Table 4. *Relative soluble salt sensitivity levels.*

mmhos/cm[1]	Description	Effect on crops
0 to 2	non-saline	none
2.1 to 4	very slightly saline	sensitive crops restricted
4.1 to 8	moderately saline	many crops restricted
8.1 to 16	strongly saline	most crops restricted
more than 16	very strongly saline	few plants tolerant

[1] *Based on saturated paste extract.*

therefore should be applied 1 year before planting. Test the pH of the soil 3 to 4 months after the initial application. If the soil pH is not in the desired range, reapply according to **Table 3**. In situations where irrigation water contains lime, additional annual applications of 300-400 lb/A elemental sulfur may be necessary to maintain pH in the desired range. Iron sulfate can also be used to acidify soils. This material reacts much faster than elemental sulfur, usually within 3 to 4 weeks. Multiply the rate of elemental sulfur recommended by 7 to determine the rate of iron sulfate needed. For high rates of iron sulfate, split applications are recommended. **Do not** apply more than 2 tons per acre of iron sulfate at a time. Use of ammonium sulfate as the nitrogen source will also help in maintaining a low soil pH. **Caution**—do not use more ammonium sulfate than that required for meeting the nitrogen requirements. Too much nitrogen can cause excessive vegetative growth, and may increase the potential for winter injury and reduce fruit quality. High lime soils with a pH greater than about 7.3 require higher rates of acidifying amendments and are not recommended for commercial blueberry production.

Soluble Salts (electrical conductivity)

The term *soluble salts* refers to the inorganic soil constituents (ions) that are dissolved in the soil water. Pure water is a very poor conductor of electric current, whereas water containing dissolved salts conducts current approximately in proportion to the amount of salt present. Thus, the measurement of the electrical conductivity of a soil extract gives an indication of the total concentration of salts. The electrical conductivity measurement is reported in millimhos per centimeter (mmhos/cm). Crops differ in their sensitivity to soluble salts. High soluble salts can restrict root growth, cause burning of the foliage, and limit crop yields. The relative values for soluble salt sensitivity levels are described in **Table 4.**

Most soils in Minnesota are nonsaline (0 to 2 mmhos/cm); however, a few soils in western Minnesota have formed under high sodium/alkaline conditions and may be high in soluble salts. Other conditions where soluble salts may limit plant growth are when fertilizers are overapplied or placed too close to the roots.

The relative salt tolerance of various fruit and vegetable crops is presented in **Table 5.**

Organic and Inorganic Fertilizers

Plant roots absorb the majority of their nutrients from the soil solution in the ionic (inorganic charged) form. Larger molecules can also be absorbed by roots, but their rate of absorption is slow. Thus, if a fertilizer (organic or inorganic) is applied, it must first be broken down to its simplest forms to be used efficiently by plants.

According to the Minnesota Department of Agriculture, a natural organic fertilizer has to be derived from either plant or animal materials containing one or more elements (other than carbon, oxygen, and hydrogen) that are essential for plant growth. Organic food production, however, allows for a broader definition that includes naturally occurring inorganic substances such as elemental sulfur and gypsum, and naturally occurring mineral materials that are not chemically modified.

Table 5. *Soluble salt test[1] values and relative salt tolerance of fruit and vegetable crops.*

0-2 mmhos/cm* Nontolerant	3-4 mmhos/cm* Slightly Tolerant	5-7 mmhos/cm* Moderately Tolerant	8-16 mmhos/cm* Tolerant
blueberries	apples	broccoli	asparagus
carrots	cabbage	beets, table	Swiss chard
green beans	celery	cucumbers	
onions	grapes	muskmelons	
radishes	lettuce	squash	
raspberries	peppers	tomatoes	
strawberries	potatoes	spinach	
	sweet corn		

[1] *Based on saturated paste extract.* ***Plants can be successfully grown at these test levels or lower.

Table 6*. Approximate nutrient composition of various inorganic/chemical fertilizers. Fertilizers marked with an asterisk (*) are acceptable for organic fruit and vegetable production. Check with certifying agency for any restrictions.*

Nutrient	Fertilizer Material	Composition N	P_2O_5	K_2O
		- - - - - - %	- - - - - -	
	Ammonium nitrate	33	0	0
	Ammonium sulfate	21	0	0
	Ammonium thiosulfate	12	0	0
	Anhydrous ammonia	82	0	0
	Calcium nitrate	15.5	0	0
	Diammonium phosphate	18	46	0
	Mono-ammonium phosphate	11	48	0
	Potassium nitrate	13	0	44
	Sodium nitrate	16	0	0
	Urea	46	0	0
	Urea, polymer coated	40-44	0	0
	Urea-ammonium nitrate (UAN)	28-32	0	0
Phosphorus Sources				
	Diammonium phosphate	18	46	0
	Mono-ammonium phosphate	11	48	0
	*Rock phosphate	0	5	0
	Superphosphate	0	20	0
	Triple superphosphate	0	46	0
Potassium Sources				
	Potassium chloride	0	0	60
	*Potassium-magnesium sulfate	0	0	22
	Potassium nitrate	13	0	44
	*Potassium sulfate	0	0	50
Calcium Sources		**% Ca**		
	*Calcium sulfate (gypsum)	22		
	Calcium nitrate	20		
	Calcium chloride	36		
	*Calcitic lime	30-40		
	*Dolomite	22		
	Calcium chelates	4-12		
Magnesium Sources		**% Mg**		
	Magnesium sulfate (Epsom salts)	10		
	*Potassium-magnesium sulfate	11		
	*Dolomite	11		
Sulfur Sources		**% S**		
	Ammonium thiosulfate	26		
	Ammonium sulfate	24		
	*Calcium sulfate (gypsum)	19		
	*Elemental sulfur	90-100		
	*Potassium-magnesium sulfate	18		
	*Potassium sulfate	18		
	Magnesium sulfate (Epsom salts)	13		
Boron Sources		**% B**		
	*Borax	11		
	*Boric acid	17		
	*Solubor	17-21		
	Sodium pentaborate	18		
	Sodium tetraborate	14-20		
Copper Sources		**% Cu**		
	Cupric chloride	47		
	*Copper sulfate	25		
	Copper chelates	8-13		
Iron Sources		**% Fe**		
	Iron sulfate	20		
	Iron chelates	5-12		
Manganese Sources		**% Mn**		
	Manganese sulfate	27		
	Manganese chelates	5-12		
Molybdenum Sources		**% Mo**		
	Ammonium molybdate	54		
	Sodium molybdate	39		
Zinc Sources		**% Zn**		
	Zinc oxide	80		
	Zinc sulfate•monohydrate	36		
	Zinc chelate	14		

National standards for organic crop production have recently been adopted (USDA National Organic Program). If you are unsure about a particular product, check with the Minnesota Department of Agriculture (MDA) (http://www.mda.state.mn.us/esap/organic/) or state certified agencies (available through the MDA website) about its suitability for organic farming before applying it to your field.

Characteristics of inorganic synthetic fertilizers are that they dissolve in water and are immediately available to the plant for uptake. When used according to recommendations, these types of fertilizers are safe for the environment and can supply the required nutrients for plant growth. However, excessive rates of these fertilizers can injure the roots of plants causing death and potentially lead to environmental degradation.

Organic fertilizers are made up of larger molecules and substances that take time to be broken down into forms usable by the plant. Compost made from animal manure and various plant residues is often used as an organic soil amendment and nutrient source. The composting process stabilizes available nitrogen into less available forms. Thus, compost and most organic fertilizers can be considered slow-release type fertilizers with a low salt index. Therefore, they can be applied in larger amounts at one time without causing injury to the plant root. For organic nitrogen sources (except urea), one application can be made without having to be concerned with losing all the nitrogen to leaching. However, even organic fertilizers applied at excessive rates can cause environmental degradation. Unless an animal operation is nearby, organic fertilizers are usually more expensive and bulkier than inorganic sources.

The nutrient composition of common inorganic/chemical fertilizer sources is provided in **Table 6.** The composition of selected organic fertilizers is provided in **Table 7**. More information about using organic fertilizers for vegetable and fruit production can be found at: http://www.extension.umn.edu/distribution/horticulture/M1191.html.

Using Animal Manure

The amount of plant nutrients in a fertilizer program can be reduced if manure is used. The nutrient content of manure varies with type of livestock and methods used in storage, handling, and application. As a general rule, the suggested rates of N, P_2O_5, and K_2O can be reduced by 5, 2, and 5 lb/A, respectively, for each wet ton or for each 250 gallons applied per acre. Some general analyses of different types of manure on a dry weight basis are provided in **Table 7**. To use these analyses effectively, the moisture content of the manure must be known. Many laboratories will measure the nutrient concentrations in manure. Manure analysis is strongly recommended if routine applications are made for crop production. The results of such an analysis will give a more precise measurement of the nutrient value of manure. Fresh manure is high in soluble forms of nitrogen, which can lead to salt build-up and leaching losses if overapplied. Fresh manure may contain high amounts of viable weed seeds, which can lead to weed problems. In addition, various intestinal pathogens such as *E. coli* may be present in fresh manure and can cause illness to individuals eating fresh produce unless proper precautions are taken. Apply and incorporate raw manure in fields where crops are intended for human consumption at least three months before the crop will be harvested. Allow four months between application and harvest of root and leaf crops that come in contact with the soil. Do not surface apply raw manure under orchard trees where fallen fruit will be harvested.

Heat generated during the composting process will kill most weed seeds and pathogens, provided temperatures are maintained at or above 131°F for 15 days or more (and the compost is turned so that all material is exposed to this temperature for a minimum of 3 days). The microbially mediated composting process will lower the amount of soluble nitrogen forms by stabilizing the nitrogen in larger organic, humus-like compounds. It is best to use well-composted manure for crops used for direct human consumption. Higher rates of composted manure will be needed because of

Table 7. *Approximate nutrient composition[1] of various organic fertilizers.*

Organic Materials	N	P_2O_5	K_2O
Manures		% dry weight basis	
Beef	1.2	2.0	2.1
Dairy	2.1	3.2	3.0
Bat guano	6.0	5.0	3.0
Horse	2.1	3.2	2.0
Poultry	3.0	5.0	2.0
Sheep	1.6	1.2	2.0
Swine	2.5	2.1	1.0
Alfalfa hay	2.5	0.5	2.5
Blood meal	13.0	2.0	1.0
Bone meal, raw	3.0	22.0	0
Bone meal, steamed	1.0	15.0	0
Castor bean meal	5.5	2.0	1.0
Cotton seed meal	6.0	3.0	1.5
Fish meal	10.0	6.0	4.9
Kelp/seaweed	1.5	1.0	0
Peanut meal	7.0	1.5	1.2
Soybean meal	7.0	1.2	1.5
Tankage[2]	7.0	10.2	1.5

[1] *These are total concentrations and only slowly available over weeks, months, or years. Many materials will vary in composition due to moisture content and methods of handling.*
[2] *May contain high levels of chromium.*

lower nitrogen availability following the composting process. For more information on manure management and calculating rates to apply for vegetable and fruit crops refer to: http://www.extension.umn.edu/distribution/horticulture/M1192.html.

Sewage Sludge (Biosolids)

Although sewage sludge from municipal treatment plants can supply nutrients for crop growth, there is concern about elevated metal content and enteric diseases in some types of sewage sludge. While preventing metals from entering the sewer system and use of certain processing techniques can minimize these problems, use of sewage sludge for fertilizing fruit and vegetable crops is questionable. Sewage sludge is best used to provide nutrients (primarily nitrogen and phosphorus) for ornamental landscape plants and crops not directly used for human consumption.

Using Green Manures/Cover Crops

Crops that are incorporated into the soil while still green are referred to as green manures. Cover crops are similar to green manures, but are usually grown to protect soil from erosion during the non-growing season. Because topsoil is higher in organic matter and nutrient content than subsoil, controlling erosion is an important method of conserving soil nutrients. Green manures and cover crops are both used to supply nitrogen and increase soil organic matter. Legumes such as clover and alfalfa can fix between 100 and 200 lbs of nitrogen per acre in one year. The use of grasses such as rye or oats without a legume will not increase the nitrogen content of the soil. These crops are used for increasing soil organic matter content. They can also scavenge residual nitrogen from the previous crop and keep it from being lost by leaching. A mixture of both grasses and legumes can be used to obtain the advantages of each. Improved soil tilth from added organic matter improves root growth, which increases the capacity of a crop to take up available soil nutrients. The decision to plant a green manure should take into account the cost of cultural practices (planting, cultivation) and seed, as well as the lost opportunity cost if the green manure is grown instead of a cash crop.

Some green manure crops accumulate high levels of phosphorus and are thought to increase phosphorus availability to subsequent crops by returning it to the soil in organic form. For example, buckwheat and oilseed radish may solubilize phosphorus from relatively insoluble minerals like rock phosphate through the action of organic acids secreted by their roots. The benefit of these phosphorus accumulating crops will depend on the following crop and to what extent recycling of organic phosphorus increases phosphorus availability to them compared to inorganic soil phosphorus. There is little research information on phosphorus response of different crops following green manures like buckwheat and oilseed radish. More information on nutrient cycling and maintaining soil fertilization can be found at the following website: http://www.extension.umn.edu/distribution/horticulture/M1193.html.

Fertigation

Fertigation refers to the application of water soluble fertilizer through the irrigation water. Nutrients in a concentrated solution are injected in the irrigation water using an appropriate injection device. Providing nutrients through the irrigation system enables more flexibility in a fertilizer program. Several types of irrigation systems are available for use in crop production. For any system used, approved backflow control valves and interlock devices are necessary to prevent accidental contamination of the water source due to irrigation system failure or shutdown. Contact the Minnesota Department of Agriculture (http://www.mda.state.mn.us/) for Minnesota state regulations regarding application of fertilizer through irrigation systems. The type of system selected will depend on the crop being grown and resources available.

Overhead irrigation

Center pivot and solid set overhead irrigation systems provide the most uniform distribution of water. Center pivot systems are especially well suited for large acreage crops such as sweet corn and potatoes, while solid set systems are used for the smaller acreage. In most cases, nitrogen is the primary nutrient applied with an overhead irrigation system. Nitrogen solutions in the form of urea-ammonium nitrate (28-32% N) are the most common and economical sources to use. Generally, 20-40 lb N/A per application can be applied through the system to supplement crop needs. Other elements such as phosphorus, potassium, and micronutrients are more efficiently used if incorporated in the soil at or before planting.

For solid set systems a batch load of fertilizer is injected. That is, the area being irrigated is calculated and the amount of fertilizer required for that given area is then determined. In making these calculations with fertilizer solutions, the density or pounds of solution per gallon needs to be known. The density is usually provided on the fertilizer label or can be obtained from the fertilizer dealer. For solid set systems, the injection rate does not need to be precisely controlled. For center pivot systems, the movement of the system in acres per hour needs to be taken into account. For calibration of center pivot systems, refer to the manufacturer's irrigator operating manual. The timing of application should be based on crop demand and can be determined using tissue analyses. For potatoes, the demand for nitrogen is generally greatest between initial tuber growth and tuber enlargement (5 to 10 weeks after planting). For sweet corn, the demand for nitrogen is greatest between the 12-leaf stage and tasseling.

Drip Irrigation

Drip or trickle irrigation is a type of irrigation where water is supplied under low pressures directly to or near the plant's root zone. Water is carried through plastic tubing and emitted through small openings. Drip irrigation is often used in combination with plastic mulch. Advantages of using drip irrigation are better control of foliar diseases and more efficient water and fertilizer use. Water savings with drip irrigation can amount to as much as 50 percent compared with an overhead sprinkler system. This method of irrigation is particularly suited for high