managing manure nutrients for crop production

Each year Iowa livestock produce enough nitrogen (N), phosphorus (P), and potassium (K) to supply 13 pounds of N, 13 pounds of P_2O_5, and 21 pounds of K_2O for every acre of corn (see Table 1, nutrient management page 6). *The manure is routinely applied to fields surrounding the livestock operations. However, it is important that manure be handled, stored, and applied to fields efficiently and carefully to avoid harming the environment.*

Nutrients in animal manure should be managed with the same care as commercial fertilizer. To do so it is necessary to determine:

- total amount of nutrients in the manure,
- availability of the nutrients to the crop, and
- amount of nutrients required to optimize crop yields.

DETERMINING NUTRIENT CONTENT

Three methods can be used to determine the total amount of nutrients in animal manure.

1. **The best method** is to have a sample of the manure chemically analyzed and measure the volume of the manure storage unit. This eliminates the need to make assumptions about storage losses of nutrients. However, it does require a representative sample of the manure and storage volume calculations. (See ISU Extension publication PM 1558 for information on how to sample.)

Example:

a. 125,000 birds produce 1,313 tons of manure annually. The chemical analysis of the manure is 40 pounds N per ton, 40 pounds P_2O_5 per ton, and 25 pounds K_2O per ton. The total amount of nutrients in the storage is:

N: 1,313 x 40 lbs. = 52,520 lbs. N
P_2O_5: 1,313 x 40 lbs. = 52,520 lbs. P_2O_5
K_2O: 1,313 x 25 lbs. = 32,825 lbs. K_2O

b. You have 500,000 gallons of manure and the chemical analysis is 50 pounds N, 35 pounds P_2O_5, and 30 pounds K_2O per 1,000 gallons the total amount of nutrients in the storage is:

N: 50 lbs. x 500 = 25,000 lbs. N
P_2O_5: 35 lbs. x 500 = 17,500 lbs. P_2O_5
K_2O: 30 lbs. x 500 = 15,000 lbs. K_2O

2. **The second method** calculates storage capacities and multiplies that by the average estimated nutrient content *(see Table 2, page 7)*. This table is a good reference to begin developing application rates. However, both volumes and nutrient concentrations can vary significantly among storage facilities and livestock operations.

3. **The third method** calculates the average amount of manure produced per day by the animals, multiplies that by the number of animals at the site, and assumes standard storage and handling losses. Table 3 *(see page 8)* lists annual N, P_2O_5 , and K_2O production after estimated losses are deducted for each confinement space for various livestock species and manure handling systems. This method is a good one for planning the number of acres that will be needed for manure application for new facilities or for expansion of existing ones.

CROP AVAILABILITY

Animal manure contains all the nutrients essential for plant growth. The form of plant nutrients in manure varies between the urine and fecal fractions, depending on nutrients and the species.

For example, about 48 percent of the N in cattle manure is contained in the feces and 52 percent in the urine (mostly as urea or uric acid). Virtually all the N in poultry manure is urea or uric acid.

The nutrients also are distributed between inorganic and organic forms within manure. The inorganic forms (primarily ammonia) are readily available for crop use. The nutrients in organic forms (pieces of soybean meal, hair, particles of corn, and complex organic acids) must be converted be used by crops. This conversion, called mineralization, is accomplished by microorganisms that live in all soils. Mineralization rates depend on factors such as soil temperature and moisture, making it difficult to predict how fast this process will occur.

Nitrogen availability

The amount of the total nitrogen available depends on the species and whether the manure is liquid or solid. Recent research suggests that 30 to 40 percent of the total N in dry beef cattle and dairy manure is available for crops the year of application with 10 percent available the second year and 5 percent the third year. All of the N in swine manure from liquid handling systems is available the first year of application and 65 percent of the total N in poultry manure is available the first year of application. These estimates do not account for potential losses (ammonia volatilization) at the time of application.

Nitrogen in ammonium and urea can be lost into the atmosphere during and after land application (volatilization). If the manure is left on the soil's surface the ammonium and urea will form the gas ammonia. Ammonia moves freely into the atmosphere. You must therefore make adjustments for volatilization losses. The amount of N available after volatilization is the amount left for crops. Suggested adjustment factors from the Iowa Department of Natural Resources (IDNR) are listed in Table 4 *(see page 9)* .

Examples:

c. You have solid manure from a dairy operation that contains 12 pounds N, 6 pounds P_2O_5, and 12 pounds K_2O per ton. The manure will be broadcast onto the land; it will not be incorporated.

The volatilization correction =
12 lbs. N x 0.7 = 8.4 lbs. N/ton

The amount of N available the year of application =
8.4 lbs. N x 0.35 = 2.9 lbs. N/ton

d. You have liquid swine manure from a farrow-to-finish operation that contains 44 pounds N, 32 pounds P_2O_5, and 24 pounds K_2O per 1,000 gallons. The manure will be broadcast and incorporated within 24 hours.

The volatilization correction =
44 lbs. N x 0.95 = 41.8 lbs. N/1,000 gallons

The amount of N available the year of application =
41.8 lbs. N/1000 gallons

(Remember that all the N in liquid swine manure is available to plants the first year.)

e. You have poultry manure from a caged layer operation that contains 35 pounds N, 80 pounds P_2O_5 , and 50 pounds K_2O per ton. The manure will be broadcast and incorporated within 24 hours.

The volatilization correction =
35 lbs. N x 0.95 = 33.3 lbs. N/ton

The amount of N available the year of application =
33.3 x 0.65 = 21.6 lbs. N/ton

Phosphorus availability

Phosphorus is present in both inorganic and organic forms. About 60 percent of the total P in manure will be available to crops the year of application but will have little effect on production if the manure is applied to soils that test "high" or "very high." See ISU Extension publication PM 1688, *General Guide for Crop Nutrient Recommendations in Iowa* ($1 per copy), for a complete list of soil test interpretations. If manure is applied to soils to replace the amount removed in the harvested portion of the crop, assume that all of the P is available.

If your soils test "very low," "low," or "optimum," crop yields likely will be reduced by underapplication of P. If the manure is being applied to these soils, assume that 60 percent of the total P in the manure is available.

Potassium availability

Potassium is present in animal manure as the inorganic ion K+. This is the form of K used by plants, so assume that 100 percent of the total K in animal manure is available to plants the year of application.

managing manure nutrients for crop production

NUTRIENT REQUIREMENTS FOR CROP PRODUCTION

Manure application rates can be determined using N, P, or K. There are two methods for determining nitrogen needs.

Method 1 for nitrogen

You can estimate your nitrogen needs by multiplying the proven yield for a given field (or area of a field) by a factor that represents the crop's N requirement. Iowa has three factors for manure supplying nitrogen to corn *(see Figure 1, page 6)*. Table 5 *(see page 9)* shows nutrient removal for other crops. Calculate the requirement by taking the nitrogen requirement and reducing it by the amount of N contributed from other sources such as the previous crop, previous manure additions, or starter fertilizers.

The equation is
N fertilizer = (Proven yield x N factor) - N credits

N credits include:
- 1 pound N equivalent per bushel of soybean up to 50 pounds N per acre
- 10 percent of the N in bedded manure applied the previous year
- alfalfa

Example:
f. You have established that you can grow 150 bushels of corn per acre on a given field in north central Iowa. Last year's soybean crop yielded 60 bushels per acre.

N fertilizer = (150 x 1.2) - 50 lbs. N/acre = (180) - 50 = 130 lbs. N/acre

The 1.2 is the N factor for most of Iowa. Even though last year's soybean crop yielded 60 bushels per acre, the maximum N credit for soybeans is 50 pounds per acre.

Method 2 for nitrogen

The other method is a Late Spring Soil Nitrate Test (see ISU Extension publication PM 1714, *Nitrogen Fertilizer Recommendations for Corn in Iowa*). A 0- to 12-inch soil sample is collected from a field or parts of a field while corn is 6 to 12 inches tall. The soil sample is analyzed for nitrate-nitrogen (NO_3 -N), and nitrogen then is applied according to Table 6 *(see page 10)*. If the test indicates less than 20 ppm NO_3 -N under conditions of normal rainfall and favorable corn prices, nitrogen or manure must be side-dressed to ensure optimum yields. This method cannot be used to determine how much manure to apply in the fall for next year's corn crop. The amount from Method 1, or slightly less, probably is a good estimate.

ALLOCATING MANURE TO FIELDS

Manure can be allocated to supply the N, P, or K requirements of the crop that will be grown. Annual applications may result in a rapid increase in soil test P and K. For instance, in Example a, if the poultry manure is applied to supply 150 pounds of N per acre and incorporated immediately, this also will apply approximately 150 pounds of P_2O_5 per acre and 95 pounds K_2O per acre.A more conservative approach is to apply the manure to supply the P or K needs of the crop either through lower annual rates or less frequent applications. This will not result in increases in soil test P or K; however, it will increase the acreage needed for manure application. Soil testing is the best way to determine the amount of P and K for optimum crop production. Applying manure to supply P or K, then using Method 2 for N (above) usually optimizes both the environmental and economic benefits of manure use.

Manure should be allocated as follows:

- Fields that test very low in P and K and are going to be planted to corn;
- Fields that test low in P and K and will be planted to corn;
- Fields that test very low in P and K and will be planted to soybeans; and
- Fields that test low in P and K and will be planted to soybeans.

(See Table 7, page 10, for a more complete list of suggested field priorities.)

When selecting fields for manure application consider the nutrient requirements of your crop rotation. For example, in a corn-soybean rotation apply the manure every other year to supply the N requirements of the corn, and the P may meet the requirements for both the corn and the soybeans. This usually is very effective in Iowa and is popular among producers. Also consider the proximity of fields to the manure storage facility and the time required to transport the manure.

SCHEDULING APPLICATION

The time of application influences nutrient availability and potential movement. Fall applications allow more time for organic portions of the manure to mineralize so they are available for plant uptake. However, the increased time for mineralization also allows for more potential nitrogen loss to the environment. Coarse-textured soils are the most likely to leach with fall-applied manure and nitrogen. Manure applied in the spring has the least amount of time for nitrogen loss to occur, but spring application is the most likely to cause soil compaction.

As a general rule, do not apply manure in the fall unless the soil temperature is 50°F to a depth of four inches and cooling. This will slow the mineralization process.

Applying manure to frozen soils increases the potential for environmental contamination. Nitrogen and phosphorus movement into surface water can be significant and nitrogen losses can be high. If manure must be applied to frozen ground, it should be applied on relatively flat land (slopes less than 4 percent and well away from streams and waterways, see IDNR rules on setback distances).

SUMMARY OF KEY POINTS

- Manage the nutrients in animal manure as you would commercial fertilizer.

- Have a representative sample chemically analyzed to determine nutrient content of your manure.

- Adjust the rate of manure application to account for the plant availability of nitrogen and phosphorus.
- Adjust manure rates to account for nitrogen volatilization.

- Base the manure application rate on either nitrogen or phosphorus needs, but do not exceed the N requirement.

- Apply manure to meet the nutrient needs of crop rotations rather than individual crops.

- Allocate manure to fields based on soil tests and the crop to be grown.

- Fall applications of manure should not be made until the soil temperature is 50° F and cooling.

References

Blackmer, A.M., R.D. Voss, and A.P. Mallarino. 1997. Nitrogen fertilizer recommendations for corn in Iowa. *PM 1714. Iowa State University Extension. Ames, Iowa*

Prepared by Randy Killorn, professor of soil fertility and Jeff Lorimor, assistant professor of agricultural and biosystems engineering.

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FIGURE 1

CORN N REQUIREMENTS

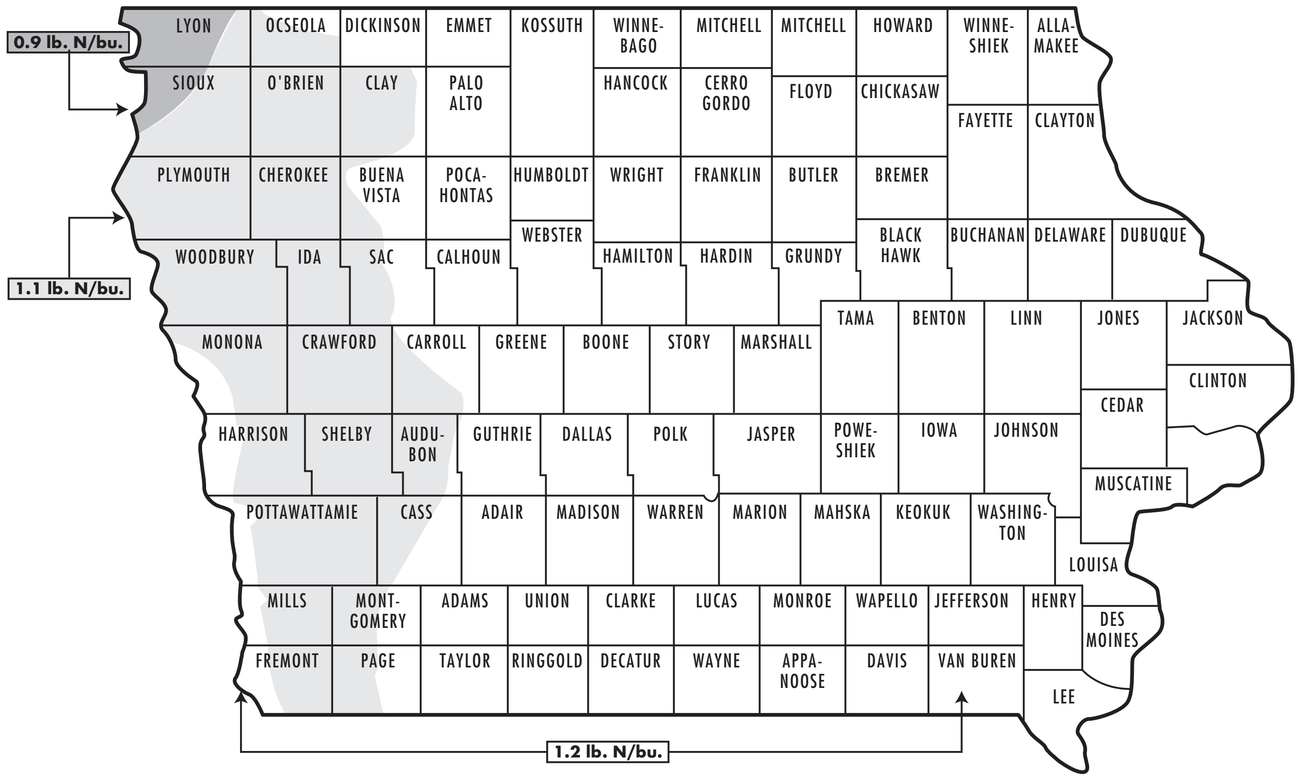

TABLE 1

PLANT AVAILABLE NUTRIENTS EXCRETED BY LIVESTOCK IN IOWA IN 1990

ANIMAL	NUMBER OF ANIMALS[a]	-----NUTRIENTS EXCRETED[b] -----			----- AVAILABLE NUTRIENTS[c] ----		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
	x 1,000	lbs./animal year			lbs. (x 1,000)		
Beef (500 lbs.)	1,347	124	91	106	41,757	42,902	71,391
Dairy (>500 lbs.)	443	180	89	143	19,935	13,799	31,675
Breeding Hogs	1,680	30	23	24	12,600	13,524	20,160
Market Hogs	11,820	30	23	24	88,650	95,151	141,840
Chickens	11,900	0.95	0.68	0.43	2,826	2,832	2,559

[a] From 1990 Crop and Livestock Reporting Service.

[b] Midwest Planning Service. 1985, Livestock Waste Facilities Handbook (2nd ed.) MWPS-18.

[c] Assuming that 50 percent of the nutrients are recoverable and that 50 percent of the N and P_2O_5 and 100 percent of the K_2O is available to

TABLE 2

NUTRIENTS IN ANIMAL MANURE

MANAGEMENT SYSTEM	N	P_2O_5	K_2O	
LIQUID, PIT	--lbs./1,000 gals. --			gals./day
Swine				
Nursery, 25 lbs.	35	20	20	0.2
Grow-finish, 150 lbs. (wet/dry)	75	54	40	0.84
Grow-finish, 150 lbs. (dry feed)	50	42	30	1.2
Grow-finish, 150 lbs. (earthen)	32	22	20	1.2
Gestation, 400 lbs.	25	25	25	1.6
Sow and litter[a], 450 lbs.	25	20	15	3.5
Farrow-nursery[b]	27	23	22	2.2
Farrow-finish[c]	44	32	24	9.4
Dairy—confined				
Cows, 1,200 lbs. or more	30	15	25	11.8
Heifers, 900 lbs.	30	15	25	8.8
Calves, 500 lbs.	30	15	25	4.9
Veal calves, 250 lbs.	30	15	25	2.5
Dairy herd[d]	30	15	25	18.5
Beef—confined				
Mature cows, 1,000 lbs.	40	25	35	7.2
Finishing, 900 lbs.	40	25	35	6.5
Feeder calves, 500 lbs.	40	25	35	3.6
Lagoon[e]				
(all animals)	4	3	4	*See Table 3*
OPEN LOT RUNOFF	-- lbs./1,000 gals. --			gals./day
Earthen lots (liquids)				
Beef, 400 sq. ft./hd.	3	1	6	4.9
Dairy, 1,000 sq. ft./hd.	3	1	6	13.5
Swine, 50 sq. ft./hd.	3	1	6	0.7
Concrete lots (liquids)				
Beef, 400 sq. ft./hd.	6	2	7	1.6
Dairy, 1,000 sq. ft./hd.	6	2	7	3.2
Swine, 50 sq. ft./hd.	15	5	10	0.5

MANAGEMENT SYSTEM	N	P_2O_5	K_2O	
SOLID MANURE (BEDDED)	----- lbs./T. -----			T./hd./yr.
Swine—confined				
Nursery, 25 lbs.	14	9	11	0.34
Grow-finish, 150 lbs.	14	9	11	2.05
Gestation, 400 lbs.	14	9	11	2.77
Sow and litter, 450 lbs.	14	9	11	6.16
Farrow-nursery	14	9	11	6.09
Farrow-finish	14	9	11	12.25
Dairy—confined				
Cows, 1,200 lbs. or more	12	6	12	19.93
Heifers, 900 lbs.	12	6	12	14.95
Calves, 500 lbs.	12	6	12	8.3
Veal calves, 250 lbs.	12	6	12	4.15
Dairy herd	12	6	12	32.77
Beef—confined				
Mature cows, 1,000 lbs.	12	6	12	12.23
Finishing, 900 lbs.	12	6	12	11
Feeder calves, 500 lbs.	12	6	12	6.11
Open lot (solids - scraped)				
Beef, 400 sq. ft./hd.	22	16	14	3
Dairy, 1,000 sq. ft./hd.	11	6	11	11.5
Swine, 50 sq. ft./hd.	15	14	9	1.2
Poultry	----- lbs./T. -----			T./birds 1,000/yr.
Layer, caged, 4 lbs.[f]	35	80	50	10.5

[a] Sow and litter figures are per farrowing crate.

[b] Farrow-nursery figures are per sow in the breeding herd and include one farrowing sow, five gestation sows, and nine nursery pig spaces.

[c] Farrow-finish figures are per sow in the breeding herd and include one farrowing sow, five gestation sows, nine nursery pigs, and 36 finishing pig spaces.

[d] Per productive cow in the herd; includes lactating cow, 330 days; dry cow, 35 days; heifer, 222 days; and calf, 165 days.

[e] Weights assumed: beef, 1,000 pounds.; dairy, 1,200 pounds.; swine, 150 pounds.

[f] Wet basis at 41 percent moisture.

TABLE 3

NUTRIENTS EXCRETED BY ANIMALS

MANAGEMENT SYSTEM	N	P_2O_5	K_2O	
LIQUID, PIT	---- lbs./space/yr. ---			gals./day
Swine				
Nursery, 25 lbs.	2	1	1	0.2
Grow-finish, 150 lbs. (wet/dry)	23	17	12	0.84
Grow-Finish, 150 lbs. (dry feeds)	21	15	11	1.2
Grow-Finish, 150 lbs. (earthen)	14	10	9	1.2
Gestation, 400 lbs.	14	14	14	1.6
Sow and litter[a], 450 lbs.	32	26	19	3.5
Farrow-nursery[b]	22	18	18	2.2
Farrow-finish[c]	150	109	82	9.4
Dairy—confined				
Cows, 1,200 lbs. or more	129	65	108	11.8
Heifers, 900 lbs.	97	48	81	8.8
Calves, 500 lbs.	54	27	45	4.9
Veal calves, 250 lbs.	27	13	22	2.5
Dairy herd[d]	203	101	169	18.5
Beef—confined				
Mature cows, 1,000 lbs.	105	66	92	7.2
Finishing, 900 lbs.	95	59	83	6.5
Feeder calves, 500 lbs.	53	33	46	3.6
LAGOON[e]	--- lbs./space/yr. ---			gals./day
Swine				
Nursery, 25 lbs.	1	0.7	1	0.7
Grow-finish, 150 lbs.	6	5	6	4.1
Gestation, 400 lbs.	5	4	5	3.7
Sow and litter[a], 450 lbs.	11	8	11	7.5
Farrow-nursery[b]	8	6	8	5.4
Farrow-finish[c]	44	33	44	30
Dairy—confined				
Cows, 1,200 lbs. or more	59	44	59	40.1
Heifers, 900 lbs.	44	33	44	29.9
Calves, 500 lbs.	24	18	24	16.5
Veal calves, 250 lbs.	12	9	12	8.2
Dairy herd[d]	87	66	87	59.8
Beef—confined				
Mature cows, 1,000 lbs.	23	17	23	15.7
Finishing, 900 lbs.	19	14	19	13.1
Feeder calves, 500 lbs.	11	8	11	7.3

MANAGEMENT SYSTEM	N	P_2O_5	K_2O	
OPEN LOT RUNOFF	---- lbs./space/yr. ---			gals./day
Earthen lots (liquids)				
Beef, 400 sq. ft./hd.	5	2	11	4.9
Dairy, 1,000 sq. ft./hd.	15	5	29	13.5
Swine, 50 sq. ft./hd.	1	0.3	2	0.7
Concrete lots (liquids)				
Beef, 400 sq. ft./hd.	3	1	4	1.6
Dairy, 1,000 sq. ft./hd.	7	2	8	3.2
Swine, 50 sq. ft./hd.	3	1	2	0.5
SOLID MANURE (BEDDED)	--- lbs./space/yr. ---			T./hd./yr.
Swine—confined				
Nursery, 25 lbs.	5	3	4	0.34
Grow-finish, 150 lbs.	29	18	23	2.05
Gestation, 400 lbs.	39	25	30	2.77
Sow and litter, 450 lbs.	86	55	68	6.16
Farrow-nursery	85	55	67	6.09
Farrow-finish	172	110	135	12.25
Dairy—confined				
Cows, 1,200 lbs. or more	239	120	239	19.93
Heifers, 900 lbs.	179	90	179	14.95
Calves, 500 lbs.	100	50	100	8.3
Veal calves, 250 lbs.	50	25	50	4.15
Dairy herd	393	197	393	32.77
Beef—confined				
Mature cows, 1,000 lbs.	147	73	147	12.23
Finishing, 900 lbs.	132	66	132	11
Feeder calves, 500 lbs.	73	37	73	6.11
Open lot (solids - scraped)				
Beef, 400 sq. ft./hd.	66	48	42	3
Dairy, 1,000 sq. ft./hd.	127	69	127	11.5
Swine, 50 sq. ft./hd.	18	17	11	1.2
POULTRY	----lbs./1,000 birds/yr. ----			T./1,000 birds/yr.
Layer, caged, 4 lbs.	367	840	525	10.5
Broiler, litter, 2 lbs.	585	585	405	9.0

[a] Sow and litter figures are per farrowing crate.
[b] Farrow-nursery figures are per sow in the breeding herd and include one farrowing sow, five gestation sows, and nine nursery pig spaces.
[c] Farrow-finish figures are per sow in the breeding herd and include one farrowing sow, five gestation sows, nine nursery pigs, and 36 finishing pig spaces.
[d] Per productive cow in the herd; includes lactating cow, 330 days; dry cow, 35 days; heifer, 222 days; and calf, 165 days.
[e] Weights assumed: beef, 1,000 pounds.; dairy, 1,200 pounds; swine, 150 pounds.

TABLE 4

CORRECTION FACTORS TO ACCOUNT FOR NITROGEN VOLATILIZATION LOSSES DURING LAND APPLICATION OF ANIMAL MANURE

APPLICATION METHOD	CORRECTION FACTOR
Direct injection	0.98
Broadcast and incorporate within 24 hours	0.95
Broadcast and incorporate after 24 hours	0.80
Broadcast liquid, no incorporation	0.75
Broadcast dry, no incorporation	0.70
Irrigation, no incorporation	0.60

Source: Iowa Department of Natural Resources

TABLE 5

NUTRIENT REMOVAL FOR IOWA CROPS

		------------------------- Pounds/Unit	-----------------------	
-				
CROP	**UNITS**	**N**	**P_2O_5**	**K_2O**
Corn	bu.	-	0.375	0.3
Corn Silage	ton (65% H_2O)	-	3.5	6.5
Soybeans	bu.	3.8	0.8	1.5
Alfalfa	ton	50	12.5	40
Oat and Straw	bu.	0.75	0.4	1.0
Wheat	bu.	1.3	0.6	0.3
Smooth brome grass	ton	40	9	47
Orchardgrass	ton	38	14	68
Tall fescue	ton	38	12	66
Switch grass	ton	21	12	66
Sorghum-sudan	ton	40	12	38
Vetch	ton	56	12	47
Red clover	ton	43	10	33
Perennial ryegrass	ton	24	12	34
Timothy	ton	25	9	32
Wheat straw	ton	13	4	25
Oat straw	ton	12	5	33

TABLE 6

NITROGEN FERTILIZER RECOMMENDATIONS FOR MANURED[a] SOILS AND CORN AFTER ALFALFA

(from Blackmer, Voss, and Mallarino, 1997)

		------------------ Recommended N rate ------------------	
GRAIN AND FERTILIZER PRICES	SOIL TEST NITRATE	EXCESSb RAINFALL	NORMAL RAINFALL
	ppm N	lbs. N/acre	lbs. N/acre
Unfavorable (1 bu. buys 7 lbs. of N)	0-10	90	90
	11-15	0	60
	16-20	0	0c
	>20	0	0
Favorable (1 bu. buys 15 lbs. of N)	0-10	90	90
	11-15	60	60
	16-25	0	30
	>25	0	0

[a] A field should be considered manured if animal manures were applied with a reasonable degree of uniformity since harvest of the previous crop or in two of the past four

TABLE 7

PRIORITY RANKING OF FIELDS FOR ANIMALS MANURE APPLICATION BASED ON SOIL TEST FOR PHOSPHORUS AND POTASSIUM AND THE CROP TO BE GROWN

SOIL TEST	A GROUP[a]	B GROUP[b]
Very Low	1	3
Low	2	4
Optimum	5	6
High	7	8
Very High	9	10

[a] Corn, sorghum, oats, wheat, sunflowers
[b] Soybean, alfalfa