Factors Affecting Seed Age and Productivity in the Columbia Basin

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Key Points:

- **Accumulation of degree-days by seed-tubers advances physiological age.**
- **Seed age affects stem numbers and tuber size distribution in a predictable manner.**
- **In-row spacing can be adjusted in relation to stem numbers to optimize tuber size distribution.**
- **Control of seed age and stem numbers can add value to both seed and commercial potato crops.**

The physiological age of seed-tubers can have a significant effect on productivity. A major research effort is underway to develop techniques to predict, manipulate, and better manage the physiological age and yield potentials of seed potatoes. Knowing the relative age of a seed lot prior to planting would facilitate optimization of management practices to produce high yields of the most lucrative tuber size classes in the progeny crop. Research support from the Washington State Potato Commission and USDA/ARS has enabled us to make good progress identifying factors that contribute to aging and developing techniques to optimize tuber size distribution in relation to the age of a seed lot.

Seed-tuber physiological age is affected by time and temperature, especially during the period from vine kill to planting. The respiration rate of tubers increases with temperature, which in turn accelerates the rate of aging. One way to estimate physiological age is to track the number of degree-days (heat-units) from vine kill through storage and handling to planting. This can be calculated in degrees centigrade or Fahrenheit by subtracting a base temperature of 4oC (39oF) from the average tuber pulp temperature on a particular day and summing the daily values over an extended period (e.g. from vine kill through storage to planting) to arrive at the total accumulated degree-days for a particular seed crop.

Variation in accumulated degree-days among seed lots translates into variable productivities among the corresponding commercial crops. Controlling this variation presents an opportunity for both seed and commercial growers to increase crop value. Figures 1 and 2 illustrate how differences in the production and handling of two seed lots translates into different physiological ages, as calculated in accumulated degree-days (oC). Clearly, seed lot B is physiologically older than seed lot A, despite the fact that chronological age (from vine kill to planting) was constant at 215 days for both lots. Seed lot B had a relatively long maturation (skin set) period under dead vines (33 days, 57oF pulp temp.) and a relatively long suberization (37 days, 54oF pulp temp.) period. Variation in degree-day accumulation during maturation and suberization likely accounts for much of the variation in age and performance among seed lots in the Columbia Basin. These two periods thus offer the greatest opportunity to manipulate (and thus control) age and productive potential.

Seed growers can potentially add value to their seed lots by certifying the number of degree-days as an indication of age. As illustrated by Russet Burbank and Ranger Russet, respectively, stem number per seedpiece increases with degree-days (Fig. 2), particularly at higher temperature, and tuber set and size development change substantially and predictably with stem numbers (Fig. 3). The number of tubers set per hill increases with increasing stems per seed piece (Fig. 4). This results in greater competition among tubers within a hill for carbohydrate and other resources during growth, resulting in smaller tubers.

In the Columbia Basin, these changes in tuber set and size occur without affecting total, marketable (including undersize), and U.S. No. 1 yields over a wide range of stem numbers (up to approximately 5.5 stems/hill) (Fig. 3). Hence, tuber size distribution, a significant contributor to overall crop value, depends on (and can be predicted from) the average stem number per hill produced by a seed lot (Table 1). Manipulating stem numbers by varying the degree-days during storage of seed is an effective technique to change tuber size distribution (Fig. 4), which can potentially add value to a crop.

Seed growers should keep records of the degree-days accumulated by their crops starting at vine kill, through storage to final sale. This will help to explain any issues that may arise later concerning performance of the commercial crop. Information on the age of seed lots in terms of accumulated degree-days would enable Columbia Basin growers to estimate average stem numbers and thus expected tuber size distributions prior to planting. Growers could then choose to manipulate agronomic practices such as in-row spacing to optimize tuber size distribution for a particular seed lot, in relation to market requirements for tuber size (seed, fresh, and processing) (Tables 2 and 3).

		Market	
Flexibility	Cultivar	Seed	Fresh
		*desired stem numbers & spacing**	
Most	CORN-3	high stems 4.0-5.0 <10-in spacing	moderate stems 2.6-3.3 10-in spacing
Intermediate	CORN-8	mod.-high stems 3.5-5.0 10-in or less	low-moderate stems 2.3-3.0 10-in spacing
Least	Norkotah	mod.-high stems 3.5-4.5 10-in or less	low stems 1.8-2.5 ≥10-in spacing

*Desired stem number ranges are for illustration purposes only and may change pending results from ongoing research.

Table 2. Estimated stem numbers and in-row spacing to produce optimum tuber size distributions of Russet Norkotah selections (CORN-3, 8 and std. Norkotah) for seed and fresh markets in the Columbia Basin. CORN-3 tends to produce high yields of oversize tubers at low stem numbers. Therefore, it is rated most flexible for changing tuber size distribution (via stem number management) to more closely match market requirements. Standard Norkotah is least flexible because it produces a tuber size distribution at low stem numbers that satisfies market requirements (albeit with much less yield than the CO selections). Higher stem numbers and closer spacing translate into more tubers per acre and smaller tubers, a desirable characteristic for seed production.

		Markets		
Flexibility	Cultivar	Seed	Process	Fresh
		*desired stem numbers & spacing**		
Most	Ranger	high stems 4.0-5.0 <10-in spacing	mod. stems 2.7-3.7 10-in spacing	mod. stems 2.6-3.5 10-in spacing
Intermediate	Burbank	high stems 4.0-5.0 10-in or less	low-mod. stems 2.5-3.5 10-in spacing	low stems 2.0-3.0 10-in spacing
Least	Umatilla	high stems 4.0-5.0 10-in or less	low stems 2.0-3.0 ≥10-in spacing	low stems 2.0-3.0 ≥10-in spacing

*Desired stem number ranges are for illustration purposes only and may change pending results from ongoing research.

Table 3. Estimated stem numbers and in-row spacing required to produce optimum tuber size distributions of Ranger, Russet Burbank, and Umatilla Russet for seed, frozen process, and fresh markets in the Columbia Basin. Ranger is rated most flexible for manipulating tuber size distribution through stem numbers because it sets fewer tubers per plant at low stem numbers and a high percentage of oversize (>14 oz) tubers. This tendency can be offset by increasing the stem numbers and closer in-row spacing to optimize tuber size distributions according to market requirements. Umatilla is least flexible because it sets more tubers at relatively low stem numbers and the tubers mature later in the season, resulting in smaller average size tubers for this cultivar.

Maintaining a constant number of degree-days in seed lots from year to year will decrease the year-to-year variability in seed performance and enable commercial growers to optimize management (e.g. in-row spacing) to get the best yield and tuber size distributions possible, within the constraints of their growing region. In-row spacing can be varied to optimize tuber size distribution and thus the value of crops produced by low- and high-stem number seed lots (Tables 4-6, Fig. 5). Divulging the number of degree-days constitutes a marketing strategy that reflects a high level of quality control for a particular seed lot.

Seed age at the end of storage can also interact with prior-to-planting handling practices to affect stem numbers and tuber size distributions in the Columbia Basin. Older seed, which accumulated more degree-days during storage, was more sensitive to handling prior to planting than younger seed. For example, the average stem number from older Russet Burbank seed cut and planted directly from cold storage was substantially higher compared with seed cut, suberized for 2 weeks at 55oF and then planted, or with seed warmed for 2 weeks at 55oF prior to cutting and planting (Fig. 6). For Ranger Russet, older seed cut directly from cold storage and suberized for 2 weeks before planting produced more stems than seed warmed for 2 weeks prior to cutting and planting. While still in progress, these studies link seed handling practices from the end of production, through storage to cutting and planting and may help to explain some of the recent, but isolated problems in stand establishment of particular seed lots in the Columbia Basin.

In summary:

- **Physiological age is most affected by time and temperature.**
- **Stem numbers increase with advancing physiological age, affecting tuber set & size development in a predictable manner.**
- **This provides an opportunity to add value to seed & commercial crops by providing seed lots with stem no./tuber set characteristics customized for a particular production area.**
- **Pending further research, seed growers should strive to manage seed lots to produce predictable stem numbers from one year to the next.**
- **A constant number of heat-units (degree-days) accumulated by seed will contribute to uniform age and thus stem numbers from year-to-year.**
- **This will allow commercial growers to optimize management (e.g. spacing) to produce the most desirable tuber size classes (= added value).**

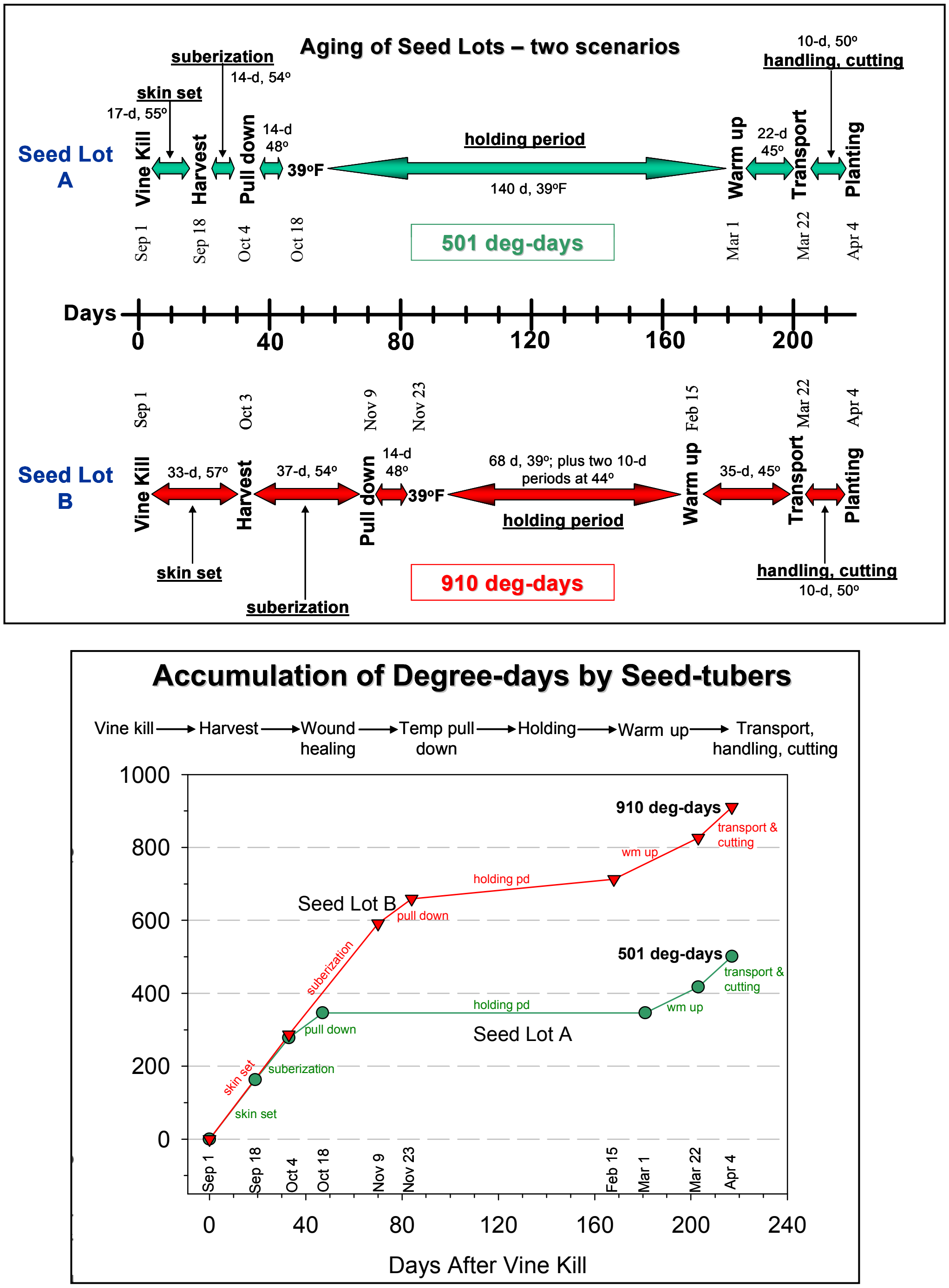

Fig. 1. (Top) A comparison of how different handling protocols for two seed lots can result in different ages, as calculated in accumulated degree-days (°C) above a base temperature of 4°C (39°F). Pulp temperatures above 39°F from vine kill through storage to cutting and planting (215 day period, Sep 1 to Apr 4) contributed to degree-day accumulation and thus the physiological age of seed-tubers. (Bottom) Time course of degree-day accumulation for the two seed lots. Note that seed lot B accumulated almost twice as many heat units as seed lot A (910 degree-days vs. 501 degree-days) due to differences in the duration of skin set and suberization. Seed lot B will produce more stems than seed lot A (see Fig. 2), which in turn will affect tuber set and size development (Fig. 3, Table 1).

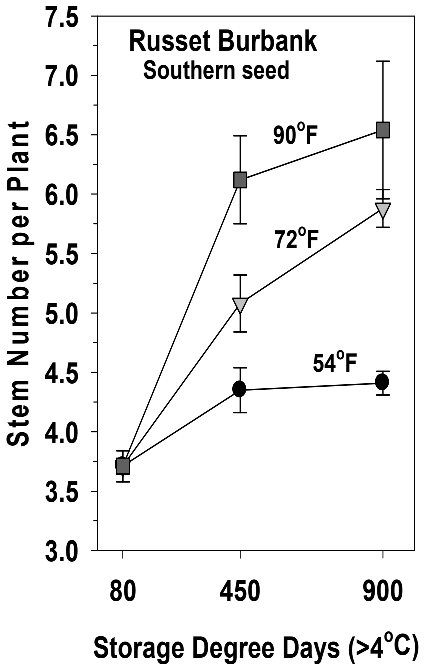

Fig. 2. Effects of storage degree-days and temperature on above ground mainstem numbers from Russet Burbank seed-tubers. Seed-tubers were aged at the beginning of storage at 54, 72, and 90°F for the indicated number of degree-days and the temperature was then lowered to 39°F for the remainder of a 210-day storage interval. Note that the temperature at which degree-days are accumulated is important in dictating age and stem numbers. Data are averaged over three growing seasons

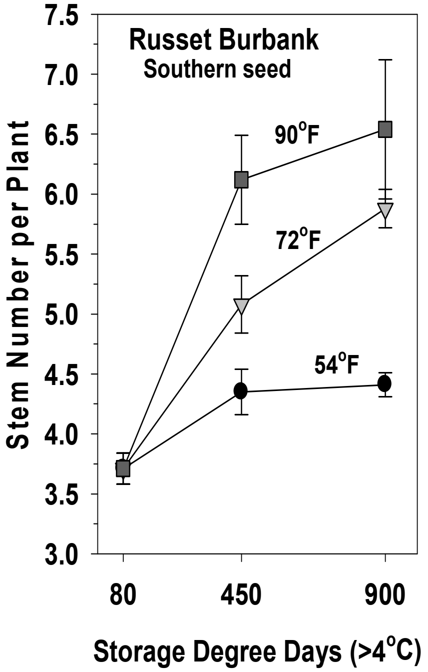

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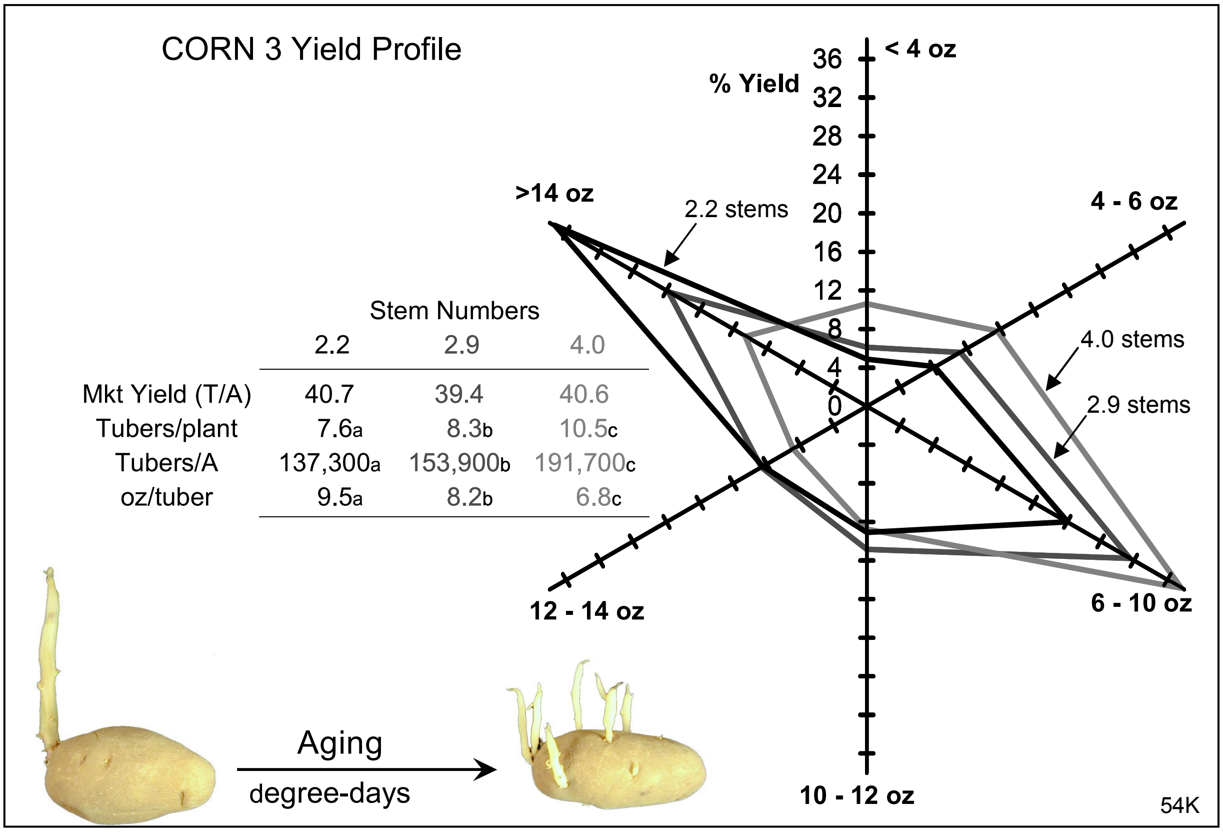
Table 1. Predicted changes in tuber set and size with increasing aboveground stems from northern-grown Ranger Russet seed-tubers planted in the Columbia Basin (regression models upon which these estimates are based were derived from three years of field data).

	Percent of Marketable Yield – northern RR seed						**Mkt. Yld**	**Tuber No.**		**Tuber Wt.**		**Tubers/A**
Stems/Plant	**< 4 oz**	**4-6 oz**	**6-10 oz**	**10-12 oz**	**12-14 oz**	**>14 oz**	**(T/A)**	**per stem**	**per plant**	**g/tuber**	**oz/tuber**	**(1000's)**
2.4	7.4	11.4	27.3	11.6	10.2	31.1	31.3	2.7	6.6	246.1	8.7	117.1
2.6	8.2	12.2	27.9	11.5	10.0	29.8	31.4	2.7	6.9	238.3	8.4	123.2
2.8	9.0	12.9	28.5	11.4	9.8	28.5	31.4	2.6	7.1	230.8	8.1	128.8
3.0	9.8	13.6	29.0	11.2	9.6	27.1	31.4	2.5	7.4	223.8	7.9	134.1
3.2	10.5	14.4	29.5	11.1	9.4	25.8	31.5	2.5	7.6	217.2	7.7	139.0
3.4	11.2	15.1	29.9	11.0	9.2	24.5	31.5	2.4	7.9	211.0	7.4	143.5
3.6	11.9	15.8	30.3	10.9	9.0	23.1	31.5	2.3	8.1	205.3	7.2	147.7
3.8	12.6	16.5	30.6	10.8	8.8	21.8	31.6	2.3	8.3	199.9	7.1	151.5
4.0	13.2	17.3	30.9	10.7	8.6	20.5	31.6	2.2	8.5	194.9	6.9	154.9
4.2	13.7	18.0	31.1	10.6	8.4	19.1	31.6	2.1	8.6	190.4	6.7	158.0
4.4	14.2	18.7	31.3	10.5	8.2	17.8	31.7	2.1	8.8	186.3	6.6	160.7
4.6	14.7	19.5	31.5	10.3	8.0	16.4	31.7	2.0	8.9	182.6	6.4	163.0
4.8	15.2	20.2	31.6	10.2	7.8	15.1	31.8	1.9	9.0	179.3	6.3	164.9
5.0	15.6	20.9	31.7	10.1	7.6	13.8	31.8	1.8	9.1	176.4	6.2	166.5
5.2	16.0	21.6	31.7	10.0	7.4	12.4	31.8	1.8	9.2	173.9	6.1	167.7
5.4	16.3	22.4	31.7	9.9	7.2	11.1	31.9	1.7	9.2	171.8	6.1	168.5
Coeff of det (R^2)[a]	0.95***	0.99***	0.73*	0.29ns	0.78**	0.95***	0.04ns	0.98***	0.98**	0.98***	0.98***	0.98***
Std. Error of Est.[b]	0.9	0.4	1.2	-	0.6	1.7	-	0.06	0.15	4.4	0.15	3.6

[a] Values (x100) represent the percent variation explained by the models.

*,**,***Correlations were significant at the 0.05, 0.01 and 0.001 levels, respectively.

[b] Standard errors of the estimates of percent yield, tuber set and size from stem number per plant.



	Stem Numbers		
	2.2	2.9	4.0
Mkt Yield (T/A)	40.7	39.4	40.6
Tubers/plant	7.6a	8.3b	10.5c
Tubers/A	137,300a	153,900b	191,700c
oz/tuber	9.5a	8.2b	6.8c

Fig. 4. Polygonal plots illustrating the shift in size distribution of CO Russet Norkotah selection 3 (CORN 3) tubers with increases in tuber age and average stem number per seedpiece. Yield axes range from 0 to 38% for each of the six tuber weight classes. For clarity, only the <4-oz tuber yield axis is labeled. The area encompassed by each polygon is indicative of total marketable yield (which includes <4-oz tubers). Changes in shape or shifts in position of the polygons characterize an effect of stem number and thus seed age on tuber size distribution. Total marketable yields were equal for the three seed lots, regardless of stem number (inset table). Tuber set increased with average stem number per seedpiece, resulting in significant declines in average tuber weight (inset table) and shifts in tuber size distributions. Approximately 38% of the marketable yield from the 2.2-stem seed lot consisted of oversize (>14 oz) tubers (darkest polygon). In contrast, increasing the average stem number to 4.0 (lightest polygon) greatly reduced the percentage of oversize tubers and increased the percentage of 6-10 oz tubers (from 24 to 38%). Data are averaged over 2 years (122-day growing season, 10-inch in-row spacing).

Tables 4, 5 & 6. Tuber set per plant increased more in high-stem seed lots of Ranger Russet as in-row spacing increased, than in low-stem seed lots (Table 4). The high-stem seed lot produced more tubers per plant and per acre than the low stem seed lot and tubers per acre from both seed lots fell to the same extent with increasing in-row spacing (Table 5). Average tuber weight increased with increasing in-row spacing for both seed lots and the response was greatest for the low stem number seed lot (Table 6). These responses resulted in substantial shifts in tuber size distribution (see Fig. 5 below).

Table 4

Tubers per Plant Increase With Seedpiece Spacing & Stems

In-row Spacing (inch)		Seed Lot 2.8-stem	Seed Lot 5.4-stem	
		tubers/plant		
6		6.9	9.4	
10	51%	8.9	13.4	74 %
14		10.4	16.4	
Age (stems)		**		
Spacing_{LT}		**		
A x Sp_{LT}		**		

**P≤0.01

RR 2-yr
49K2004/05

Table 5

Tubers per Acre Decrease With Seedpiece Spacing & Increase With Stems

In-row Spacing (inch)		Seed Lot 2.8-stem		Seed Lot 5.4-stem	
		tubers/acre (1000's) (1000's)			
6		212		288	
10	-31 %	165	+49K	247	-31 %
14		135		214	
Age (stems)		**			
Spacing_{LT}		**			
A x Sp_{LT}		ns			

**P≤0.01, ns=not significant

RR 2-yr
2004/05

Table 6

Avg. Tuber Wt Increases With Seedpiece Spacing & Decreases With Stems

In-row Spacing (inch)		Seed Lot 2.8-stem	Seed Lot 5.4-stem	
		oz/tuber		
6		7.3	5.0	
10	36 %	8.7	5.7	28 %
14		9.9	6.4	
Age (stems)		**		
Spacing_{LT}		**		
A x Sp_{LT}		**		

**P≤0.01, ns=not significant

RR 2-yr
2004/05

Yield Profiles of Low & High Stem No. Seedlots
Shift With In-Row Spacing

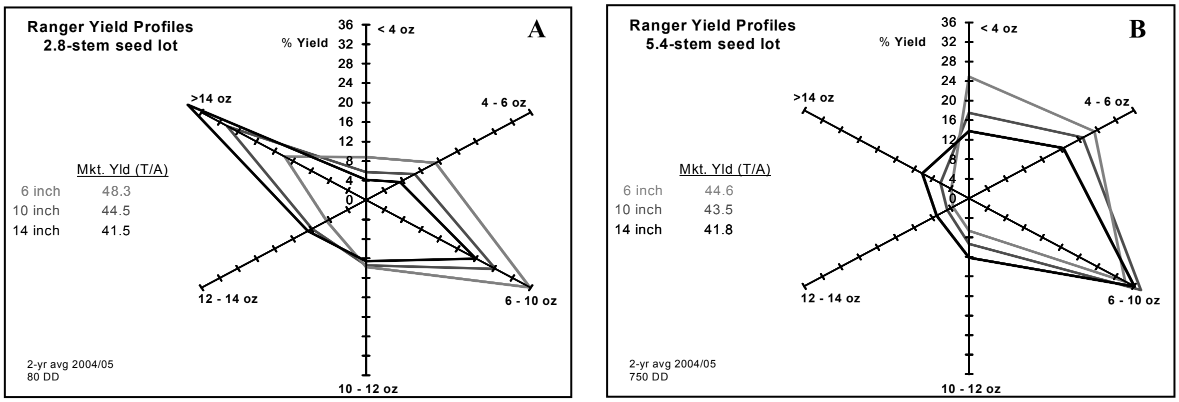


Fig. 5. Effects of in-row spacing on tuber size distributions from low (A) and high (B) stem number seed lots of Ranger Russet. Tuber size distribution shifted to favor more moderate size tubers at the expense of oversize tubers when the 2.8-stem seed lot (A) was planted with 6-inch spacing (lightest polygon). The 5.4-stem seed lot (B) produced a greater proportion of >10-oz tubers when planted with 14-inch spacing (darkest polygon). These results indicate that spacing can be adjusted in relation to the age and estimated stem numbers of a seed lot to change final tuber size distribution and potentially add value to a commercial crop.

Fig. 6. Responses of Russet Burbank (RB) and Ranger Russet (RR) seed tubers to seed handling practices prior to planting. Seed harvested from OR seed fields was aged in storage for 80- and 450-degree-days after wound-healing. The storage temperature was then lowered to 39°F for the remainder of a 200-day storage period. Seed was cut and planted directly from 39°F storage (CP); cut and suberized at 55°F for 14 days prior to planting (CSP); or warmed for 14 days at 55°F and then cut and planted immediately (WCP). Note that the response to these treatments depended on the seed age and was different for each cultivar. In general, older seed produced higher stem numbers than younger seed and was more sensitive to the prior-to-planting handling treatments. For RB, older seed cut and planted directly (CP) with no warm up and suberization periods produced more stems. For RR, older seed cut and suberized for 2 weeks prior to planting (CSP) produced more stems than seed warmed prior to cutting and planting. The variable responses of the differentially aged seed may help to explain some of the year-to-year variation in stem numbers observed among seed lots in the Columbia Basin. For seed growers, these results emphasize the importance of controlling heat-unit accumulation by seed from vine kill through storage to planting.