A Survey of Stand Establishment and In-Row Spacing Uniformity in Washington Potato Fields

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ABSTRACT

Missing plants and non-uniform in-row plant spacing can result in economic loss for potato growers. In-row seedpiece and plant spacing uniformity of 70 Washington potato fields was measured, and factors contributing to missing plants investigated from 2000 through 2002. Ninety-one percent of the fields were planted with cut seedpieces, and the remaining 9% were planted with whole, uncut seed tubers. Russet-type cultivars were planted in 79% of the fields, and the remaining 21% were planted with red-skinned and yellow- and white-fleshed cultivars. Seedpiece or plant spacing deviated an average of 25% from the intended spacing mean, with a range of 7% to 43%. Coefficients of variation (CV) for grower in-row plant and seedpiece spacing ranged from 18% to 69% compared with a hand-planted check average of 13%. Based on the growers' intentions, the average plant population of the 70 fields should have been 44,000 plants ha^{-1}, but averaged only 40,600 plants ha^{-1}. On average, 6% of the grower-intended stand was missing because of planter skips, while less than 1% was missing due to seedpiece failure or decay. There were 1,980 clumped seedpieces ha^{-1} and each clump typically contained two seedpieces. Twenty-one percent of the fields had at least 700 planter-skips ha^{-1} where three or more consecutive plants were missing. Despite management efforts, planters were typically unable to place seed uniformly at the intended spacing. Improved planter and seed-cutting-operation management along with new planter technology would likely improve Washington potato stands.

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ADDITIONAL KEY WORDS: missing plants, plant population, plant density, seed spacing, plant spacing, irregular spacing, planter skips, planter performance

RESUMEN

Espacios vacíos y falta de uniformidad en el espaciamiento de plantas en el surco puede resultar en pérdidas económicas para los productores. La uniformidad en el espaciamiento de la semilla fue estudiada en 70 campos de papa de Washington y los factores que contribuyen a la presencia de espacios vacíos fueron investigados desde el 2000 al 2002. El 91% de los campos se sembró con semilla cortada y para el restante 9% se usó semilla entera. Los cultivares del tipo rojizo se sembraron en el 79% de los campos y el restante 21% se sembró con cultivares de piel roja y amarilla y pulpa blanca. El espaciamiento de semilla cortada o de plantas tuvo en promedio una desviación de 25% del promedio proyectado de espaciamiento, con un rango de 7 a 43%. Para plantas en surcos, los coeficientes de variancia (CV) de espaciamiento de la semilla estuvo entre 18 y 69% en comparación con el testigo sembrado manualmente, cuyo promedio estuvo en 13%. Basado en lo proyectado por el productor, el promedio de población de los 70 campos debería haber sido 44,000 plantas/ha^{-1}, pero solo promedió 40,600 plantas/ha^{-1}. Faltó el 6% de plantas proyectadas por el productor debido a escapes en la siembra, mientras que menos del 1% faltó debido a fallas de la semilla cortada o por pudrición. Hubo 1,980 pedazos agrupados de semilla cortada/ha^{-1} y cada grupo contenía típicamente dos pedazos de semilla. El 21% de los campos tuvo al menos 700 fallas/ha^{-1} debidas a la sembradora, donde faltaban tres o más plantas consecutivas. A pesar de los esfuerzos en el manejo, las sembradoras fueron incapaces de colocar la semilla

uniformemente a la distancia conveniente. Sembradoras mejoradas y manejo de la operación de corte junto con una nueva tecnología de siembra parece que mejorarían los sembríos de papa en Washington.

INTRODUCTION

How important are optimally spaced plant populations to commercial potato growers? A study by Rupp and Thornton (1992) determined that a 10% increase or decrease from the optimum (most profitable) plant population would reduce grower returns between 2% and 12%. They also determined that planter skips and double-clumped seedpieces typically reduced economic return over uniform in-row spacing. James et al. (1973) estimated that an 8% loss in total tuber yield from planter skips had reduced New Brunswick grower revenue by $1.5 million (Canadian). Conversely, some studies indicate that a loss in yield may not be detectable due to compensation from plants surrounding missing or irregularly spaced neighbors (Entz and LaCroix 1984; Hide et al. 1995, 1996; Pascal et al. 1977; Sieczka 1986). However, yield alone does not determine the economic worth of a potato crop. Tuber-size profile also plays a crucial role. Despite the effect or lack of effect on yield, irregular spacing may change tuber-size profile and reduce economic return (Rupp and Thornton 1992).

Over the past 74 years, less-than-optimum plant populations and in-row plant spacing in potato fields have inspired commercial field surveys in six states and two provinces (Idaho [Thornton et al. 1997], Minnesota [Preston 1986], New Jersey [Martin 1931], New York [Sieczka et al. 1986], North Dakota [Preston 1986], Washington [Thornton 1971, 1979], Alberta [Andrew 1971; Klassen 1974], and New Brunswick [James et al. 1973], Canada). The surveys indicated that most commercial potato fields have a high frequency of irregularly spaced plants, planter skips, and clumped seedpieces. Stand reductions from inadequate planting operations occurred in most fields. Less frequently, stands were reduced because of seed-related problems.

Six of the surveys found that field plant populations were 80% to 90% of intended (Klassen 1974; Martin 1931; Sieczka et al. 1986; Thornton 1971, 1979; Thornton et al. 1997), and the remaining three surveys found plant populations were closer to 75% of what was intended (Andrew 1971; James et al. 1973; Preston 1986). Martin (1931) reported plant spacing in New Jersey was irregular and emphasized that it was not uncommon for 10% to 15% of the intended plant population to be missing due to a combination of planter skips, non-uniform in-row spacing, and disease (*Rhizoctonia solani*). It was concluded that improper planter adjustments, worn parts, and the poor maintenance of planters were major factors contributing to the planter skips and irregular spacing.

Sieczka (1986) found that the in-row plant spacing of commercial potato fields in New York was not uniform. Coefficients of variation (CV) ranged from 43% to 70% with the average seed placement 4 cm wider than intended. Mechanical failure of planters was cited as the primary reason as to why plants were missing. The mechanical failure was presumably due to a combination of factors, which included planting speed, poor planter condition and maintenance, and low seed bowl levels. Similar to the findings of Sieczka (1986), Entz and LaCroix (1983) found planters under similar conditions placed seed non-uniformly and that in-row spacing CVs ranged from 50% to 77%. They also found that planter performance improved when seed was of uniform shape and size.

A survey of Idaho potato fields in 1995 and 1996 found that 55% of seedpieces were within 7.6 cm of the intended spacing (Thornton et al. 1997). The remaining 45% were within 7.6 to 41 cm of the intended spacing. Planter skips and double-clumped seedpieces were common. A combination of improper tractor speed during planting, non-uniform seedpiece size, and planter type and condition led to less-than-intended plant populations in the Idaho fields.

Two commercial field surveys were conducted in Washington during the 1970s (Thornton 1971, 1979). These surveys also indicated that plant populations were compromised by poor planter performance rather than seed-related problems. In 1970, growers planted 87% of the seedpieces they intended (Thornton 1971). When plants were missing, 81% of the time no seed was dropped (planter skip), 10% of the time seedpieces lacked a viable meristem, and 9% of the time seedpieces were decayed. Eight years later, commercial plant populations had not improved and poor planter performance was still the primary cause (Thornton 1979).

These surveys indicate that most issues common to potato stands are related to the planter, not seed quality. Adjusting the planting speed as needed, in conjunction with uniformly sized seed (Thornton 1997) and well-maintained planters (Sieczka 1986) may improve planter performance; however, the high incidence of similar problems seen across all surveys indicates that planter design may play a larger roll than management. Given the history of continued problems establishing desired potato stands, this study was initiated (1) to determine the extent to which modern planters affect plant population; (2) to determine the extent to which seed-related factors affect plant population; (3) to evaluate planter performance by comparing actual plant populations and spacing to grower-intended values; and (4) to measure the uniformity of in-row plant and seedpiece spacing in Washington potato fields

MATERIALS AND METHODS

Over a three-year period, 70 commercial potato fields in Washington State were sampled to determine why plants were missing. Actual in-row plant or seedpiece spacing of 56 mechanized planters was recorded and compared to grower intentions. Eleven of the planters were sampled during more than one year or in more than one field, bringing the total number of planter observations to 67. Potato cultivar, seed type (cut or whole), and planter make/manufacturer were recorded. Fifteen meters of emerged in-row plants were counted at four sites within 14 fields during 2000. A total of 24 fields were sampled in 2001 and 32 fields in 2002. Seven and one-half meters of uncovered seed (pre-emergence) or emerged in-row plants were sampled at four to six sites within each field. During 2001 and 2002, fields were sampled either pre- or post-emergence. No attempt was made to do both pre- and post-emergence sampling in the same field.

During all years, spaces between emerged plants that were close to or greater than twice the intended in-row spacing were excavated by hand to determine if plants were missing due to planter skips, decayed seedpieces, or seed without an apical meristem. An in-row spacing gap was classified as one planter skip if the gap was greater than or equal to twice the intended plant spacing (x) minus 5 cm (i.e., 2x – 5 cm). This formula is based on the idea that some seedpiece spacing variability is likely and that an unplanted area does not have to be exactly twice the length of the intended spacing to be considered a planter skip. Additionally, this formula is one used by a local implement company (Evergreen Implement Inc., Othello, WA, USA), and the authors felt that by using the same formula the data may be more relevant to the local industry. To determine if a spacing gap should be classified as a multiple planter skip (i.e., double, triple, etc.), the formula was altered for each potential, consecutive missing plant (*mp*) and compared to the actual measurement. A double planter skip at an intended spacing of 30 cm would have been an unplanted area between two plants ranging from 80 cm (i.e. 3x – [5 cm (2 *mp*)]) to 105 cm (i.e., 4x – [5 cm (3 *mp*)]); and a triple planter skip would be an area between two plants ranging from 105 cm to 130 cm (i.e., 5x – [5 cm (4 *mp*)]); etc. If a measurement fell on a cut-off value, the gap would be recorded as the next larger skip size.

In-row spacing between each emerged plant within a sample was measured during 2001 and 2002. Additionally, distance between pre-emerged, uncovered seedpieces was measured and recorded in 27 fields during 2002. Uncovered seedpieces spaced closer than 10 cm were recorded as clumped, along with the number of seedpieces per clump. Distance between individual plants or seedpieces was not measured in 2000, except when determining whether a gap was large enough to be classified as a single or multiple planter skip. Other than plant or seedpiece spacing uniformity, data collected in 2000 were similar to that for 2001 and 2002.

To provide a standard by which commercial planters could be compared, 43 to 85 g 'Russet Burbank' seedpieces were planted in one-row plots by hand or with a custom-built assist-feed small-plot planter at the Washington State University Research Unit near Othello, WA, during 2001 and 2002 (referred to as plot data). Each plot was 7.5 m and replicated four times in a completely randomized design. In-row spacing for the plot-planted seedpieces was 26 cm. Hand planting consisted of uniformly placing seedpieces every 26 cm in an open furrow and covering them with tractor-pulled hilling disks. Mimicking the sampling techniques from the commercial field survey, data were collected from each small plot during 2001 and 2002.

From the field and plot data, average in-row spacing, percent absolute deviation [(actual – intended in-row spacing/ intended in-row spacing) x 100] of each seedpiece or plant from intended in-row spacing (2001-2002 only), CV (2001-2002 only), actual plant population vs intended plant population, number of planter skips, clumped (2002 only) and rotted seedpieces, and non-emerged plants were calculated. Absolute deviation (%) and CV of in-row spacing, clumped seedpieces, and planter skip (% of intended plant population) data were analyzed using analysis of variance, and the means statistically separated using Fisher's Protected Least Significant Difference Test at the 0.05 level of probability. A completely randomized design with a one-way treatment structure was used. There were seven treatments, including two plot-planted treatments, "hand-planted" and "small-plot planter," and five commercially planted treatments. Each commercially planted treatment represented data from one of the five commercial planter makes used by growers in the survey. The number of observations of each commercial planter type ranged from six to 26, and provided a good representation of the planters used by Washington growers. The sums of squares from the analysis of variance were partitioned to compare the plot-planted treatments with the commercially planted treatments.

Due to large variations in tractor/planting speeds, seed lots, cultivars, soil type and condition, planter condition, planter model and modifications, and seed cutting and planter management, no attempt was made to directly compare commercial planters. In order to preserve anonymity among the five planter makes, neither the names of planter manufacturers nor the mechanical type (pick or cup) are presented in the data analysis; instead, each planter make is referred to as either type "one," "two," "three," "four," or "five." The mean of the four to six sites sampled from each field served as one replication for each commercially planted treatment. Emerged plant and uncovered seedpiece data were not separated. Year was not considered as a variable during analyses.

RESULTS

Of the 56 planters included in the survey, there were three cup-type (Grimme, Kverneland, and Lockwood [AireCup]) and two pick-type (Harriston and Lockwood) planters. The majority (91%) of fields in the survey were planted with cut seed. Seventy-nine percent of the fields were planted with russet-type cultivars, the remaining 21% with red-skinned or yellow- or white-fleshed cultivars. Russet-type cultivars included Russet Norkotah, Russet Burbank, Ranger Russet, Umatilla Russet, and Gem Russet. The non-russet cultivars included Red Lasoda, Yukon Gold, and Cascade. All non-russet cultivars and whole-planted seed tubers sampled were planted in the Skagit Valley (northern coastal region of Washington).

The plant population in the commercial potato fields averaged 40,600 plants ha^{-1}. An average of 7% of the grower-intended stand (44,000 plants ha^{-1}) was missing, with a range of 1% to 25%. Similar to the 1970 survey, when plants were missing, most of time it was because the planter failed to plant a seedpiece (Table 1).

An average of 6% (2,700 plants ha^{-1}) of the intended plant population was missing due to planter skips, with a range of 1% to 20% (Figure 1). The plot-planted treatments contained no skips and were significantly different (P = 0.0034) from the commercially planted treatments. Thirty-nine percent of the fields contained an average of 1,300 planter skips ha^{-1} where two or more consecutive plants were missing. Moreover, 21% percent of fields contained an average of 700 planter skips ha^{-1} where three or more consecutive plants were missing (data not shown). Nearly 19% of all planter skips were followed by clumped seedpieces on one end of the skip (data not shown).

TABLE 1—*Why potato plants were missing in commercial Washington potato fields during 1970 (Thornton 1971) and 2000-2002, and the percentage of the intended plant population that was actually planted.*

	1970 %	2000-02 %
Planter skips	81	92
Seed without sprout	10	4
Seed with decay	9	4
% of intended population planted	87	93

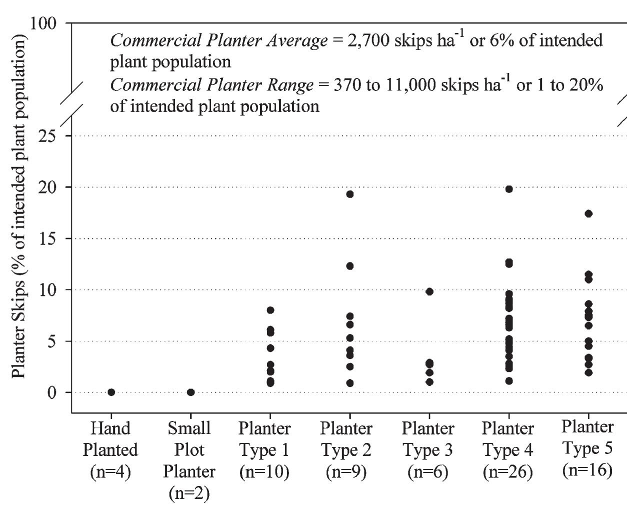

FIGURE 1.
Percentage of intended plant population missing due to planter skips in Washington potato fields during 2001 and 2002. Each dot represents the mean of four to six replications of counts within 7.5 m of row. The number of means per category is indicated by "n"; some means overlap. Plant and seedpiece spacing from commercial planters averaged 29 cm; equivalent to 40,600 plants or seedpieces ha^{-1}. The intended mean spacing was 26 cm or 44,000 plants or seedpieces ha^{-1}.

It is unclear, however, whether these skip-clump combinations were created because a seedpiece rolled or bounced upon contacting the soil surface, or if the planter failed to drop seed at the appropriate time and location.

Less than 1% (250 seedpieces ha^{-1}) of the intended plant population was missing as a result of seed-related issues, such as disease or lack of a viable meristem. Compared to the 1970 survey, there was a trend for less seed decay and fewer seedpieces without a viable meristem (Table 1).

On average, 5% (1,980 seedpieces ha^{-1}) of commercially planted seedpieces were found in clumps of two or more in 2002 (Figure 2). Despite an average of 0% clumps, the plot-planted treatments were not significantly different ($P = 0.0616$) from the commercially planted treatments.

Average plant and seedpiece spacing in the commercial fields was 29 cm, despite a grower-intended mean of 26 cm. Grower-intended spacing ranged from 19 to 33 cm, while the actual in-row spacing average ranged from 20 to 36 cm. Each commercially planted plant or seedpiece deviated an average of 25% from the intended spacing mean, with a range of 7% to 43% (Figure 3). The plot-planted plants and seedpieces deviated an average of 12% from the intended spacing mean, which was significantly less ($P < 0.0001$) than the commercially planted mean. Furthermore, relatively high CVs indicated that commercially planted plant and seedpiece populations were not uniformly spaced (Figure 4). CVs of the commercial planters averaged 34%, and were significantly ($P < 0.0001$) higher than the plot-planted treatments, which averaged 15%. The commercial planters CVs ranged from 18% to 69%, and the range within each planter type was broad and inconsistent (Figure 4).

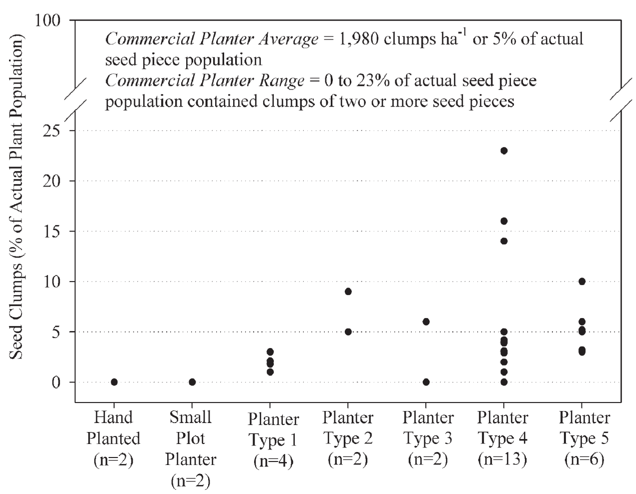

FIGURE 2.
Percentage of actual seedpiece population composed of clumped seedpieces (<10 cm in-row spacing) in Washington potato fields during 2002. Each dot represents the mean of four to six replications of counts within 7.5 m of row. The number of means per category is indicated by "n"; some means overlap. Seedpiece population averaged 39,600 pieces ha^{-1} in 2002.

DISCUSSION

This survey found that most issues common to Washington potato stands are planter-related and not seed quality-related. Planter skips accounted for more than 90% of missing plants in Washington fields, while seed-related factors contributed to less than 10%. Moreover, in-row spacing was typically non-uniform. These findings are quite similar to those reported in the earlier surveys (Andrew 1971; James et al. 1973; Klassen 1974; Martin 1931; Preston 1986; Sieczka et al. 1986; Thornton 1971, 1979; Thornton et al. 1997).

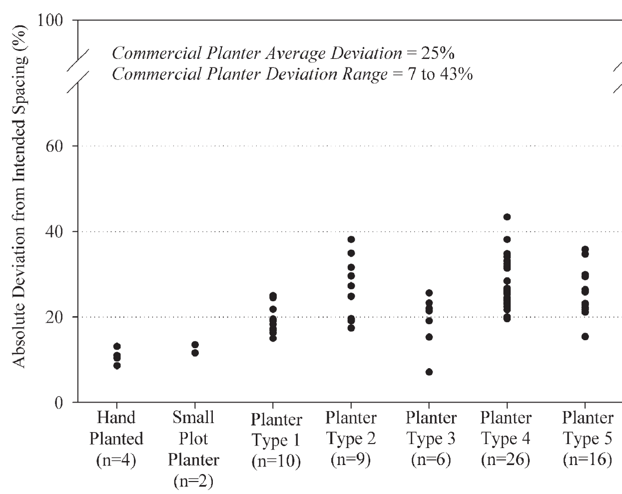

FIGURE 3.
Average deviation (%) of actual plant or seedpiece spacing from the intended spacing mean in Washington potato fields during 2001 and 2002. Each dot represents the mean of four to six replications of absolute deviations [(actual - intended spacing/intended spacing) x 100] from each of 25 or more plants or seedpieces for each planter or planting method. The number of means per category is indicated by "n"; some means overlap. Plant and seedpiece spacing from commercial planters averaged 29 cm. On average, seedpieces and plants in the commercial fields deviated ± 6.5 cm or 25% from the intended mean spacing of 26 cm.

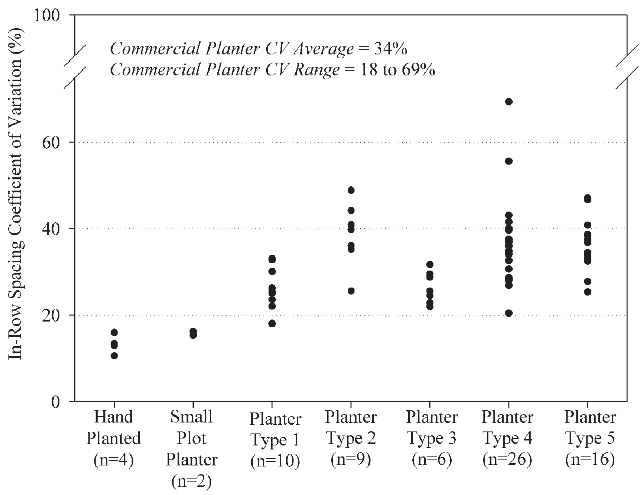

FIGURE 4.
Variation of in-row plant and seedpiece spacing in Washington potato fields during 2001 and 2002. Each dot represents the mean of four to six replications of spacing variation between each of 25 or more plants or seedpieces. The number of means per category is indicated by "n"; some means overlap. Plant and seedpiece spacing from commercial planters averaged 29 cm.

On the upside, Washington growers appear to be planting better-quality seed and more of their intended plant population than in 1970. Similar to their 1970 counterparts, however, many modern growers struggle to achieve uniform in-row spacing. CVs for the Washington growers averaged 34% and ranged as high as 69%. The uniformly spaced plot-planted treatments averaged 15%. Several operations did quite well, however, achieving in-row spacing CVs of 22% or less. The operation with the most uniform stand of potatoes achieved a CV of 18%. These values are quite respectable considering the lower end of the CV ranges reported by Sieczka (1986) and Entz and LaCroix (1983) were 43% and 50%, respectively. Additionally, all five planter types represented in the Washington survey were able to produce in-row spacing CVs of 25% or less within at least one commercial field.

Why did some planters in this survey do so well and others so poorly? Several studies indicate that in addition to sufficiently intense management, planter performance may improve with proper seed-bowl levels, maintenance, ground speed, and pick arrangement (Hyde et al. 1979; Sieczka et al. 1986); and by using seed or seedpieces of uniform shape and size (Entz and LaCroix 1983). Entz and LaCroix (1983) reported that planter performance improved when whole seed tubers (single drop) were used instead of cut seedpieces. This may provide some improvement to Washington growers; however, an economic analysis of producing and buying single drop tubers vs producing, buying, and cutting larger tubers into pieces should be conducted.

New or improved planter technology is another factor that would likely improve commercial potato stands. The difficulty comes in designing a planter that will accommodate both whole and cut seed tubers of many shapes and sizes. In addition, market demand for potato planters is small in comparison to the demand for planters used in other markets such as corn or wheat. The resulting lack of economic incentive for manufacturers may be the largest limitation to new potato planter designs. Despite this, new technology found in the recently introduced vacuum planters appears promising; however, research under controlled conditions is needed for a proper evaluation.

Due to a high number of variables, the economic impact that less-than-desirable plant populations have on the Washington potato industry is difficult to completely assess. Using commercial plant population values from this survey, Pavek and Thornton (2003) estimated that missing and irregularly spaced Russet Burbank and Russet Norkotah plants cost Washington potato producers between 3% and 5% of their seed-cost-adjusted gross revenue. The estimated revenue loss came from a combination of yield reduction and changes in the tuber size profile. Growers with potato stands similar to the 70-field average from this survey would be losing close to \$250 of seed-cost-adjusted gross revenue ha^{-1} compared to a uniformly spaced stand that was not missing plants. With a potential loss of \$250 ha^{-1}, there appears to be adequate incentive for most Washington growers to improve their potato stand uniformity.

Although the economic loss may vary from situation to situation, growers everywhere should strive to improve their stand uniformity. Growers should not replace an old, functional planter unless there is good evidence a new planter can perform at a higher level. To achieve uniform plant populations, growers should use certified seed that is sorted by size prior to cutting. Cutting mechanisms should be adjusted as needed and over- or under-sized seedpieces should be trimmed or discarded. Seedpiece profile should be monitored to obtain the desired average seedpiece size and uniformity. Growers should identify and maintain the optimum planting speed and seed-bowl levels by monitoring planter performance frequently.

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