fewer and larger tubers at harvest. Water stress limited only to the vegetative growth stage of Russet Burbank potatoes has been shown to decrease total yield but actually increase yield of U.S. No. 1 quality tubers (Table 1). A general management guideline is to withhold irrigation until full emergence for silt loam soils, if winter precipitation has been sufficient to fill the soil profile to near field capacity. In drought years, however, irrigation may be needed before full emergence to limit water stress, particularly on coarse-textured soils. Under these conditions, it is usually best to apply irrigation before planting to minimize disease development. As a general guide, soil water depletion in the upper 12 inches of the root zone should be limited to 50% available soil water during vegetative growth. However, caution must be used to ensure that water stress is reduced or eliminated at the time of tuber initiation and early bulking. This will not normally be a problem with irrigation systems other than center pivots or linear-moves. However, center pivots or linear-move systems with flow rates less than 7 to 7.5 gpm/acre may never be able to catch up on irrigation throughout the remainder of the season.

Tuberization - Tuberization begins when stolon tips begin to swell and tubers begin to develop but are not appreciably enlarging (<1/2 inch diameter). Although additional tubers may continue to form on stolons during later stages of plant development, tubers that contribute the most to marketable yield are formed at this time. Water stress during tuber initiation can substantially reduce tuber yield and quality. In a 1987 field study at the Aberdeen Research and Extension Center, Russet Burbank potatoes exposed to moderate (10 days) to severe (14 days) periods of water deficits during different stages of tuber development had lower total and U.S. No. 1 yields when stress occurred during tuber initiation (Table 2). Tubers that are stressed during tuberization often are severely misshapen with pointed stem ends, multiple knobs, and other malformations.

Tuber Bulking - The tuber bulking growth stage extends from the time tubers are about one-half inch in diameter to canopy senescence. Under ideal conditions, this growth stage is characterized by a relatively constant rate of increase in tuber size and weight. Interruptions in tuber growth by water stress often result in misshapen tubers having knobs, growth cracks, and irregular shapes characterized as “bottlenecks,” “dumbbells,” and other irregular curved shapes. Thus, periods of water stress during tuber bulking often decreases U.S. No. 1 yields by increasing the percentage of U.S. No. 2 tubers. Sustained irrigation deficits during the tuber bulking will reduce tuber size and marketable yields.

The effects of water stress during tuber bulking were evaluated in an Aberdeen study in which the nine weeks immediately following tuberization were divided into three 3-week intervals designated as early (E), mid (M), and late (L) bulking. Constant water stress was imposed during 2 or 3 of these periods by irrigating at the rate of 80% or 60% of normal crop water use. The greatest reductions in total yield generally occurred when deficit irrigation was imposed during early-mid (EM), and mid-late (ML) bulking, regardless of water stress intensity (Table 3). Spreading deficit irrigation evenly over the three periods or during the early- and late-bulking periods resulted in less total yield reductions. Effects of drought timing on U.S. No. 1 yield were similar to those for total yield. Water stress during the tuber bulking increased the percentage of undersized tubers with a corresponding decrease in 4 to 10 oz size tubers. Water stress during the early and mid bulking periods resulted in the lowest specific gravities and increased the percentages of dark ends.

In drought years, irrigation cutoffs during the month of August are highly probable in fields dependent on surface-water supplies. In a 1992 study at Aberdeen, water was cut off during the first or third week in August either abruptly or gradually over a 2-week period (Fig. 1). The same amount of water was applied for both cutoff methods at a given cutoff date. The mid-August cutoff reduced total and U.S. No. 1 yields by about 13%, while cutting off water the first week in August reduced total yield by 30% and U.S. No. 1 yield by 50%. There was little benefit from gradual irrigation cutoff compared to abrupt irrigation cutoff. Late July and early August are peak tuber bulking periods and severe water stress during this period will substantially reduce tuber yield and grade, regardless of the manner it is imposed. Over the past 20 years, research at the Aberdeen Research and Extension Center has shown that total yield of Russet Burbank will generally be reduced 25 cwt/acre for every inch crop water use is reduced due to water stress during the tuber bulking growth stage.

<u>Maturation</u> - Maturation stage of growth begins with canopy senescence. Tuber growth rates gradually decline with loss of canopy, although significant amounts of carbohydrate are transported from the vines to the tubers during this growth stage. Exceptionally dry soil conditions late in the growing season not only reduce yield but can also shorten dormancy, reduce specific gravity, and increase reducing sugar content. Dry soil conditions can also dehydrate tubers, making them more susceptible to blackspot bruise. Consequently, care should be taken after irrigation is cut off to make sure the available soil water does not drop below 50% prior to vine kill. It is also important to get complete vine kill or removal since remaining live vines will continue to extract soil moisture.

Under dry soil conditions, the tuber moisture content or hydration level will steadily decrease resulting in increased susceptibility to blackspot bruise. Tubers can be partially rehydrated by irrigating prior to harvest. For tubers maturing in dry soils (<50% available soil moisture), irrigation should be applied about 7 to 10 days prior to harvest to adequately rehydrate tubers. Tubers maturing in soils with adequate available moisture (>60%) can usually be rehydrated by irrigating two to three days prior to harvest. Growers and irrigation districts should always hold back adequate water to properly condition the soil and rehydrate the tubers before harvest. This is particularly important on medium and heavy textured soils where soil conditioning is necessary to soften clods to minimize tuber damage during harvest.

FERTILITY MANAGEMENT

If irrigation deficits are anticipated, the nitrogen management program needs to be adjusted accordingly. The degree of yield response to nitrogen fertilizer decreases markedly as crop water use is reduced by water stress. Specific gravity is also greatly affected by water and nitrogen management. Specific gravity generally decreases with reduced water application and increased available nitrogen. High nitrogen availability during late tuber-bulking often delays tuber maturity in indeterminate varieties such as Russet Burbank. Research at Aberdeen has shown that for every 15 to 20% reduction in water application from the optimum amount during the growing season, the amount of nitrogen required for maximum yield is reduced by about 40 lb N/ac (Table 4). Applying large amounts of preplant nitrogen should also be avoided since it will likely delay tuber bulking and make the impact of late season water stress more pronounced.

CULTURAL MANAGEMENT

In addition to adjusting irrigation fertility management to mitigate drought effects, producers should also consider changing other management options including the following:

Potato Acreage - Potatoes grown in southeastern and south central Idaho require 18 to 23 inches of water for maximum yield. Two to three inches more water is required in southwestern Idaho due to the longer growing season. Peak daily crop water use is 0.31 to 0.34 inches. In locations where irrigation districts can and do elect to reduce delivery rates to extend the time of delivery, reducing potato acreage to match the available water supply is likely a better management option than deficit irrigation.

Field Choice - If possible, potatoes should be grown in fields that have the greatest potential for maintaining adequate soil moisture, such as fields with loams or silt loam soil. Coarse-textured soils such as sands and sandy loams have low water-holding capacities and will lead to rapid development of water stress under deficit irrigation. In locations where irrigation districts elect to reduce the frequency of water delivery to extend the water delivery period, fields with predominately loam and silt loam soils are the best choice for potato production under deficit irrigation.

Variety Selection - Late-maturing varieties such as Russet Burbank are affected more by early irrigation cutoff than earlier-maturing varieties such as Russet Norkotah and Shepody. Therefore, earlier varieties are usually preferable in locations where surface water supplies may run out during the latter part of the season. In addition, some late-season varieties are less susceptible to drought than others. For example, tuber yield and quality of three russet varieties under two different irrigation regimes are shown in Table 5. Available moisture was allowed to decrease to 70% in one treatment and to 50% in the other. Total and U.S. No. 1 yields for Ranger Russet were less affected by drought than those for Russet Burbank or Frontier Russet.

<u>Seed Condition and Spacing</u> - Physiological aging of potato seed often results in earlier plant emergence and tuber development. If water shortages are anticipated late in the season, efforts to accelerate tuber development by planting seed that has been aged by warming during storage may be beneficial. This may reduce the magnitude of yield reduction from early irrigation cutoff by completing more of the tuber-bulking growth stage before water stress develops.

Seed piece spacing can also be modified to partially mitigate the effects mid-season water stress on tuber bulking and yield. A 1991 study was conducted to determine the effect of seed spacing (10, 15 or 20 inches) on tuber yield and quality under several levels of water stress during tuber bulking. The different levels of water stress were imposed by limiting the amount of water applied after July 13 to 100, 81, 50, or 24% of crop water use. U.S. No. 1 yields were consistently the lowest for the 10 inch spacing, while U.S. No. 1 yields for the 15- and 20-inch spacing were not significantly different for mild to moderate water stress (Fig. 2). However, under severe water stress, the 20 inch seed spacing produced a significantly higher U.S. No. 1 yield compared to either the 10 or 15 inch spacing. As distance between plants increases, tubers have a larger soil area from which to draw water and nutrients, resulting in increased size and yield (Fig. 3).

Table 1. Effect of increasingly severe water stress during the vegetative growth stage on yield and grade of Russet Burbank tubers. Water stress severity is expressed as days soil moisture is below 60% available soil water (ASW).

Duration Soil Moisture	U.S. No. 1		Undersized	U.S. No. 2	Yield	
<60% ASW	4-10 oz	>10 oz	<4 oz	Total	Total	U.S. No. 1
days	%	%	%	%	--- cwt/ac ---	
0	52.1	9.5	32.2	3.0	489	302
6	57.0	4.8	30.5	2.2	473	270
12	58.3	5.9	28.8	0.5	518	333
21	56.7	9.7	22.5	2.1	507	336
27	60.9	16.0	17.6	1.4	477	366

Adapted from: Shock, C.C. et al. 1992. Impact of Early-Season Water Deficits on Russet Burbank Plant Development, Tuber Yield, and Quality. Amer. Potato J. 69:793-803.

Table 2. Effect of deficit irrigation during tuberization and early tuber bulking on Russet Burbank yield and quality.

Period Without Irrigation	Total Yield	U.S. No. 1 Yield
days	cwt/acre	cwt/acre
None	342	230
Tuberization – 10 days	313	185
Tuber bulking – 10 days	317	182
Tuberization – 14 days	262	112
Tuber bulking – 14 days	293	175

Table 3. Effect of two levels of water stress during three periods of the tuber bulking growth stage on yield and grade of Russet Burbank tubers. Three-week water stress intervals are designated as early (E), mid (M), and late (L) bulking.

Irrigation	Water Stress	U.S. No. 1		Undersize	U.S. No. 2	Specific	Yield	
Level	Timing	4-10 oz	>10 oz	<4 oz	Total	Gravity	Total	U.S. No. 1
%	E,M,L	%	%	%	%		-- cwt/ac --	
100	---	65	5	04	6	1.083	417	292
80	EML	57	7	31	5	1.081	381	245
80	EM	56	6	32	6	1.079	363	228
80	ML	58	9	26	7	1.082	360	240
80	EL	56	7	31	6	1.080	380	240
60	EML	52	6	36	6	1.079	338	197
60	EM	52	7	36	5	1.078	316	186
60	ML	56	6	33	5	1.081	298	194
60	EL	54	7	32	7	1.080	333	203

Adapted from: Stark, J.C. and I.R. McCann. 1992. Optimal allocation of limited water supplies for Russet Burbank potatoes. Amer. Potato J. 69:413-421.

Table 4. Russet Burbank yield response with five nitrogen application rates and four seasonal water application amounts. The highest water application amount was 100% of crop water requirement.

	Seasonal Irrigation Applied (inches)			
N Rate	13.0	15.4	16.8	18.2
lb/ac	-------------------- Relative Yield (%) --------------------			
0	87.4	89.5	86.0	89.6
40	100.0	100.0	97.0	95.9
80	98.6	100.0	100.0	98.8
120	93.5	96.8	97.0	100.0
160	91.3	95.6	93.6	95.9

Table 5. Yield response of three Russet potato cultivars to two levels of irrigation scheduling regimes. Irrigation was initiated at 50% and 70% available soil water (ASW) throughout the growing season.

	Total Yield			U.S. No. 1 Yield		
Variety	70% ASW	50% ASW	Difference	70% ASW	50% ASW	Difference
	------ cwt/acre ------		%	------ cwt/acre ------		%
Russet Burbank	418	388	-7.2	286	262	-8.4
Ranger Russet	430	404	-6.0	311	319	+2.3
Frontier Russet	360	307	-14.7	296	254	-14.2

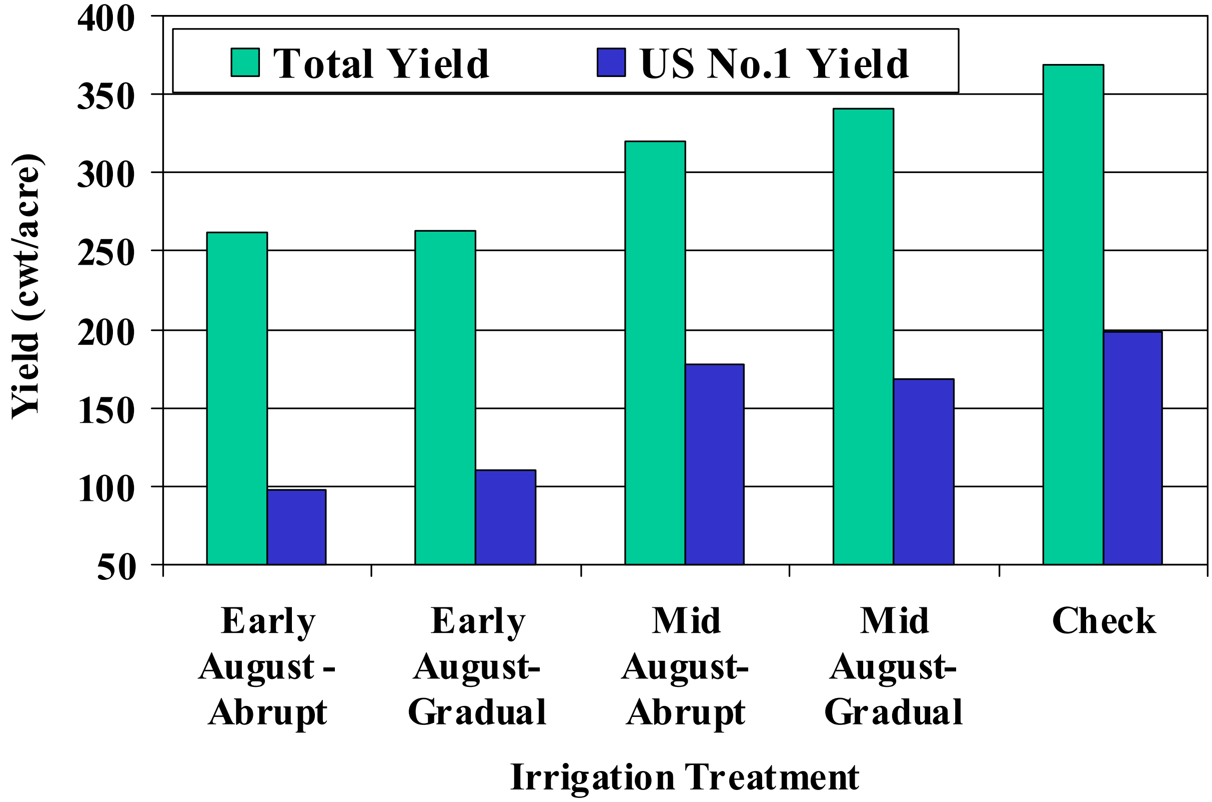

Figure 1. Effect of early irrigation cutoff on Russet Burbank total and U.S. No. 1 yield.

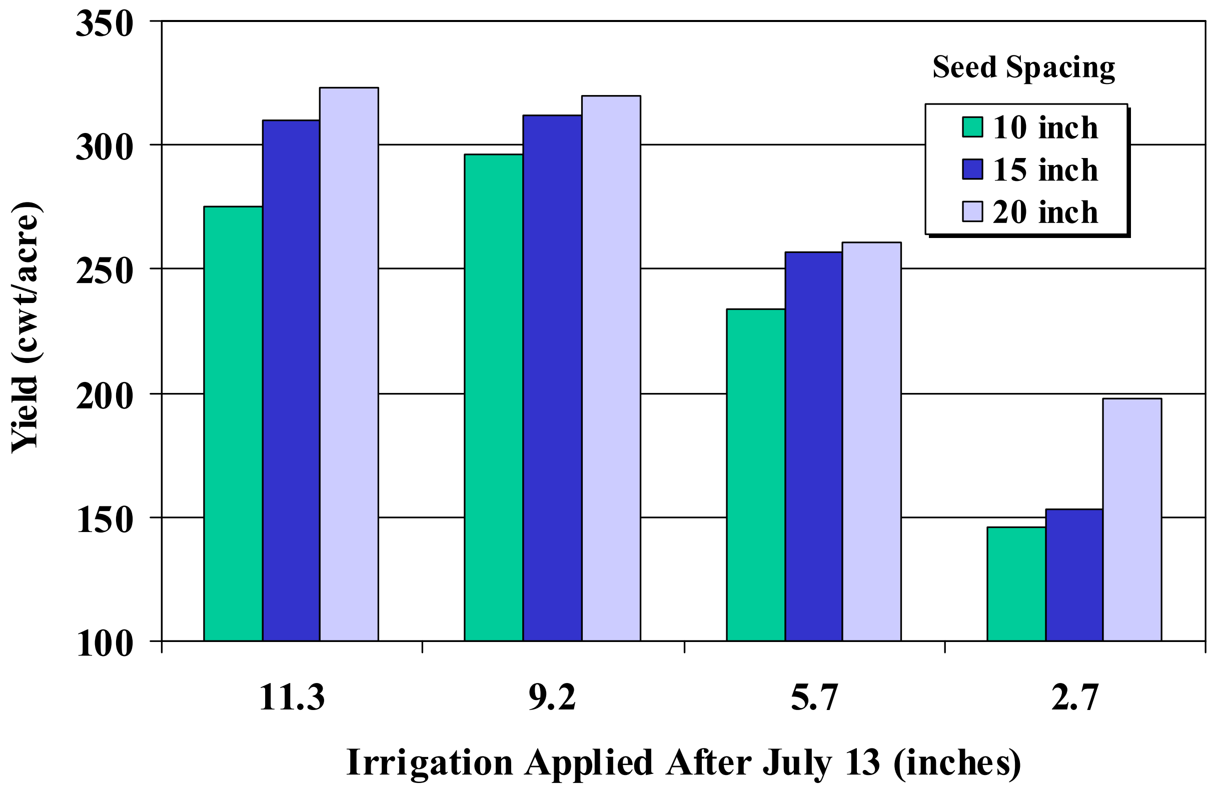

Figure 2. Seed spacing effects on Russet Burbank U.S. No. 1 yield under different level of water stress during tuber bulking.

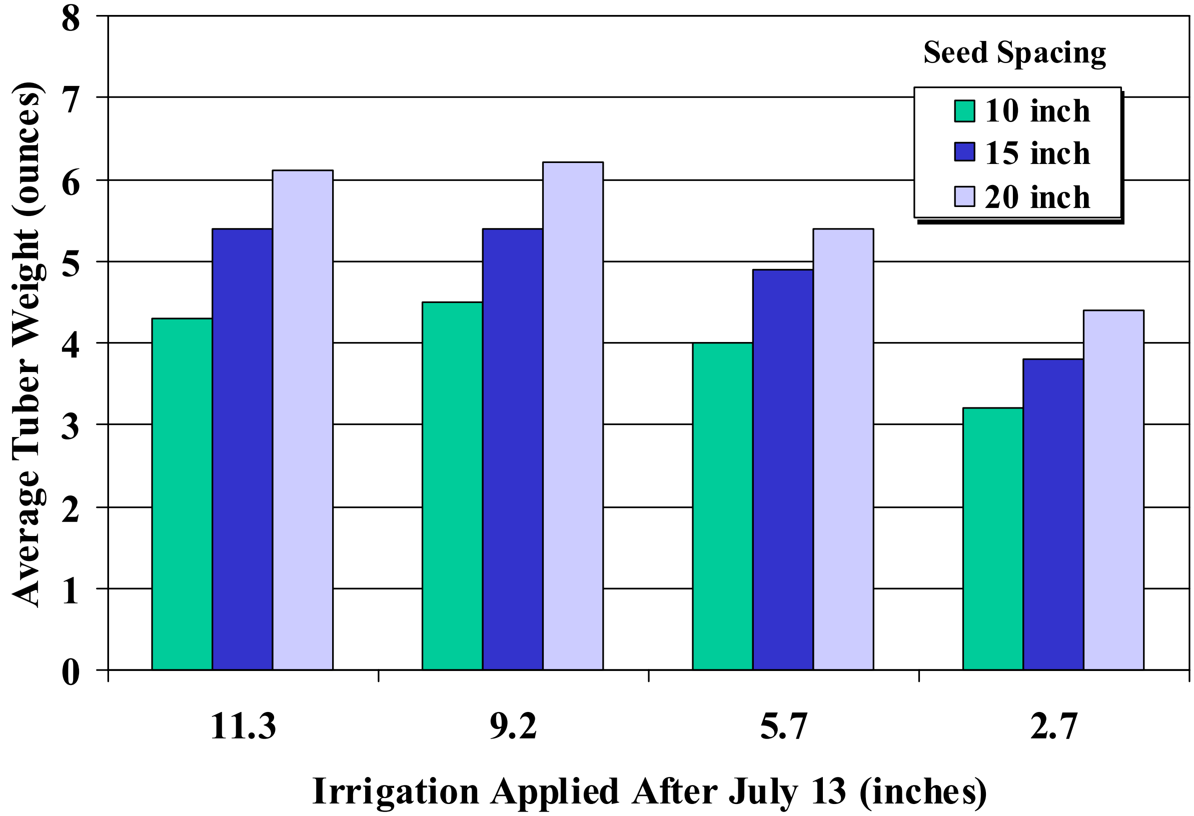

Figure 3. Seed spacing effects on Russet Burbank average tuber size under different levels of water stress during tuber bulking.