The following is an excerpt from a seed saving, cleaning, and production overview put together as part of the Public Seed Initiative in 2002. Although the Public Seed Initiative is over, much of its work was continued under the banner of the Organic Seed Partnership (OSP) and organic breeding and outreach continues as part of the Northern Organic Variety Improvement Collaborative (NOVIC).

There is a resource list at the end. Addditional resources of note that been published more recently are:

Breeding Organic Vegetables: A Step-by-Step Guide for Growers by Rowen White and Bryan Connolly (available from NOFA-NY)
Available spiral bound from Amazon or as a free download http://www.nofany.org/sites/default/files/BreedingOrganicVegetables-2011.pdf

Organic Seed Production and Saving: The Wisdom of Plant Heritage
By Bryan Connolly
Available from http://www.chelseagreen.com

The Public Seed Initiative (PSI) is a joint project of the Cornell University Department of Plant Breeding, Farmer Cooperative Genome Project- Oregon Tilth, Northeast Organic Farming Organization of New York, and the USDA-ARS Plant Genetic Resources Unit- Geneva. Funding for PSI is provided by a grant from the USDA Initiative for Future Agricultural and Food Systems Plant Genome Project.

Basic Concepts of Seed Production and Seed Regeneration

Seed Production and Regeneration: The basics for producing and harvesting seed from plant material for the purpose of distribution, storage or sale.

In contrast to plant breeding or development, the aim in seed regeneration is to maintain the variety unchanged. In order to produce seed which is true to type, one must become knowledgeable in the variety's reproductive process, as well as, the techniques used for maintaining genetic diversity and identity, seed harvesting, seed cleaning and seed storage.

Plant Reproduction 101:

Plants can be broken down into 2 main reproductive categories…Self-Pollinating and Cross-Pollinating.

- Self-Pollinating Plants ("selfers"): transfer of pollen from the male anther to the female stigma within the same flower or on the same plant.
    - These plants usually require smaller minimum population sizes (*minimum number of plants needed to ensure genetic diversity*) and shorter isolation distances (*distance needed between same species varieties to ensure no crossing*) than crossers.
    - Examples: beans, tomatoes, barley, lentil, oat, rice, soybean, wheat.
- Cross-Pollinating Plants ("crossers"): transfer pollen from the anther of one plant to the stigma of another plant. This process is usually accomplished naturally by wind and insects or can also be accomplished manually by hand-pollination.
- **POINTS TO REMEMBER:**
    - Cross-pollinating plants evolve under conditions of constant gene recombination and suffer from "inbreeding depression" (*symptoms of decreased vigor and the appearance of negative recessive genes when inbred*).
    - When breeding cross-pollinating plants one must be cautious to prevent crossing varieties of the same species. This can be accomplished through various methods of isolation.

- The Latin name (scientific name) reveals the genus and species. Plants can look different and have a different common name, but are members of the same genus and species and therefore will cross with each other.
    - Examples:
        - *Beta vulgaris*(beets and swiss chard)
        - *Brassica oleracea* (Broccoli, collards, cauliflower, cabbage, kohlrabi, kale (except Siberian kale) and brussel sprouts)
        - *Brassica rapa* (Turnips, Chinese mustards and Chinese cabbages)
- Genetic diversity must be maintained. H*igh genetic diversity ensures that all possible genes (characteristics) are being represented in the variety*.
- Examples of cross-pollinated: onion, beets, corn, cucumber, cole crops, squash, radish, celery, rye, and buckwheat.

Means of Pollination:

1. Wind: These species require the largest isolation distance (pollen can travel for miles depending on the strength of the wind and the presence or absence of barriers). Varieties that are wind pollinated should be planted in dense blocks to ensure total pollination. Wind pollinated species can either be self-pollinated (wheat or oats) or cross-pollinated (corn or beets).

2. Insects: These plants have flowers that encourage insects to travel from flower to flower. For plants that prefer insects as pollinators, it is important to find out which pollinators (flies, bees, etc.) that the plant prefers. Insect pollinated species require less isolation distance than the wind pollinated species but still require up to a mile of separation from same species varieties to ensure no crossing within species.

3. Self-pollinating species: Self-pollinated plants (for example: beans, tomatoes, and potatoes) have flowers that are evolved to self-pollinate with no assistance. Although self-pollinating species are designed to reduce/eliminate cross pollination within species, crossing can occur. For example, certain heirloom varieties of tomato have long, protruding styles which can encourage cross-pollination. If you attempt to produce seed from these varieties, you must treat them as a cross-pollinating species and isolate them from other varieties in their species.

Annual Crops: Annual crops require only one growing season to produce seed and complete their lifecycle. But because you are growing the crop for seed rather than fruit, you may have to plant the crop earlier than usual and harvest much later.

Biennial Crops: Biennial crops require 2 growing seasons to produce seed and complete their lifecycle.

- These crops generally require a period of vernalization (*exposure to cold*) in order to flower. [Tip: Before exposing the vegetable to the cold (less than 45 degrees Fahrenheit), they should be partially developed].
    - ❖ Plants that have their roots as the food part (carrots or parsnips) need to over winter in the ground.
    - ❖ Plants that we eat the leafy part (cabbage) can be dug up, transplanted into pots and over wintered in a greenhouse or root cellar, then transplanted back to the garden in the spring to flower and set seed.
    - ❖ Cabbage stems should be at least as large as a lead pencil in diameter.
    - ❖ Cauliflower accessions should be potted and placed in vernalization for 60 days.
- Average chilling temperature should be less than 45 degrees Fahrenheit and chilling should continue for at least 1 – 2 months.

Photoperiod Response: Some crops require a specific day length in order to initiate flowering.

- Short day plants require a day length shorter than a specific period.
- Long day and intermediate day plants require a day length longer than a specific period.

Open Pollinated or Hybrid:

- **Open pollinated:** Seed produced from open pollinated plants will produce stable plants and fruit that look just like the parents.
- **Hybrids:** Hybrids are seeds of parents with different qualities. They don't produce plants like themselves. Their traits separate out in the next generation or the seed will be sterile. Similar to crossing a horse and a donkey, the mule offspring is sterile.

Plant Genetics 101:

Genetic Integrity: To prevent varieties from crossing, seed producers must use some means of isolation (cages, distance isolation, time isolation, or hand pollination) during periods when pollination can occur. Genetic diversity within a variety is maintained by including a minimum number of randomly selected parents into the breeding population. This number will vary by crop species.

Ways to protect a varieties genetic integrity:

1. Properly identify and label plants.
2. Plant on clean land which has not been used to grow the same crop in the past cycle.
3. Isolate plants from cross-pollination.
4. Plant at least 200 plants for cross-pollinated crops and 50-100 plants from self-pollinated crops (this number varies dependant on who you talk to).
5. Rogue off-types.

Rogue: A rogue is a plant which is "off-type" (*different from the variety*) or is otherwise undesirable. Rogue plants should be removed as soon as possible in order to protect the genetic integrity of the variety.

- For leafy greens, look at the flower stalk. Often the thickness with be larger in respect to its vigor.

Reproductive Isolation:

1. Isolation strips: plot of a crop which separates seed plots, preventing crossing and mechanical mixtures.
    - This strip would theoretically catch windblown pollen and distracts insects from visiting the plots on either side of it.

2. Distance Isolation: Try to follow this general rule, selfers should be isolated by at least 150 feet AND an isolation strip. Wind pollinated crossers should be separated by at least 1 mile (but up to 5 miles), insect pollinated crossers should be separated by at least ¼ mile AND some other barrier (or 1 mile in open land). Once again these figures vary depending on the source of your information.

3. Caging and Artificial Barriers: Cages can be constructed with PVC and fabric row covers. Brown paper or fine meshed bags

can also be used. Non-porous bags are not recommended because they can lead to rot.

- When these methods are used it is required that either plants are hand-pollinated or pollinators must be introduced into the caged/bagged environment.
- Caged crops are normally pollinated for 4 – 6 weeks.

4. Time Isolation: You can plant different varieties of the same species in the same year as long as the times they flower do not overlap. For annuals, this could mean starting one variety early in the season and then starting another several weeks later. For biennials, you could have multiple varieties of the same species (such as onions) growing in the same place but only one that is in it's second year and going to flower.

Hand-pollinating:

Basically, you are transferring pollen from one flower to the stigma of another and then you must cover the pollinated flower to isolate it from being pollinated by a different variety.

1. The flower to be pollinated is emasculated (*stripped of anthers or male parts*).
    - This should be done BEFORE the male parts begin to release pollen (typically just before the flower opens).
2. To transfer the pollen, either…
    - Remove the entire flower and touch the anthers to the stigma.
    - Place a bag over the flower heads and shake to collect the pollen and then transfer the pollen with a feather or fine brush.
3. After pollination has occurred, the flower should be covered with a bag or taped (squash flowers and other large flowers).
4. Remove the bag or tape after approximately one week.

Minimum Population Size: This refers to the smallest number of plants that can be grown of one variety to ensure genetic integrity. To maintain vigorous, resilient plants for the range of unforeseen conditions for future generations, save seed from healthy plants with a wide variety of characteristics. If a minimum population size is not maintained, crops can suffer from inbreeding depression.

- In general,
    - 200 plants for cross-pollinated varieties.
    - 60-80 plants for self-pollinated varieties.
    - These figures often vary depending on who you talk to.

Seed Harvesting:

- Labels and Records: Label seeds and seed lots! Labels should be affixed to whatever the seed is being stored on or in during processing.
- Harvesting Methods:
    - Dry Seeds: Let the plant material completely dry either in the field or after you harvest in mesh bags or on mesh tarps (turn frequently to ensure proper drying).
        - Harvest when the seeds begin to rattle in their pods but, keep a daily check to ensure the pods don't open and you don't waste any seed.
    - Wet Seeds: Harvest entire fruit and scoop out seeds and place in container.
        - Most fruits should be allowed to slightly over-ripen (but before decay) before you harvest for seed.
        - After harvesting, store fruits in single layer in the shade for further curing. This can last for a couple days (peppers) up to 5 weeks (winter squash). During this time, the fruits are devoting all its energy to seed production. When rot begins, proceed to next step.
            - Be very careful with Hot Peppers…don't process them without gloves and don't touch your eyes
            - Watermelons don't ripen much more off the vine so you can eat the fruit and save the seeds
- Seeds should be harvested from as many plants as possible throughout the growing season to help ensure genetic integrity.

Seed Cleaning:

When seeds come out of the field, they may contain many types of particles (the desired seed, weed seed, plant material, etc.). In addition to the many different types of particles, the desired seed may have broken or other unviable seed mixed in to the lot. By removing these undesirable seeds and particles, you will improve the vigor and germination rate for your lot.

When removing the undesirable seed from your seed lot, there are many differences in the seed used to make separations.

1. **Size** (large vs. small and length, width, and thickness). The most popular way to separate particles of different sizes is by scalping (using a screen which allows the desired seed fall through the screen holes while removing the larger particles) or sifting (dropping out smaller particles by using a screen in which only the particles smaller than the seed are allowed to pass). Both of these separations can be made manually by using separating boxes or mechanically using devices like the Clipper Office Tester (see equipment section). Making length separations can be done by using an indented cylinder or disc machine.
2. **Weight** (heavy vs. light and differences in specific gravity and surface area). This separation is best done with a box fan, an air column or aspirator (see equipment section). These work by passing a stream of air past the seed allowing the light (often unviable) seed to be blown out of the seed lot. This method will also remove any light chaff that remains within the seed lot.
3. **Shape** (round vs. non-round). This separation can be done with a spiral separator (round seeds will roll faster than flat or non-round seeds).
4. **Surface Texture** (rough, smooth or pointed). A flat piece of roughed-up cardboard works well for this separation. Round seed will roll to the bottom when placed at a slight angle while flat seed will be "caught" on the roughed cardboard. Also a velvet roller works well (see equipment section).
5. **Color:** This separation is most often done by hand-picking although there are color separation devices; they are not commonly used by small-scale seed producers.

Other things to keep in mind when cleaning seed:

- Labels, Records and Mechanical Mixing: Affix labels to all seed containers and spaced far enough apart to ensure there is no mechanical mixing of seed lots.
- Cleaning Supplies: Dry seed should be free of seed pods, hulls, and stalks by being smashed in a tarp, bag or mechanical thresher (clipper mill, belt thresher, brush mill, etc.) and then screened. Screens are used to separate out material that is larger or smaller than the seed being cleaned. Wet vegetable seed cleaning supplies include buckets for fermenting, hand mashers (4 x 4 with a handle), a wet vegetable seed separator (See Seed Cleaning Equipment section) and sieves and colanders.

- Always dry seeds completely before storing!

Cleaning Dry Seed:

- Seed pods can be dried then smashed in a number of ways…stomping and smashing in a threshing box, or using a mechanical thresher is common. Once all the seeds are released from the pods, you can separate the seeds from the pods by using handscreens or a "Clipper Mill" (See Equipment section).
    - A threshing box can be built by making a 3 x 3 box (without a top) and placing a corrugated plastic mat at the bottom of it.
- Once the larger pods are removed, lighter chaff can be removed by winnowing or using an air column (See Equipment section). Finer removal of chaff can be accomplished by using a velvet roller (See Equipment section).
- When using a fan to blow chaff from the seed, make sure you lay down a contrasting colored sheet in the event of seed blowing with the chaff.
- Once all chaff has been removed, seeds should be stored in a dark, clean, dry, pest-free environment.

Wet Seed Cleaning:

- Seeds can be removed from fruit by cutting the fruit open and scooping out the seeds or by using a "Wet Vegetable Seed Separator" for tomatoes, peppers, and cucumbers. (See Equipment section).
- After seeds are removed, some species (tomatoes, for example) can benefit from a fermentation process.
    - Fermentation Process: Place seeds (covered with pulp/gel) into a container and cover seeds with an equal amount of water for approximately 2 days. You should stir this mix at least twice a day.
- Once the fermentation process is finished (there will be a pungent odor and layer of mold growing on the top of the bucket), seeds should be rinsed thoroughly. Strainers and fryer baskets come in handy during this step.
- After seeds are rinsed, they can be dipped in a 20% Clorox solution (this process protects the seed from Tobacco Mosaic Virus) and then rinsed again with clean water to protect the seeds against certain viruses.

    - The seeds only need to be dipped for enough time to ensure that all the seeds have contacted the bleach solution.
- Once seeds are treated, they should be dried completely prior to storing.

Drying Seeds:

- Drying seeds at 10 – 25 degrees Celsius (50 – 77 degrees Fahrenheit) and at 10 – 20 % relative humidity using either some type of desiccant (silica gel or activated alumina) or a dehumidified drying chamber (set at the **lowest** heat setting or no the "no heat" setting) is ideal but air drying is common as well. Desiccants should be replaced every 3 to 5 years and dehumidifiers should be carefully watched so that seeds are not damaged by the heat.
- Seeds should be dried as soon as possible after harvest to avoid fungal and viral growth.
- Drying time is variable depending on the seed and the conditions in which the seed is being dried.
- If you can push your nail into the seed, it is probably not dry enough to store!!!
- Ovens are not recommended for drying seeds since heat can damage many seeds

Seed Storage:

- Optimal storage is airtight, low humidity, and low temperature. (We store at -20 degrees Celsius, 5% moisture)
    - Except for peas and beans which like some "open air".
- Containers should ideally be moisture proof and sealable (keep in mind that most plastics are not moisture proof).
- Metal, foil-lined heat sealable envelopes are often used at seed banks.
- Cold storage in a chest type deep freezer is invaluable for extending the lifespan of seeds. Low temperatures slow the process of seed decay. But be careful, most seeds can tolerate freezing but, it may damage others. Test a small sample of seeds first before putting the whole seed lot into freezer storage.
- If you use an "above the fridge" freezer to store your seed, make sure you contain the seed extremely well so that the opening and closing of the freezer doesn't fluctuate the temperature of the seed enough to damage it.
- Leak, onion, corn and parsnip seed is short-lived, the seed will most likely only last 1 – 2 seasons.

- Always remember that **before** opening any seed container that has been in a freezer, let the container acclimate to room temperature! If you just open the container straight from the freezer, condensation will form on the interior walls of the container and you will have to dry the seed again (possibly damaging it).

Germination Testing:

- Germination testing is important to both the seed regenerator and the seed producer.
- To do your own germination test: Place 100 seed evenly on a towel, mist to keep them moist and in place, fold the towel and cover with another lightly misted towel. Check after 5 days then daily to calculate the germination rate.
- Always try to germinate a random sample of the seeds you are wanting to plant.
- For long term storage, initial germination should be at least 85% for cereals, and 75% for vegetables.
- Wild species often have lower germination rates.
- See Germination testing section of workbook for more information about the New York State Seed Testing Laboratory.

If you have any questions regarding what you have read in this workbook, please feel free to contact any project coordinator from the PSI project.

Major Self-pollinating and Cross-pollinating Crops

Major Self-pollinating Crops:

Barley	Flax	Oat	Soybean
Dry bean	Jute	Pea	Tobacco
Chickpea	Lentil	Peanut	Tomato
Eggplant	Lettuce	Potato	Triticale
Endive	Mungbean	Sesame	Wheat

Major Cross-pollinating Crops:

Alfalfa	Clovers	Redtop
Amaranth	Corn	Rye
Arugula	Cucumber	Safflower
Beet	Dill	Squash
Broccoli	Grasses	Sugar beet
Buckwheat	Melons	Sugarcane
Cabbage (cole crops)	Mustard Greens	Sunflower
Cantaloupe	Onion	Sweet clover
Carrots	Pepper	Sweet potato
Celery	Radish	Timothy
		Wild rice

Guidelines for Vegetable Seed Production

Common Name	Genus	Species	sub-spp	Pollination	Min. Iso. (feet)	Min. # Plants	Seeds per Ounce	In row spacing	B/t row spacing	Days to Germinate
Alfalfa	Medicago	sativa		Cross	400	100	13,750	1-2"	24-48"	
Amaranth	Amaranthus	spp		Cross	1500	50	37,000	Use 30" wide row		3-4
Artichoke	Cynara	cardunculus		Cross	600	50	800	3-4"	3-4'	10-14
Arugula	Eruca	sativa		Cross	1500	50	8,000	6-9"	12-15"	14
Asparagus	Asparagus	officinalis		Cross	600	50	800	12-18"	36-72"	15
Barley	Hordeum	vulgare		Self	100	NA		22 plants/ft2		
Basil	Ocimimum	basilicum		Cross	600	100	22,000	8/inch	24"	8-14
Bean, Common	Phaseolus	vulgaris		Self	300	10-50	75	8"	18-24	5-8
Bean, Fava, Broadbean	Vicia	faba		Mostly Self	300	10-25	15-50	4-5"	18-24"	6-14
Bean, Lima	Phaseolus	lunatus		Self	300	10+	60	3-8"	18-36"	6-10
Bean, Runner	Phaseolus	coccineus		both	1500	10+	75	6-12"		7-12
Beet	Beta	vulgaris	esculenta	Cross	1500	50 - 100	1200-1700	1-4"	18-36"	7-14
Borage	Borago	officinalis		Cross	1500	50		Broadcast		
Broccoli	Brassica	oleracea	botrytis	Cross	1500	100	8,000	12-24"	24-40"	6-10
Brussel Sprouts	Brassica	oleracea	gemmifera	Cross	1500	100	8,000	16-24"	18-36"	6-10
Buckwheat	Fagopyrum	esculentum		Cross	660	100		55lb/acre	6"	
Cabbage	Brassica	oleracea	capitata	Cross	1500	100	8,000	10-24"	24-40"	6-10
Cabbage, Chinese	Brassica	rapa	pekingensis	Cross	1500	100	8,000	10-24"	24-40"	6-10
Cantaloupe	Cucumis	melo		Cross	1500	100	1,000	36"	60"	7-12
Cardoon	Cynara	cardunculus	cardunculus	Cross	600	50	700	18-24"	36-48"	10-14
Carrots	Daucus	carota		Cross	1500	100	20,500	1/2-3"	15-24	8-18
Cauliflower	Brassica	oleracea	botrytis	Cross	1500	100	8,000	15-24"	24-36"	6-10
Celeriac	Apium	graveolans	rapaceum	Cross	1500	50	65,000	4-8"	18-36"	14-25
Celery	Apium	graveolans	dulce	Cross	1500	50	65,000	4-8"	18-36"	14-25
Chard, Silverbeet	Beta	vulgaris	cycla	Cross	1500	100	1,700	6"	24-36"	8
Chicory	Cichorum	intybus		Cross	1500	50	14,500	18"	7-8"	10-14
Chives	Allium	schoenoprasum		Cross	1500	100	33,000	Grow in clumps		8-13
Cilantro	Coriandrum	sativum		Cross	1500	100		8"	15"	10-18
Citron	Citrullus	lanatus	citroides	Cross	1500	100	315	12-24"		3-5
Collards	Brassica	oleracea		Cross			8,500	8-18"	24-36"	6-10
Corn	Zea	mays		Cross	1500	200	150	8-12"	30-42"	6-10
Crambe, Sea Kale	Crambe	maritima		Self	660	20		6-12"	20-30"	

Guidelines for Vegetable Seed Production

Common Name	Genus	Species	sub-spp	Pollination	Min. Iso. (feet)	Min. # Plants	Seeds per Ounce	In row spacing	B/t row spacing	Days to Germinate
Cress, Garden	Lepidium	sativum			1500	100		1-2"		
Cucumber	Cucumis	sativus		Cross	1500	20	1,000	12-36"	2-6'	6-10
Dill	Anethum	graveolans		Cross	1500	20	13,500	2-4"		7-10
Eggplant	Solanum	melongena		Self	150	10	6,250	16-24"	24-60"	7-14
Endive, Escarole	Cichorum	endivia		Self	150	50	18,750	8-12"	18-24"	5-14
Fennel	Foeniculum	vulgare		Cross	1500	50	7,000	4-6"	24"	7-10
Flax	Linum	usitatissimum		Both	100	50		15/ft		
Garbanzo, Chickpea	Cicer	arietinum		Self	25	10		12-18"		10
Garlic	Allium	sativum		clonal	25	10 cloves		12"	12"	
Gourd, Cucuzzi, Calabash	Lagenaria	siceraria		Cross	1500	20	200-600	16-24"	8-10'	6-10
Jerusalem Artichoke	Helianthus	tuberosus		Cross	1500	50	tubers	12-18"		
Kale, Collards	Brassica	oleracea	acephala	Cross	1500	100	8,500	4-24"	18-36"	5-10
Kohlrabi	Brassica	oleracea	gongylodes	Cross	1500	100	8,800	3-18"	18-24"	5-10
Lamb's quarters	Chenopodium	alba		Cross		50		4-6"		
Lavender	Lavandula	vera	angustifolia		50	10		12"	12"	14-21
Leek	Allium	ampeloprasum	porrum	Cross	200	50	10,300	2-6"	12-30"	10-14
Lentil	Lens	culinaris		Self	25	10		4-6"		5-7
Lettuce	Lactuca	sativa		Self	50	20	26,250	4-15"	12-24"	6-10
Luffa, Silk Gourd	Luffa	spp.		Cross	1500	30	300	18"		10-12
Lupine	Lupinus	spp		Cross	1500	30		6"	6"	
Melon	Cucumis	melongena		Cross	1500	20	1,125	18-24"	6-8'	4-8
Muskmelon	Cucumis	melo		Cross	1500	100	1,200	18-24"	60-72"	4-8
Mustard, Black	Brassica	nigra			1500	100	12,600	8-12"		5
Mustard Greens	Brassica	juncea		Cross	1500	100	16,000	4-12"	12-24"	5-10
Oats	Avena	sativa		Self	200	50		Broadcast		
Okra	Abelmoschus	esulentus		Cross	1500	50	500	12-24"	24-60"	7-14
Onion	Allium	cepa		Cross	1500	100	8,250	2-4"	16-24"	7-14
Onion, Welsh, Ciboule	Allium	fistulosum		Cross	1500	100	12,500	1/2-1"	12-18"	7-12
Parsley	Petroselinum	crispum		Cross	1500	50	18,100	3-5"	9-30"	14-28
Parsnip	Pastinaca	sativa		Cross	1500	50	9,125	2-4"	12-24"	14-28
Pea	Pisum	sativum		Self	50	10	120	1-3"	24-48"	6-12
Peanut	Arachis	hypogea		Self	25	NA	28-56	10-12"	36"	7-10

Guidelines for Vegetable Seed Production										
Common Name	**Genus**	**Species**	**sub-spp**	**Pollination**	**Min. Iso. (feet)**	**Min. # Plants**	**Seeds per Ounce**	**In row spacing**	**B/t row spacing**	**Days to Germinate**
Pepper	Capsicum	annuum		Self	100	10	8,000	15-24"	12-36"	10-20
Quinoa	Chenopodium	quinoa		Self	1500	50		10-12"		
Radicchio							22,000	6-7"	18"	10-14
Radish	Raphanus	sativus		Cross	1500	50	3,300	1"	9-18"	3-10
Rutabaga	Brassica	napus	napobrassica	Cross	1500	100	10,700	4-8"	12-24"	5-10
Salsify	Tragopogon	porrifolius		Self	1500	100	1800	3"	18-24"	8
Sorghum, broomcorn	Sorghum	bicolor		Self	990	40	1,400	4-6"		4-10
Sorrel	Rumex	acetosa		Self	250	50		12"		14-21
Soybean	Glycine	max		Self	30	10	100	3-4"		5-7
Spinach	Spinacia	oleracea		Cross	1500	100	2800	1-6'	12-24"	6-16
Squash (butternut, cushaw)	Cucurbita	moschata		Cross	1500	20	100-300	12-18"	48"	6-12
Squash, marrow, pumpkin	Cucurbita	maxima		Cross	1500	20	100-300	16"-6'	2'-10'	6-10
Squash	Cucurbita	pepo		Cross	1500	20	100-300	12-18"	36-72"	6-12
Sunflower	Helianthus	annuus		Cross	1500	20	220	9-12"	30-36"	8-10
Tomato	Lycopersicon	esculentum		Self	100	20	8,725	18-30"	36-72"	7-14
Turnip	Brassica	rapa	rapifera	Cross	1500	10+	13,500	2-4"	12-24"	5-10
Watermelon	Citrullus	lanatus		Cross	1500	20	500	24-48"	6'-9'	5-12

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Intellectual Property Rights

There are a number of mechanisms used for the protection of intellectual property rights with crop plants and varieties. These include plant variety protection (PVP), plant patents, utility patents and the use of trade secrets. All of these are used for protection of plant varieties and have different requirements for issuance and have different restrictions on the re-propagation and use of the protected material for development of newer varieties by other parties. These will be discussed below.

Plant Variety Protection (PVP)

The Plant Variety Protection Act (PVPA) was enacted in December of 1970, and amended in 1994, provides legal intellectual property rights protection, to developers of new varieties of plants that are sexually reproduced (by seed) or are tuber-propagated. Bacteria and fungi are excluded. PVP provides protection also for essentially derived varieties. The PVPA is administered by the USDA. A Certificate of Protection is awarded to an owner of a variety after an examination shows that it is new, distinct from other varieties, and genetically uniform and stable through successive generations. The term of protection is 20 years for most crops and 25 years for trees, shrubs and vines. The owner of a US protected variety has excusive rights to multiply and market the seed of that variety. A plant variety can also receive double protection under a utility patent and plant variety protection.

PVP requires that the cultivar that plant protection is requested for is novel which requires it is distinctive and described for uniformity and stability. These are defined as:

1. Distinctive – which the cultivar differs by one or more identifiable morphological, physiological or other characteristics.
2. Uniformity – a cultivar must demonstrate that the variations in the cultivar are describable, predictable and commercially acceptable.
3. Stability – the cultivar must remain essentially unchanged with regard to essential and distinctive characteristics with a reasonable degree of reliability as compared to cultivars of the same type.

In addition the applicant must provide:

- The name or temporary designation of the new variety;
- The pedigree, breeding methods, and selection criteria used in developing the variety;
- A statement of the basis of ownership and explanation of who, including the breeder, has rights to the variety;
- A sample of at least 2,500 of the untreated viable seed required to reproduce the variety, or for a tuber-propagated variety, a declaration that a viable cell culture will be deposited in a public depository and will be maintained for the duration of the certificate;
- Filing and examination fees totaling $2,705 (prices may change) payable when the application is submitted.

Without explicit consent from the owner, a person is prohibited from selling, marketing, offering delivering, consigning, exchanging, or exposing the variety for sale. In addition, a person is prohibited from soliciting an offer to buy the variety, transfer or possess it in any manner. It is also illegal to import or export the variety, sexually multiply it, propagate it by tuber, use the variety in producing (as distinguished from developing) a hybrid, or condition the variety for the purpose of propagation. Growers and home gardeners can grow any legally purchased and protected variety they wish. The can collect and save the seed for future planting on their own holdings without violation of the law. There are 2 exemptions to the protection provided:

1. A research exemption to allow the sue for breeding to develop a new variety; and
2. A farmer's exemption to allow the saving of seed for the sole use of replanting the farmer's land. However, a farmer is not allowed to produce seed of a protected variety and sell it to someone else. Neither plant patens nor utility patents provide these exemptions.

The owner of a protected variety may bring civil action against persons infringing on his or her rights. The owner may ask a count to issue an injunction to prevent others from further violations. It is the owner of the protected variety who must bring suit in such cases. USDA will not take that action.

Plant Patents:

The plant Patent Act of 1930 provided for the protection of asexually propagating varieties excluding tubers. The law provides for the granting of a patent to anyone who has invented or discovered and asexually reproduced any distinct and new variety of plant, including cultivated sports, mutants, hybrids, and newly found seedlings, other than a tuber-propagated plant or a plant found in an uncultivated state.

With a plant patent, the grant confers the right to exclude others from asexually reproducing the plant or selling or using the plant. Farmers who buy varieties protected under plant patents do not have the right to reproduce the variety, even for their own use. The grant lasts for 20 years from the date of filing the application.

There are several requirements for the issuance of a plant patent. The three most important are:

1. Novelty – The person who is the first inventor must show that it is original in some manner.
2. Utility – What is being protected is something that is capable of being used beneficially for the purpose for which it was developed.
3. Non-obviousness – The plant is something that goes beyond what people who have ordinary skill in the art would know.

Utility Patents:

Utility patents currently offer protection for any plant type or plant parts. A plant variety can also receive double protection under a utility patent and plant variety protection. The United States Patent and Trademark Office (USPTO) administers the utility patent system. A utility patent is a property right granted by the US Government

that gives its owner the right to exclude others from making, using, offering for sale, or selling, throughout the United Sates, or importing into the United States, for a defined period of time. In addition, if the invention is a process, the patent owner has the right to exclude others from using, offering for sale or selling throughout the United States, or importing into the United States, products made by that process, for a defined period of time. In exchange for an exclusive right, the public receives a detailed description of the invention intended to allow practice of the invention after the expiration of the patent term. This disclosure is also intended to stimulate further research by competitors to develop new inventions that are not covered by the patent.

An invention may be protected by means of a utility patent if it is:

1. novel,
2. non-obvious
3. useful and amenable to the descriptive requirements of the applicable law

In addition, the invention must fall into one of the statutory categories of protectable subject matter: processes, machines, articles of manufacture, and compositions of matter.

A utility patent can accommodate claims drawn to different features of the invention. For example, it the invention relates to a new development in a tomato obtained through traditional breeding methods, the claims of a utility patent could be drawn to genetically diverse tomato plants that express a particular trait, to a new tomato variety *per se*, to plant parts such as fruit and seeds produced by the variety, to cultured cells, or to tomato breeding methodology.

On the other hand, if the invention concerns new tomato plants obtained through genetic engineering, the claims might be drawn to any tomato plant containing the cloned gene(s) of interest. Specific tomato varieties transformed with the gene(s) of interest also could be described and claimed in the utility patent application, along with the seeds and fruit of the genetically engineered plants. In addition, it would be possible in principle to claim the cloned gene(s) and expression vectors containing the genes, as well as methods of plant transformation or producing proteins of interest in a transformed plant, in the same application. A chemical extracted from plants could be claimed in the context of a pharmaceutical composition of food supplement. Thus, a utility patent can be used to claim many different aspects of plant-related innovation.

Trade Secrets:

Trade secrets are another protection mechanism used for protecting plant material. Unlike the laws governing utility patents, plant patens and PVPA certificates, trade secret law is controlled by the laws of individual states and not Congress. Although these laws may differ from state to state, a trade secret is commonly regarded as any formula, pattern, device, or compilation of information that is used in a business and gives that business an opportunity to obtain advantages over competitors. Public disclosure of the invention is required to obtain a utility patent, plant patent or PVPA certificate. However, to enforce trade secret rights, reasonable efforts must have been made to keep confidential the material and information which is the subject of the trade secret. Companies have successfully sued others for use of their trade secrets with inbred lines of corn (Pioneer). Unlike other types of protection, trade secrets do not have a time limit to

their protection and the information is not publicly available. Inbred lines used in hybrid seed production are usably kept as a trade secret.