Seeding Rates for Vegetable Crops

By Darbie M. Granberry, Terry Kelley and George Boyhan
Extension Horticulturists

One of a grower's first decisions in the production of a vegetable crop is the number of acres to be planted. Soon after, the question is "How many pounds of seed will I need?" Without more information, the most appropriate response is, "Well, that depends." Because, in truth, it does depend on a number of factors.

Factors to Consider

How many pounds (ounces, grams) of seed should be planted on each acre? That depends on (1) the desired number of plants per acre (plant population), which depends on the spatial arrangement (within-row and between-row spacing) of the plants, (2) the number of seed per pound, (3) the percent germination and (4) planting precision.

Number of Plants per Acre

Determining the desired number of plants per acre is the first step in estimating the quantity of seed needed per acre. Genetics and environment interact to determine the effect of various plant populations on growth and yield of crops.

For specific vegetables, broad but reasonable population ranges can be obtained from general crop production information and experience. However, management on a higher and more competitive level seeks to identify the optimum plant population for a specific vegetable crop during a given growing season.

You should consider (1) spatial arrangement, (2) cultural practices, (3) harvesting method (hand vs. mechanical harvesting), (4) specific variety to be planted, (5) relative size desired for harvested product, (6) suitability of the growing season for that population, and (7) foliar disease and insect considerations. For examples of plant populations at selected in-row and between-row spacings, see Table 1 on page 5.

Spatial Arrangement. Vegetable crops require adequate sunlight if they are to produce acceptable yields and develop optimum levels of pigments, flavors and aromas that are essential in achieving desired market qualities. Therefore, an appropriate spatial arrangement produces high yields of good quality produce.

Spatial arrangement (within-row and between-row spacing) and plant population are closely related. Different growers often plant the same number of plants per acre but use different spatial arrangements to accommodate their specific equipment. The best plant spacing design positions (arranges) plants for the best possible yields of high quality produce. In theory, plants of a given vegetable variety require a certain "optimum" amount of water, nutrients, sunlight and space under a given set of growing conditions. An ideal spatial arrangement should allot plants equal portions of these growth enhancing factors by uniformly placing plants equidistant from each other. In practice, this rarely occurs. Equidistant spacing is usually compromised to accommodate tractors, machinery and, in many cases, people.

Within limits, plants tend to fill in, adapt and yield satisfactorily at uniform spacings that are not necessarily equidistant. Within the restrictions imposed by practical limitations, spatial arrangements should equalize allocated space as much as possible. For example, assume a grower has determined that 1,200 plants per acre is the optimum population for his or her water-melon crop. If that grower has the option of either a 4' x 9' spacing or a 6' x 6' spacing, the latter would be preferred because it tends to equalize allotted area.

Although plants do not necessarily have to be equidistant, they should be *uniformly* spaced to facilitate uniform growth and the development of uniformly-sized harvestable product.

CULTURAL PRACTICES. Within reason, most vegetable crops tend to use available resources. However, as a general rule, higher plant populations need more water, nutrients and sunlight for optimum production of quality produce. Plant higher populations only if the crop is to be irrigated, fertilized and maintained to adequately provide for the increased number of plants. As the population is increased, fruit size tends to decrease (see **DESIRED SIZE OF HARVESTED PLANT PART**).

HARVESTING METHOD. Plant populations should accommodate harvesting procedures. Crops can be harvested once or many times; they can be harvested by hand, by machine or by a harvesting aid such as a "mule train." For multiple hand harvests, allow sufficient space for workers to gather harvest-ready produce without damaging plants and jeopardizing future harvests. If the crop is to be harvested by machine or harvesting aid, the plant population should be compatible with the capacity and physical requirements of the harvester.

VARIETY. Plant vigor, a genetically governed trait, is expressed to varying degrees in most vegetable crops. Under similar growing conditions, highly vigorous vegetable varieties (cultivars) will grow faster and become larger than less vigorous ones. Larger plants need more space than smaller plants. As a general rule, varieties that produce larger plants should not be seeded at the higher populations suitable for smaller plants. Sometimes, high populations of vigorous varieties are planted to prevent the harvestable plant part (head of cabbage, ear of corn, etc.) from reaching its maximum size.

DESIRED SIZE OF HARVESTED PLANT PART. Identical varieties can produce larger or smaller sized produce (heads, fruits, roots, tubers or leaves) depending on the number of plants per acre. In fact, increasing the plant population is a cultural practice routinely used to help decrease the size of many vegetables including watermelon, cantaloupe, cabbage, broccoli and sweet corn. Good markets exist for extra large "Jubilee" watermelons; other markets prefer medium-sized "Jubilee" melons. This same analogy holds for a number of other vegetable crops. Manage all aspects of production, including plant population, to produce the size and quality your primary market desires.

SUITABILITY OF THE GROWING SEASON. Many producers grow the same vegetable variety for more than one production window (early spring, spring, late spring, summer or fall) in the same year. Most vegetables respond to a more favorable growing environment (especially warmer, growth-enhancing temperatures and increased sunlight) by growing more vigorously.

During growth-limiting production seasons (especially early spring and early fall), yields can often be increased by increasing the population. In late spring and summer, when growing conditions favor increased plant growth, plant populations may be reduced to accommodate additional growth.

FOLIAR DISEASE AND INSECT CONSIDERATIONS. High humidity, moisture and reduced air movement encourage the incidence and severity of many foliar diseases (excluding soil-borne diseases). Overlapped and intermeshed plant canopies reduce effective coverage of foliarly applied pesticides. In addition, some vegetables risk developing foliar diseases that cannot be satisfactorily controlled by currently available chemical and biological control measures.

Insect populations may thrive and cause increased damage when protected from chemical control agents and from natural predators by a dense canopy. Especially in these situations, high plant populations may provide an environment that predisposes certain vegetable crops to insect and disease damage.

Number of Seed per Pound

The number of seeds needed to weigh a pound, commonly referred to as "seed count," depends on the weight of individual seeds. The weight of an individual seed for a given species (assuming uniform moisture content) is determined by seed size and specific gravity of the seed. Larger seed are usually heavier, so normally it takes fewer of them to weigh a pound.

Growing conditions can affect seed size. However, within a given vegetable crop, heritable traits (genotypes) cause most of the variation in seed size and, subsequently, in the number of seed per pound. In some crops, including Lima bean, green bean, pole bean, cantaloupe (muskmelon), southern pea, English pea, pumpkin, squash and watermelon, plant genotypes result in moderate to large variations in seed sizes. For example, 5,000 seed of a large-seeded watermelon variety may weigh one pound, but it would take 10,000 seed of a small-seeded variety to weight a pound. Seeding rates are further complicated because, within a given variety, seed sizes usually range progressively from smaller to larger seed.

Variation in seed size can have a two-fold effect on recommended seeding rates. To illustrate: Assume a grower is precision seeding a 10-acre watermelon field on 8-foot centers with plants 6 feet apart in the row. Approximately one pound of seed would be recommended for a small-seeded variety (10,000 seed count). However, for a large-seeded variety (5,000 seed count), two pounds of seed would be required for planting the same population.

Percent Germination

In addition to the number of seed per pound, growers should also consider "percent germination" (proportion of the seed that will germinate) when determining the pounds of seed needed per acre. Because of certain hereditary and/or seed quality factors, only a portion of the seed (usually from 70% to 90%) in a given lot will germinate. Percent germination is determined by subjecting samples of specific seed lots to conditions conducive to germination. The percent germination calculated from this test should be shown on the seed label. Always check this label to confirm the percent of seed expected to germinate. If there is any doubt about the percent germination, a germination test should be done before planting the seed. Contact your local county extension office if you need instructions for conducting a germination test.

When determining seeding rates, growers compensate for less than 100 percent germination by including "extra seed." Calculate the appropriate amount of seed (including extra seed) by dividing percent germination into the desired number of plants per acre. For example, for 70 percent germination bean seed and a desired population of 87,120 plants per acre, a grower should actually plant 124,457 seed per acre (87,120 divided by .70 = 124,457). This additional seed can significantly increase the amount of seed a grower needs to plant to obtain the desired population. Assume (using the example above) a grower is planting 50 acres of beans (1,600 seed/lb). Based on seed count alone, the grower would need 2,722 pounds of seed. However, taking percent germination into consideration, the grower would actually need to plant 3,889 pounds of seed.

Planting Precision

The precision with which seed is planted significantly influences the amount of seed required to plant a given acreage. Precision seeding involves placement of seed relative to each other in both a horizontal and vertical plane. The horizontal plane involves the placement of seed relative to other seed and relates to within-the-row and between-the-row seed spacing. The vertical plane involves placement of seed relative to the soil surface and relates to planting depth.

Ideally, precision seeding uniformly places single seed precisely where they are desired in each of the two planes. In any other planting arrangement, planters are generally set to put out additional seed, so at least some of the seed will be placed at predetermined critical intervals. With the non-uniform and somewhat random placement characteristics of many conventional (non-precision) planters, seed are often heavily oversown and then thinned after emergence. This practice can double or even triple the amount of seed needed for a given acreage. In general, with increased precision of seeding, fewer seed are required. At the highest degree of precision planting, the seeding rate closely approaches the desired number of plants per acre (assuming 100% germination).

Emergence and Crop Establishment

The number of seed per pound, percent germination, and seeding precision influence percent emergence and crop establishment. Seed holding/storage after receiving the seed, and handling and planting procedures can also significantly affect seed quality and the number of seed necessary for a good stand. For optimum plant emergence and the establishment of a strong, viable stand, properly prepared seedbeds and adequate soil moisture are absolutely essential.

HOLDING/STORAGE. If planting is imminent and seed are to be held for a short period of time before planting, make sure they are kept cool and dry. If seed are purchased early for later planting, contact your county extension office for long-term storage recommendations for specific vegetables.

HANDLING PROCEDURES. Seed are fragile and are, therefore, subject to physical damage if handled roughly. When loading, transporting and unloading seed, be careful so they are not cracked or bruised.

PLANTING. When planting seed, make sure the planters are properly set and operating correctly. Malfunctioning planters can cause extensive seed damage and reduce stands dramatically.

SEEDBED PREPARATION. The seedbed should be free of clods and debris and be firm but not so hard or compacted that it restricts emergence. Seedbed soil should allow the rapid, unhindered growth of new, emerging roots. The soil should be sufficiently pulverized so air pockets do not form around seed and interfere with water imbibition and subsequent seed germination and root growth. If the soil dries and becomes crusted, light irrigation or timely cultivation with a rotary hoe or similar implement may be necessary.

SOIL MOISTURE. Adequate moisture in the seedbed during germination and stand establishment is crucial. There needs to be sufficient moisture so seeds can imbibe water needed for germination. However, there should not be so much water in the soil that lack of oxygen becomes a problem.

Under conditions of excessive water and insufficient oxygen, seeds rot, seedlings dampen-off excessively, and any plants that manage to survive are usually stunted and weak.

Using Seeding Rates and Plant Spacing Tables

Seeding Rate Tables (Table 2) provide information on number of seed per pound, seeding rates and plant spacings. However, these tables do not necessarily indicate optimum seeding rates for ***your*** specific situation. Seeding rates are management decisions that require thorough planning, careful consideration of available resources, and the acceptance of perceived risk factors consistent with production objectives.

In order for seeding rate tables to be applicable to a broad spectrum of production situations, they often lack the degree of specificity growers would like to see. Seeding rate tables are necessarily generalized for two reasons: (1) These tables provide information pertaining to plants that exhibit significant variation both among and within given populations. The ranges in seed counts for Lima bean, pumpkin, squash and watermelon are vivid examples of this inherent variability. (2) Seeding rate tables encompass a range of possibilities so they can used by many growers with different needs, objectives and resources.

To effectively determine seed needs and seeding rates, think about the factors discussed in the preceding section, *Factors to Consider*. However, seeding rate tables can provide concise, pertinent information to facilitate the process of determining the most appropriate seeding rates and plant spacings.

Table 1. Plant Population* per Acre

INCHES IN THE ROW	INCHES BETWEEN ROWS								
	8	**12**	**26**	**30**	**36**	**38**	**40**	**42**	**60**
1	784,080	522,720	241,255	209,088	174,240	165,069	156,816	149,349	104,544
2	392,040	261,360	120,628	104,544	87,120	82,535	78,408	74,674	52,272
3	261,360	174,240	80,418	69,696	58,080	55,023	52,272	49,783	34,848
4	196,020	130,680	60,314	52,272	43,560	41,267	39,204	37,337	26,136
5	156,816	104,544	48,251	41,818	34,848	33,014	31,363	29,870	20,909
6	130,680	87,120	40,209	34,848	29,040	27,512	26,136	24,891	17,424
8	98,010	65,340	30,157	26,136	21,780	20,634	19,602	18,669	13,068
10	78,408	52,272	24,126	20,909	17,424	16,507	15,682	14,935	10,454
12	65,340	43,560	20,105	17,424	14,520	13,756	13,068	12,446	8712
14	56,006	37,337	17,233	14,935	12,446	11,791	11,201	10,668	7467
16	49,005	32,670	15,078	13,068	10,890	10,317	9801	9334	6534
18	43,560	29,040	13,403	11,616	9680	9171	8712	8297	5808
20	39,204	26,136	12,063	10,454	8712	8253	7841	7467	5227
22	35,640	23,760	10,966	9504	7920	7503	7128	6789	4752
24	32,670	21,780	10,052	8712	7260	6878	6534	6223	4356
26	30,157	20,105	9279	8042	6702	6349	6031	5744	4021
28	28,003	18,669	8616	7467	6223	5895	5601	5334	3734
30	26,136	17,424	8042	6970	5808	5502	5227	4978	3485
40	19,602	13,068	6031	5227	4356	4127	3920	3734	2614
50	15,682	10,454	4825	4182	3485	3301	3136	2987	2091
60	13,068	8712	4020	3485	2904	2751	2614	2489	1742
70	11,201	7467	3447	2987	2489	2358	2240	2134	1493

* Populations are rounded off to whole numbers. Percent germination is *not* considered in this table.

Table 2. Seed per Pound, Seeding Rates and Plant Spacings

Vegetable	No.	Lbs/A[1]	Within[2]	Between[2]	Example	Seed/A[3]
bean, green	1600-2000	60-100	2"-4"	30"-36"	2" x 36"	87,120
bean, Lima	400-1200	50-100	3"-4"	30"-36"	4" x 36"	43,560
baby Lima	1600-1800	65-100	3"-4"	30"-36"	4" x 36"	43,560
bean, pole	1600-2000	50-90	6"-9"	36"-48"	6" x 48"	21,780
pole, Lima	400-1200	30-40	6"-9"	36"-48"	9" x 48"	14,520
broccoli	140,000-144,000	TP*	10"-16"	30"-36"	12" x 36"	14,520
cabbage	142,000-145,000	0.15-1.0	9"-16"	30"-36"	10" x 36"	17,424
cantaloupe	18,000-21,000	0.5-2.0	24"-36"	48"-72"	24" x 48"	5,445
collard	128,000-144,000	0.15-1.0	10"-24"	32"-40"	12" x 36"	14,520
carrot	368,000-390,000	1-2	1"-3"	16"-20"	3" x 18"	116,160
sweet corn	2200-2900	10-15	8"-12"	30"-36"	10" x 36"	17,424
supersweet corn	3400-4200	6-8	8"-12"	30"-36"	8" x 36"	21,780
cucumber	16,000-17,600	1-3	6"-12"	36"-72"	6" x 48"	21,780
eggplant	100,000-104,000	TP	18"-30"	36"-48"	24" x 48"	5,445
kale	128,000-144,000	0.15-1.0	10"-18"	18"-36"	10" x 36"	17,424
mustard	240,000-280,000	0.5-2.0	4"-10"	12"-36"	6" x 36"	29,040
okra	7000-8000	6-8	12"-18"	36"-48"	12" x 36"	14,520
onion, bulb	120,000-144,000	1-3	4"-6"	10"-18"	4" x 12"	130,680
onion, green	120,000-200,000	5-15	1"-3"	10"-18"	2" x 12"	261,360
pea, English	1400-2100	80-120	2"-4"	24"-36"	2" x 36"	87,120
pea, southern	3000-4000	20-50	3"-4"	30"-38"	4" x 36"	43,560
pepper, bell	73,000	TP	12"-18"	32"-36"	12" x 36"	14,520
pepper, hot	73,000	TP	16"-24"	36"-42"	18" x 36"	9,680
pumpkin	1600-4000	1-3	18"-60"	72"-96"	60" x 72"	1,452
squash, bush	4000-5000	2-4	12"-24"	36"-48"	18" x 36"	9,680
squash, vine	2000-4000	1-3	24"-48"	48"-96"	24" x 36"	7,260
tomato	120,000-190,000	TP	18"-30"	60"-72"	24" x 72"	3,630
turnip	190,000-240,000	0.50-2.0	2"-6"	12"-36"	4" x 32"	49,005
watermelon	4800-9900	0.25-2.0	24"-73"	48"-96"	72" x 96"	908

[1] Range in pounds of seed commonly planted per acre. Lbs/A does not apply to transplanted vegetable crops.
[2] Range of within-the-row and between-the-row spacings (inches).
[3] Number of seed per acre at the spacings in the example. Seed/A assumes 100 percent germination.
* TP = Transplanted

Note: Percent germination is *not* considered in this table. Lbs/A may not agree with Seed/A divided by No. Seed/Lb since Seed/A does not account for percent germination and variability in seed size. Also, the Actual Lbs/A required will depend on spacing, precision of planting, and percent germination.

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