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Uniform Plant Stand Is Key to Crop Yield and Quality

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Introduction

STAND ESTABLISHMENT IS AN IMPORTANT OBJECTIVE for growers because it involves and affects all aspects of crop production: efficient use of agricultural inputs (e.g., water, fertilizers, and pesticides), crop yield, and quality. When nonuniform plant stands develop, the results can thus devastate a crop. Nonuniformity occurs for a variety of reasons, including poor seed quality, planting equipment issues, poor soil conditions, and crop injury due to weather and pests. But seed and soil quality are central to achieving healthy stand establishment.

Seed and Soil Issues

Seed Quality

Seed quality (e.g., trueness to variety, germination percentage, purity, vigor, and appearance) is crucial because it defines the potential performance of a seed lot. High-quality seed lots in Idaho thus must meet the minimum standards specified by the Idaho Crop Improvement Association (ICIA) (www.idahocrop.com). Appointed by the regents of the University of Idaho as their agent, the ICIA has been the designated seed-certifying agency in the state for over sixty years.

Seed Viability

Seed viability is a related concept that affects stand establishment. The potential of a seed to germinate, a seed's viability is not necessarily revealed by its appearance. Although viable and nonviable seeds may be virtually identical visually, the latter won't germinate no matter how ideal the conditions are. *Germination* (the emergence and development from the seed of essential structures that produce a normal plant under advantageous conditions) as well is a more complex concept than it may seem at first glance, for it involves more than the protrusion of the root and shoot from a seed. All seedling structures must be present and healthy. *Field emergence*, the elongation of the seedling axis that results in the protrusion of the seedling shoot from the soil, indicates that successful arrival. Favorable seed-moisture levels, proper seed-to-soil contact, beneficial soil temperature and moisture, and adequate oxygen supply to the seed are the prelude to healthy seed germination.

Soil Condition and Seedbed Preparation

Soil condition and seedbed preparation are also important for stand establishment. The best seedbed is weed free and uniformly firm with adequate moisture near its soil surface. Common plant stand problems related to poor soil and seedbed preparation include surface crusting, random soil clods, variable seed furrow closure, soil texture differences, inadequate/variable soil moisture, soil compaction around the seed, variable surface residue, volunteer plants, and weeds. Insect and disease damage are significant indicators as well, possibly leading to poor plant vigor or death prior to or after emergence.

Additional Soil Concepts

Five other soil-related concepts help to improve crop performance across the field:

Soil Variability

A smooth, firm seedbed encourages uniform seed placement at an appropriate depth. Uniform planting depth, in turn, improves the odds for a uniform emergence pattern to develop.

Soil Texture

Affects soil's capacity to retain water and is an important consideration in regards to soil compaction: compared to fine-textured soils, coarse-textured soils have a lower water-holding capacity and a higher risk of drainage beyond the root zone.

Soil Moisture

A major factor that determines the initiation of seed germination. For cereal crops, for example, soil moisture of 1.2x the wilting point is adequate for the onset and successful completion of germination. In general, approximately seven days after planting, seed germination is complete and seedling emergence occurs. The germination may be stalled if the soil moisture drops below 1.2x the wilting point mark within four days after the initiation of germination. Damage to the germinating seeds takes place if the drying-out period is greater than four days. Continuous dry conditions persisting for six or more days often result in irreversible seed deterioration.

Soil Temperature

Affects the germination and growth of all crops. Soil temperature first depends on solar radiation reaching the soil surface, and then a soil's thermal conductivity and heat capacity. Temperature also varies with the time of day and depth in the soil profile. Complicating all of this even further, soil temperature planting guidelines are crop-specific. For example, 68°F is the optimum temperature for the emergence of spring cereals, but their germination may be initiated at soil temperatures as low as 39°F.

Soil Fertility

Healthy, productive soil optimizes crop yield and quality. Although a seed contains the necessary nutrients for initial seedling growth and development, nutrient deficiencies and/or toxicities may affect plant stand establishment and uniformity. Appropriate soil sampling and testing methodology should be followed for each field prior to planting to ensure proper soil fertility.

Planter/Equipment-Related Issues

Planter maintenance and operation play an important role as well in uniform plant stand establishment. Proper placement of seed creates an environment where timely and consistent germination ensures the potential for maximum yield. The most common planter-related issues include variable depth of planting, double seed drops, wheel compaction, varied seed size and shape within the furrow, and variable distance between seeds.

Uniform planting remains one of the most critical steps in setting the stage for successful crop management. In corn, for example, a yield advantage of up to 20 bu/ac can be expected due to effective planter calibration. Planter maintenance and calibration is one of the most straightforward and controllable of all crop production practices affecting farm profitability; every grower should fine-tune planting equipment annually to achieve the best plant stand.

Planter Checklist

Seed placement, a consistent plant population, seedling emergence timing and rate, and seed-spacing uniformity are some of the most common characteristics growers use to assess planter performance:

- *Seed Depth*. Soil conditions vary due to location, soil type, and weather, so the seed placement must be checked for depth, spacing, and seed-to-soil contact.
- *Optimum population* is vital for maximizing crop yield potential. The uniformity of population can be checked manually and monitored using a population monitor that has been designed to keep track of the seed flow.
- The *seed openers*, *cover disc*, and *pack wheels* must be checked and adjusted as necessary. If this is not done, the depth wheels' contact with the soil may be inadequate; also, additional down-pressure may be required for the seed opener to achieve the desired planting depth. Crop-specific recommendations for seeding rates and planting time should be followed.
- *Uniformity of seed distribution* by the planter within the row is important. Very crowded plants are typically caused by planter malfunction. Gaps between plants of various sizes may be caused by planter issues and/or poor germination or survival of plants.

Will Replanting Pay Off?

Perhaps, but its success depends on many different factors. If the plant stand unevenness is mostly row-to-row, replanting will probably not greatly increase the yield. If plant emergence is delayed by less than two weeks, replanting may increase yields by about 5%, regardless of the pattern of unevenness. In general, if approximately half of the plants are three weeks behind, replanting may increase yields up to 10%. Estimated economic returns of the yield increase must be compared to replanting costs and the risk of emergence problems in the replanted stand. These estimates are general, however; replanting decisions must be made individually for each specific field by taking into account the cause of inadequate plant stand, which may include seed quality, planting procedures, herbicide application, and/or weather and soil conditions at planting and shortly thereafter.

Seed Damage at Planting

Damaging the seed at planting is frequently overlooked as a cause of poor stands. Appropriate planting equipment and procedures must be followed to minimize damage to the seed. Exceeding the recommended planting speed is one of the most common causes of seed damage at planting.

Sunlight Interception

Plants must maintain a high and stable rate of photosynthesis for optimal growth and development. Light interception is key to effective carbon assimilation by plants. Planting patterns determine the crop canopy structure and affect physiological characteristics, including light interception and radiation use efficiency. Evenly spaced plants advantageously and effectively capture and utilize the sunlight. As a rule, nonuniform plant stands produce lower yields because the smaller, late-emerging plants are not able to adequately capture sunlight. Furthermore, the yield loss from the smaller, weaker plants is not fully compensated by the larger, stronger neighboring plants.

Input use efficiency is reduced in uneven plant stands due to the difficulty of matching costly fertilizers and irrigation water needs. For example, late-emerging plants compete for nutrients and water but produce little to no yield. Uniform plant stands and emergence result in decreased plant-to-plant variation, which leads to superior yields.

Crop-Specific Considerations

Corn

Idaho growers planted 360,000 ac of corn in 2018, resulting in the production of 6,600,000 FT of corn silage and 28,755,000 bu of corn grain, a 15% increase over 2017 (USDA National Agricultural Statistics Service [NASS], 2018, 2019).

The number of ears per acre, the number of kernels per ear, and the weight of each kernel determine corn yield potential. The interaction between factors such as corn genetics, weather conditions, soil types, pest pressure, and available nutrients at specific times in the growing season can affect corn yield potential. Establishing a good, uniform stand is the first step in optimizing yield potential in order to help maximize the number of ears per acre.

Variability in corn stands is well documented. Modern corn planters are marketed as having the capability to singulate individual kernels from the seed hopper and deliver them to the seed furrow uniformly. The actual spacing between corn plants within rows is often nonuniform. A 2001 study of over 350 commercial corn fields in the Midwest calculated the standard deviation (a statistical measure used to quantify the amount of variation within a set of data values) of corn plant spacing as 3 in or less in only 16% of the fields (Nielsen 2001). In 60% of sampled fields, they noted the standard deviations of plant spacing as between 4 and 5 in. Notably, plant spacing standard deviation in a quarter of the fields ranged from 6 to 12 in. The study showed that a yield loss of at least 2.5 bu/ac can be expected for every single inch increase in the standard deviation in plant-to-plant spacing. With the average observed standard deviation of plant spacing of 7 in, the estimated corn grain yield loss came to almost 20 bu/acre.

Corn seeds must be spaced as evenly as possible within the row to ensure optimal crop performance regardless of seeding rate and planting date. Although corn plants next to a gap within the row may produce larger ears (or additional ears), this slight yield increase does not compensate for the yield loss due to missing plants. However, crowding often causes stalk-lodging and ear-disease problems and, more importantly, typically results in barren corn plants or unharvestable, small-sized ears.

Late-emerging/smaller plants are at a competitive disadvantage with larger plants in the stand and will have reduced leaf area, biomass, and yield (Figures 1 and 2). Potential yield losses of up to 20% can be expected if 25% of the plants are 2 or more leaf stages behind. The loss in yield potential from uneven stand establishment in corn begins the day the field is planted. In the words of Randy Dowdy, a Georgia farmer and 2014 world corn-yield record holder: "When you see a plant come up 24 hours later than the others, you now have a weed with 25% less grain on it" (Miller 2015). A 3% yield reduction may not be enough to rationalize replanting the field but it is enough to justify efforts to minimize in-field variability in corn plant emergence when it could affect output to this extent.

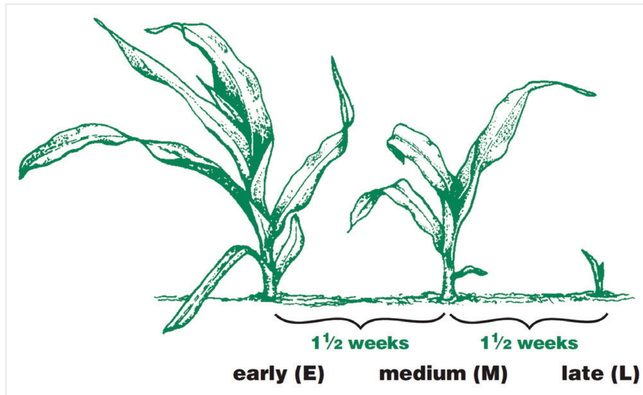

Figure 1. Effect of delayed emergence on corn plant height. Source: Carter et al. 2002.

Figure 2. Effect of delayed emergence in corn-on-the-cob development and grain production. Source: Balderson and Thomason 2016.

Dry Beans

Idaho ranked the sixth in the nation in dry bean production in 2017, representing approximately 10% of all beans grown in the United States (USDA NASS 2017). Idaho is a leading U.S. producer of garbanzo, small red, pink, and pinto beans as well as certified dry bean seed. Dry beans ranked fourth in value in Idaho in 2018 (US Dry Bean Council 2017).

In bean production, uniform maturity of the pods is extremely important. Timely harvest is vital for minimizing yield losses due to mold or pod shattering (Figure 3). The objective is to harvest bean plants as soon as the bean seeds have dried down to a moisture content of 15%–18%, levels acceptable to bean processors. Uniform planting is key to establishing an even stand. Uneven planting of beans results in uneven plant emergence, delayed maturity, and delayed harvest.

Planter speeds of 3 mi/hr have been shown to result in minimum bean seed cracking, maximum uniformity of bean plant spacing, and the highest uniform emergence of bean seedlings. Bean seeds are very fragile; cracked seeds do not germinate, resulting in decreased plant population. Precision planters have been shown to provide the most uniform seed drop per foot of row, while minimizing the amount of seed required.

Figure 3. Bean pods shattering and dropping seed prior to harvest. Source: Brouwer et al. 2015.

Sugar Beets

Sugar beets represent a key raw material for sugar manufactured in Idaho; one of eleven sugar beet–producing states, the state ranks second in sugar beet production. Idaho farmers plant them on about 170,000 ac annually, with a typical sugar beet yield across the state of about 35 FT/ac (Walsh et al. 2019).

Uniform plant stand establishment sets the foundation for optimizing sugar beet yield. According to Steve Poindexter, sugar beet Extension specialist, Michigan State University, “Growers who aren’t able to establish a good stand in their sugar beet crop end up fighting a season-long battle that’s nearly impossible to win” (Thayer 2013). For western Idaho, the typical target plant stands of 95 beets/100 ft of row or higher are recommended for optimal sugar beet yields and estimated recoverable sugar per acre (The Amalgamated Sugar Company 2014). Adequate populations of uniformly spaced sugar beets will produce optimum root weight and sucrose yields.

Variety selection is important and can impact sugar beet emergence by up to 20% (Poindexter et al. 2014). Seedbed preparation is also important; firm seedbeds tend to provide the best seed-to-soil contact and encourage sugar beet emergence.

Stand uniformity is also important for quality. A nonuniform stand of sugar beets can reduce sucrose content by as much as 3% (Poindexter et al. 2014). When the stands are uneven and too thin, the sugar beets tend to compensate and grow larger due to increased in-row spacing. Larger beets tend to have lower sugar content. However, sugar beets less than 1.5 lb in weight cause substantial issues during harvest (Figure 4).

Uniformity is important for defoliation. Uniformly spaced plants enable operators to easily adjust the defoliator and remove all petioles effectively. Nonuniform plant spacing results in a much slower defoliator operation and may cause incomplete defoliation and a lower price per ton, thus reducing revenue. Studies have shown that poorly defoliated sugar beets have lower Clear Juice Purity and poor storability.

Figure 4. Delayed emergence and within-row plant skips in sugar beets. Photo credits: Olga Walsh.

Small Grains

Wheat and barley are typically produced on upwards of 1.5 million ac in Idaho (with wheat acreage nearly triple that of barley). Idaho wheat production represents all major classes and growing seasons, while barley production primarily involves malting quality, which require tight quality specifications to maximize profit and ensure acceptance. Both barley and wheat have similar production practices that ensure stand uniformity.

Wheat and barley growers are increasingly mindful of the fact that the grain they harvest is not a uniform product—they produce a raw material that will be processed into a variety of foods and industrial goods. Furthermore, wheat and barley growers produce a variety of specific types of products, each with its own specific (and often very different) quality standards, such as low- or high-protein-level requirements. To satisfy various end-product requirements, growers have adopted an attitude that quality is the number one priority (Robertson et al. 2004).

Seedbed conditions that encourage rapid germination and uniform emergence are required for cereals. Good seed-to-soil contact promotes rapid seed germination and enables uniform, rapid seedling emergence. Overworking a seedbed results in loss of soil moisture and often causes soil crusting. The soil needs to be worked just enough to create a moderately fine but firm seedbed. If the soil is worked too deeply, substantial moisture loss will inhibit cereal seed emergence (Figure 5).

Optimum seeding dates ensure successful germination, development of strong plants, and establishment of vigorous root systems. Recommended seeding dates should be followed; planting cereals too early or too late often has adverse consequences. For example, delaying winter wheat planting by 30 days (from recommended mid-September to mid-October) reduces grain yield by 20% (Robertson et al. 2004).

Approriate seeding depth is key to cereals emergence. Best germination and emergence of wheat and barley occur at seeding depths of 1–1.5 in. If soil moisture allows, seeding at a lesser depth can be successful if good seed-to-soil contact is ensured.

Precision-planted cereal crops (soil coverage is uniform for all seed) typically have a more uniform emergence, and are easier to manage, resulting in a higher grain yield. Seeding depth in barley is particularly important, as deeper planting can decrease the stand uniformity and potentially lead to decreased plant vigor.

Figure 5. Contrasting winter wheat emergence under conditions of limited precipitation and inadequate soil moisture. Source: Romulo Lollato 2016.

No-till wheat and barley producers often plant deeply in order to reach adequate moisture. The planting depth also depends on the soil texture; sandier soils tend to dry out faster compared to soils with higher clay content.

Seed treatments can improve stand uniformity and protect the crop from pests, particularly under cold/wet conditions (Rogers et al. 2015). Seed treatments should be considered in fields with a history of root diseases or where wireworm presence has been an issue.

Potatoes

Idaho is first in the nation in potato production, representing approximately 33% of all potatoes grown in the United States (Shahbandeh 2019). Potatoes are produced for seed, fresh and processing markets, and storage (often for up to eleven months).

The uniformity of plant stand affects the cost of seed, plant growth and development, and yield and quality in potato production (Pavek and Thornton 2005). Within-row plant spacing plays a critical role in optimizing potato yield and quality (Seyedbagheri 2015). Optimal within-row spacing for potatoes range from 6 to 15 in, depending on the region, targeted market, and variety grown. Although a loss in yield may not be detectable due to compensation from potato plants surrounding missing or unevenly spaced neighboring plants, yield alone does not determine the economic value of a potato crop (Boydas and Uygan 2012). Production goals necessitate optimizing potato tuber size to maximize crop value. Tuber size distribution is an important determinant of potato crop price. Indeed, different tuber sizes are associated with different price incentives. Therefore, uneven plant spacing can change the tuber-size profile and reduce the economic return for potato growers (Figure 6).

A Pacific Northwest (PNW) potato study indicated that a 10% deviation from the optimum (most profitable) plant population can reduce grower returns by between 2% and 12% (Rupp and Thornton 1992). Based on growers' data from southern Idaho, potato planter efficiency increased from 32% (in 1988) to as high as 98% (in 2006) (Seyedbagheri 2015). Bussan et al. (2007) surveyed commercial potato fields in Wisconsin and found that irregularly spaced plants were very common. Plant spacing deviated approximately 25% from the intended spacing mean, with a range of 7%–43%. On average, 6% of the grower-intended stand was missing because of planter skips. More than 20% of the fields had at least 1,730 planter skips/ac where three or more consecutive plants were missing. The most common causes of missing plants were mechanical failure of planters associated with excessive planting speed, nonuniform seed-piece size, poor planter maintenance, low seed-bowl levels, and, to a lesser extent, seed-related problems that led to decay prior to emergence.

Potato seed-piece profiles must be monitored to obtain the desired average seed-piece size. To obtain uniform plant populations, potato growers are encouraged to plant certified seed that is effectively sorted by size prior to cutting. Adjusting the cutting mechanisms, discarding undersized seed pieces, and hand trimming oversized seed pieces can greatly improve planter performance.

Figure 6. Poor plant stand in a potato field. Photo credit: Michael Thornton.

Onions

Idaho is a major producer of winter storage onions (Idaho State Department of Agriculture 2018). Most of the acreage contains yellow Sweet Spanish onion varieties, but red and white onions are also grown in the state.

Plant population is an important factor for onion yield and bulb size, both of which affect the economic return to producers. Different marketing opportunities dictate the required target onion plant populations. Studies in the PNW showed that nonuniform emergence often results in the actual plant populations being lower than planned (Shock et al. 2015).

Onions can be grown on a wide range of soil types but prefer fertile, well-drained, noncrusting soils with good moisture retention (Welbaum 2005). Onion seed is expensive and small in size with demanding requirements for successful plant stand establishment in terms of environment and management. The shallow planted seeds require a fine-tilled seedbed free of crop residue and soil clods to emerge successfully (Yorgey and McGuire 2018). Onion seeds can germinate at relatively low soil temperatures—soil temperatures above 34°F encourage onion seed germination. Seed germination is most effective and even at soil temperatures above 52°F (Sullivan et. al. 2001).

Cultural practices and field management are extremely important for onions (Figures 7 and 8). For example, too much space around an onion plant often results in thick necks, while crowding of onion plants results in small bulb size. After seeding, the soil should be kept moist to enhance germination and successful and uniform early seedling development. Indequate soil moisture has been shown to reduce seedling emergence (Finch-Savage and Phelps 1993).

Figure 7. Poor stand establishment in onions. Photo credit: Michael Thornton.

Figure 8. Small onion size on the right due to crowding. At left, onion with thicker neck due to too much room. Photo credit: Michael Thornton.

Some other key considerations for establishing and maintaining good plant stands of onions include effective weed and pest control. The initial growth rate of onions is slower compared to other plants mainly due to slower leaf area development. This makes weed control extremely important in onions, particularly early in the growing season, to ensure their competiveness. Most herbicides labeled for postemergence application are selective due to the waxy coating on onion leaves. Cloudy, cool conditions can lead to poor wax development, resulting in onion injury and even stand loss.

Major pests affecting stands in onion plantings include seed corn and onion maggot, bulb mites, wireworms, and nematodes. In some cases, seed treatment, in-furrow, or drip-applied insecticides can be used to reduce damage from these pests.

Alternative Crops (Quinoa, Canola, Cover Crops)

Uniform emergence and plant development are also crucial components to successfully growing alternative crops. For some, like fall-planted cover crops, the growing season is short, which presents unique challenges. For example, cover crops that are susceptible to frost injury (e.g., turnip, radish, mustard, peas, etc.) cannot produce a large amount of biomass. Irrigation, if available, can improve uniform emergence if precipitation is low after seeding them.

Invasive flora and fauna create complications as well. Poor and nonuniform cover crop stands are not as effective in suppressing pests and weeds; they're also not as beneficial in improving soil health due to low quantity and quality of plant biomass available for incorporation into the soil. This is highly problematic because many alternative crops are new to Idaho; consequently, information regarding weed competition and effective herbicides may not be available yet. For instance, quinoa grows slowly after emergence and is unable to compete well with established and emerging weeds (Figure 9). In addition, no herbicides are registered for use in Idaho on this minor crop. Weeds with rapid growth and canopy development (e.g., common lambsquarters, pigweeds, and nightshades) have freer rein to diminish quinoa plant stands, thus threatening to cause severe yield losses by the end of the season. Flax has a short plant stature and cannot compete well with weeds either.

Decision-making should thus incorporate environmental requirements (e.g., temperatures, precipitation, weed populations, and species compositon, etc.) and compulsory management practices (e.g., irrigation, cultivation, etc.) as well as consider the availability of effective herbicides.

Figure 9. Poor quinoa stand due to weed pressure (left); a good quinoa stand (right). Photo credits: Xi Liang.

Summary

Uniform stand is important for all aspects of crop production, from efficient use of agricultural inputs to in-season field management, and, of course, for optimizing yield and quality. Seed quality, seedbed preparation, and equipment maintenance are very important components of uniform stand establishment. Although total uniformity can never be achieved, due to the many agronomic and environmental variations present in every field, growers should always strive to create as uniform a stand as possible to ensure the best starting conditions for crop production.

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ALWAYS read and follow the instructions printed on the pesticide label. The pesticide recommendations in this UI publication do not substitute for instructions on the label. Pesticide laws and labels change frequently and may have changed since this publication was written. Some pesticides may have been withdrawn or had certain uses prohibited. Use pesticides with care. Do not use a pesticide unless the specific plant, animal, or other application site is specifically listed on the label. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

Trade Names—To simplify information, trade names have been used. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

Groundwater—To protect groundwater, when there is a choice of pesticides, the applicator should use the product least likely to leach.

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