Cooperative Extension Service
Colorado State University
Fort Collins, Colorado 80523

AGRON-O-GRAM

May, 1986

We have four subjects in this newsletter. Calvin Pearson, Harold Golus and Phil Micklas wrote an excellent paper on "Conducting Off-Station Agronomic Research." They have provided some very good general guidelines for researchers, extension agents, and others to work with farmers to conduct research on their farms. John Shanahan and Dan Smith have written an article on "Chemical Treatments in Hay Preservation Systems." This article may help answer some of the questions that we have been getting on hay preservatives. We have been getting some questions on the irrigation of winter wheat. Wayne Shawcroft and Bob Croissant have written an article on "Irrigation of Winter Wheat in Colorado."

Last July, the Soil Testing Laboratory started a domestic water quality test. Since then, we have received over 1400 water samples. Hunter Follett and Steve Workman have written an article that explains the domestic water quality test. The Soil Testing Laboratory offers three different tests for water--Irrigation, Livestock, and Domestic. The cost for the routine water tests for each of these three tests is $12.50. Water sample information sheets and sampling bottles can be obtained from the Soil Testing Laboratory.

There are three new Service In Action Sheets that have recently been published. They are: No. .100, Sesame Production, No. .109, Pearl Millet Cultivation in Colorado, and No. .110, Rapeseed Production in Colorado. If you do not have these SIA publications, they can be obtained from the Bulletin Room.

Sincerely,

Hunter Follett — Bob Croissant — James W Echols

R. Hunter Follett	Bob Croissant	James W. Echols
Extension Specialist	Extension Specialist	Extension Specialist
Soils	Crops	Crops

FILE: AGRONOMIC RESEARCH
MAY, 1986

CONDUCTING OFF-STATION AGRONOMIC RESEARCH

BY

CALVIN H. PEARSON, HAROLD M. GOLUS, AND PHILLIP N. MIKLAS[1]

Off-station agronomic (field crop) research is routinely conducted by CSU personnel. Studies conducted on-farm allow researchers to test ideas, determine application of laboratory and greenhouse results, and evaluate technology developed in other climates and field practices. This permits farmers to observe new methods, equipment, products, and plant materials first-hand. The objective of this report is to promote high quality off-station research by providing farmers, extension agents, and others with general guidelines for conducting off-station agronomic research.

PLANNING

Cooperators (farmers) are usually very willing to permit researchers to conduct research on their farms. Communication between researcher and cooperator is essential and should begin well ahead of the start of the experiment. The local extension agent can provide worthwhile assistance in identifying and working with cooperators. The researcher should have a planning meeting with the cooperator, extension agent, and others to discuss objectives, field procedures, application of chemicals, fertilizers and pesticides, and other details of the research. Financial matters related to the experiment and a possible field tour at the site should also be discussed during the planning meeting. In some cases, a telephone planning meeting may be adequate. The researcher should consider making a written summary of the arrangements and forwarding it to the cooperator. The summary could also include liability considerations of the researcher and cooperator that relate to the research.

Subsequent discussions between the researcher and cooperator will often avoid problems encountered during the experiment. Despite thorough planning, unexpected problems may occur (e.g., insect, weather, and disease problems); thus, the researcher and cooperator should be in communication with each other during the experiment.

SITE SELECTION

The site for the experiment should be thoughtfully selected. The extension agent can provide valuable

1/Calvin H. Pearson, CSU assistant professor; Harold M. Golus, CSU assistant professor; Phillip N. Miklas, CSU research associate, all department of agronomy, Fruita Research Center, Fruita, Colo.

suggestions for a suitable site for the experiment. Uniform, representative soils for the locality should be used. Select an area of the field where soil variation within the experiment is minimized and where horses, cattle, dogs, deer, rodents, or other domestic and wild animals will not damage plants or disturb the area. Avoid old plow furrows, low spots in the field where water may collect, turn rows for equipment, and areas where soil compaction, snow drifts, or other undesirable conditions may exist or occur. Areas where buildings, trees, or other objects may shade part or all of the experiment at any time during the day, or cause otherwise abnormal situations in the experiment site, should also be avoided. We suggest that a minimum of 50 to 100 feet separate the edge of the experiment from fences, ditches, buried pipelines, or other structures.

SEEDBED PREPARATION AND PLANTING

The condition of the seedbed has a direct impact on planting and subsequent seed germination, plant emergence, and crop growth. Consequently, seedbed preparation is an important consideration in field experimentation. Seedbed preparation and planting on the site may require practices and equipment different from those used on large acreages. This may be necessary to accommodate the objectives of the study, small plots, or specially designed equipment. The researcher may plant the research plots with his own equipment.

CULTURAL PRACTICES

Cultural practices are defined as field operations performed during the cropping season. These include planting, tillage, pest control, fertilizer application, and harvesting operations. The cultural practices used in field research may or may not be similar to those used traditionally by the cooperator. The design of the experiment may require modification to accommodate cooperator's equipment. For example, an expanded four-row plot (achieved by a slight change in the planting method using a four-row plot planter) may be necessary to allow for six-row cooperator equipment. During the planning meeting the cultural practices needed in the experiment should be discussed.

HARVESTING

Harvesting the experiment area is often accomplished with equipment provided by the researcher. This equipment is specially designed for small plots. However, occasionally the cooperator's commercial equipment is needed. The researcher should discuss harvest needs with the cooperator before field work begins and confirm plans as harvest approaches. The cooperator should contact the researcher to inform him when the plots will be ready for harvest. A few days of advance notice will allow time to prepare equipment and arrange schedules. Occasionally, inclement weather occurs and schedule changes become necessary. During harvest cooperators and extension agents are invited to be present. This often provides a good opportunity for researchers, extension agents, and cooperators to exchange ideas and information. Disposition of the harvested commodity should be discussed between the researcher and the cooperator. The researcher may need to transport the harvested plot samples to the laboratory for analysis and arrangements should be made to return the samples if desired by the cooperator.

DATA COLLECTION AND PROCESSING

Once harvested plot samples are processed to determine factors of interest (e.g., seed yield, seed quality, forage yield, moisture content). The data are statistically analyzed to characterize responses and to determine if differences between treatments (e.g., varieties, fertilizer rates, tillage practices) are significant or if these differences are just due to chance. The researcher interprets the results and usually writes a summary of the experiment. Depending on many factors, the results of the experiment may be available within a few days, or several weeks may be required to organize, summarize, analyze, and interpret the data. Final results of experiments may not be available until data for several years are collected.

DISSEMINATION OF RESULTS

A summary and interpretation of data collected over a 2- or 3-year period is often published. Publications may be experiment station technical bulletins and reports, articles for newspapers or magazines, or technical journal papers. Copies of these publications, particularly experiment station reports, are usually available from local extension offices. Check with your local extension agent for the latest agronomic information for your area. If you are interested in the results of particular tests, contact the researchers directly. They will be happy to discuss the results of the research with you and consider your suggestions for improvement of future experiments.

CHEMICAL TREATMENTS IN HAY PRESERVATION SYSTEMS

J.F. Shanahan and D.H. Smith[1]

Introduction

Growing a good forage crop is only the first step in producing a quality hay crop. The way forage is harvested and stored determines how well the quality of the standing crop is preserved.

Large quantities of water must be passively removed from cut forage during field-curing of hay. For each ton of 12% moisture hay produced, approximately 1.7 and 2.2 tons of water is removed from the fresh herbage of grasses and legumes, respectively. The time for field curing is variable and depends on weather conditions and mechanical handling at cutting. The rate of drying is accelerated by low relative humidity, high air temperature and good air movement around the cut forage. Since the leaves of cut herbages lose water more rapidly than stems, mechanical conditioning (crushing or crimping) can also reduce the time required for curing. However, this effect is generally greater for legumes than grasses.

Reducing the curing time is of critical importance in haymaking. Dry matter losses (ranging from 4 to 15%), due to respiration, continue until the plant moisture content is reduced to approximately 35%. Dry matter losses associated with leaf shattering during the curing process have been estimated to range from approximately 2 to 5% for grasses and 3 to 35% for legumes. Prolonged periods of curing also increase the potential for losses due to rainfall. Leaching, leaf shattering, and excessive biological decomposition are commonly observed consequences of rainfall during field curing. Rain can also indirectly contribute to losses during curing, since rain-soaked hay frequently requires additional raking, resulting in further leaf shattering.

All the various kinds of dry matter losses that occur during haymaking contribute to serious losses in nutritive value. This is because the most nutritious components of the plant are most susceptible to loss. Therefore, management practices that reduce these losses will always result in hay quality improvement.

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Recent advances in haymaking technology employ chemical treatments to reduce dry matter losses during field curing. The two types of chemicals used are 1) preservatives and 2) drying agents. Hay preservatives are designed to reduce microbial activity and spoilage in high moisture hays. Drying agents accelerate curing rates to reduce the chances of exposing hay to rainfall.

Preservatives

The use of hay preservatives permits greater flexibility in haymaking operations. Hay can be baled at moisture levels of up to 35%, thereby reducing the time required for curing. This reduces the severe leaf shattering losses associated with handling dry forage. Since moisture content is difficult to determine accurately in curing windrows, preservatives can ensure proper preservation when hay is baled at moisture levels of between 20 and 35%.

Anhydrous ammonia has fungicidal properties and has been used successfully in the preservation of high-moisture hays. Use of 1% anhydrous ammonia has been shown to reduce storage dry matter losses and prevent heating and mold development in hays containing up to 32% moisture. Increased crude protein content is an additional benefit of ammonia preservation. However, this method of chemical preservation has not received wide acceptance because of problems in supplying the ammonia to large volumes of hay. Recent data suggest that dry urea could be used as an alternative to anhydrous ammonia in preserving high-moisture hays and increasing the crude protein content of poor-quality hays. However, application equipment has not yet been developed for this material; therefore, use of this material is presently not recommended on a commercial basis.

Organic acids have been the most widely accepted hay preservatives. Materials such as propionic acid and ammonium isobutyrate act as fungicides to reduce mold development, heating and deterioration in hays baled at high moisture content. The most common commercial formulations consist of propionic acid and mixtures containing propionic acid and ammonium isobutyrate, acetic acid or formaldehyde. Flavoring ingredients have also been added to some of the commercial products.

Organic acid preservatives must be applied at an appropriate rate as the hay is fed into the baler. Applicators consisting of a corrosion-resistant tank, a 12-volt pump powered by the tractors' electrical system, spray nozzles and plastic tubing are commercially available and can be attached directly to most conventional balers. Recommended application rates are based on the moisture content of the hay (Table 1). These rates are appropriate for propionic acid alone, mixtures of propionic acid and acetic acid (80:20%) of formaldehyde (70:30%), and ammonium isobutyrate. Although hays containing moisture levels higher than 35% moisture can be effectively preserved with these materials, the practice is not recommended because of preservative costs and difficulty of handling wet bales.

Certain precautions should be observed in using organic acid-based preservatives. Goggles and protective clothing should be used in mixing or transferring the material, and water should be available at all times to flush affected areas if an accident occurs. Equipment surfaces and applicator systems should be thoroughly washed and flushed immediately after use to prevent excessive corrosion.

Table 1. Recommended application rates for organic acid hay preservatives.

Hay moisture content	Application rate	
% of fresh weight	% of D.W.	lb. chemical/ton of D.W.
20-25	0.5	10
25-30	1.0	20
30-35	1.5	30

Source: Clark, P., G.T. Lane and J.K. Evans. Hay preservatives. University of Kentucky Cooperative Extension Bulletin (ID 46).

Treated hay should be stored under protective cover because the preservatives can be leached or diluted easily on outer surfaces by rainfall. Preserved hay should not be stored in contact with normally field-cured hay, since the drier hay can absorb moisture and mold development is possible.

The cost effectiveness of organic acid preservatives is difficult to determine. Obviously, their cost is minimal compared to losing an entire hay crop because of inclement weather. Detailed assessments of less severe alternatives indicate that the cost of the preservatives is justified when the value of the treated hay is compared to that of rain-damaged or wet (greater than 25% moisture) hay. However, preservatives are not cost-effective when hay can be produced with minimal leaf loss under "ideal" curing conditions.

Other hay preservatives have been evaluated on a limited basis, but have not yet received widespread scrutiny. Several microbial additives have been shown to be effective in preventing heating and mold development in wet hays. However, their effectiveness appears to be limited to hay containing 20-25% moisture; therefore, use of these materials is questionable considering the proven value of organic acids.

<u>Drying Agents</u>

Treatments designed to accelerate drying rates of forages reduce the potential for rain damage during field-curing.

Mechanical conditioning has long been used to accomplish this purpose. Recently, chemical drying agents have been proposed as an additional means of reducing the duration of field-curing.

Preliminary studies conducted in Australia suggested that potassium carbonate solutions were effective in increasing drying rates of alfalfa. Subsequent research has confirmed these results and demonstrated increased effectiveness of using combinations of potassium carbonate and emulsions of fatty acid esters. Most results with alfalfa indicate that curing times can be reduced by at least one day. They are least effective under cool, humid conditions. Evidence available suggests that drying agents are of limited effectiveness with grass hay.

Several different carbonate-based commercial formulations are available and have generally produced similar results when used on alfalfa. The carbonate-based drying agents function by modifying the waxy cutin layer of the plants so it is more permeable to water. The formulations are most effective when applied to stems at cutting. Commercially available applicator kits include a holding tank and pump, hoses, nozzles, and deflector bar mounted in front of the header about 8 to 10 in. above the cutting level. This device pushes plant tops over so the spray can be directed primarily at the stems.

Current projections using solutions containing potassium carbonate alone indicate that this treatment is cost effective for alfalfa except under cool, humid conditions. Since sodium carbonate is much cheaper, solutions containing a mixture of one-half potassium carbonate and one-half sodium carbonate may make the cost effectiveness of this treatment even more favorable.

Summary

Hay preservatives and drying agents allow for increased flexibility in haymaking systems. Under certain conditions, they can greatly increase the efficiency of nutrient preservation. However, individuals should carefully assess the magnitude of problems in their current hay handling operations before making a decision on the use of these materials.

An additional factor is important in evaluating the potential benefits of preservatives and drying agents in a given situation. Certain commercial formulators fail to indicate the composition of their products. This causes considerable confusion for hay producers because the nature of the product determines how it should be used and the anticipated benefits. If a preservative is justified, the organic acid-based formulations have proven most successful. Of the drying agents available, carbonate-based products which also contain fatty acid esters have proven to be most beneficial. Before making a final decision one should know the general composition of the products to be evaluated.

IRRIGATION OF WINTER WHEAT IN COLORADO

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Winter wheat is predominantly a dryland crop in Colorado, but the importance of winter wheat as an irrigated crop has increased as farmers have become concerned with reducing the costs of pumping water for crop production. While the irrigation of winter wheat can produce relatively high yields, some irrigation management techniques are important in producing consistently high yields with minimum input costs. Winter wheat will respond to additional water in Colorado as is shown in Table 1.

Table 1. Average yields of winter wheat variety trials under irrigated or dryland condition in eastern Colorado during 1984 and 1985.

	Dryland		Irrigated	
	Yield Bu/A	Number of Locations	Yield Bu/A	Number of Locations
1984	45.8	17	87.2	7
1985	52.8	19	91.4	6

The Wheat Plant

Wheat grows best under dryland conditions where stored water promotes a deep, extensive root system. Irrigation practices should be conducted to provide soil water storage promoting the development of this type of root system. The amount and timing of irrigation on wheat and water storage will depend on the type of soil, i.e. sandy vs. silt or clay loams (See Table 2).

Table 2. Available water holding capacity of different textured soils.

Soil Texture	Inches of Water/Foot of Depth
Coarse Sand	0.75
Fine Sand	1.00
Fine Sandy Loam	1.50
Silt Loam	2.00
Clay Loam	2.20
Heavy Clay	2.00

Wheat Water Use

During fall growth, moisture is removed primarily from the top foot of soil. The wheat plant will extract most of its moisture from the 0-4 foot depth in the spring. As the plant develops and moisture needs increase, the root system will continue to develop and compete in zones where soil moisture is present. If needed, the plant will use moisture from the 4-6 foot zone to meet its water needs. Total water use by winter wheat will vary but under optimum soil moisture conditions, total seasonal use may reach 23-24 inches (see Figure 1).

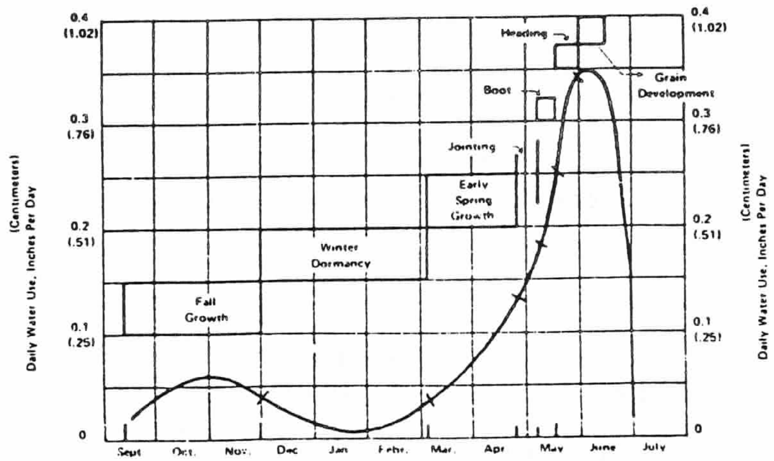

Figure 1. Characteristic water use of winter wheat.

General rules regarding water requirements by wheat are that the crop needs about 3-5 inches of water from seeding until April 1, and it takes about 9 inches of additional water to produce the first bushel of grain. Wheat will produce from 2 to 6 bushels for each additional inch of water thereafter depending on evapotransporation during the heading and grain filling period.

Critical Timing of Irrigations

There are two growth stages where irrigations will promote the greatest increase in yields. The first critical period is the fall vegetative stage where a single irrigation should fill the soil profile to a depth of 4-6 feet on flood or furrow irrigated fields. With sprinkler irrigation, filling the profile becomes more difficult, since the amount of water necessary cannot be applied in a single application. The center pivot should be adjusted to turn very slow and apply as much water as possible on a single pass.

A fall application of two inches on sandy soil or four inches on clay loam soil should be adequate to fill the soil profile about two feet deep. This level of irrigation will allow the soil to store winter moisture, if available.

After spring growth begins, irrigation amounts are based on the amount of water used over the winter. In a normal year, water should be applied to loamy soils in the late boot stage. Earlier irrigation will produce rank growth and may cause lodging.

Obviously, runoff and erosion problems must be considered when using a high application rate. Several light sprinkler applications will only keep the water near the surface causing high evaporation losses and reduced infiltration rates. High amounts of crop residue on or mixed in the surface soil is helpful when applying large amounts of water with a center pivot system.

If the soil profile is filled to a depth of 6 feet in the fall, additional water probably will not be necessary until the boot stage. Avoid irrigations during the early spring vegetative period, because they have the tendency to promote "straw" rather than grain. Irrigations during this period are only necessary if there has been a warm, dry winter or in case of very coarse sandy soils. Monitoring soil moisture early in March and then later during the boot stage is important in determining if additional water is necessary. To monitor soil moisture, a moisture probe (steel rod with ball bearing tip), a soil tube that will extract a core from the soil profile, or simply a shovel is helpful in determining the presence of moisture in the root zone. For more information in estimating soil moisture, see SIA No. 4.700, "Estimating Soil Moisture for Irrigation." The need for early spring irrigations is more likely with sandy soils, because of the low water holding capacity.

Irrigation from the boot stage through the bloom stage will increase grain yield and test weight. The boot through bloom stage occurs during the highest precipitation month (May) of the year. Late irrigation near the dough stage may be beneficial, but the result may be a higher incidence of lodging.

Fertilizer Management

Nitrogen requirements will depend heavily on the cropping system, i.e., wheat after fallow, wheat after corn or continuous wheat. Soils in eastern Colorado testing 25-30 ppm NO_3-N in the soil with 1.1 to 1.5% organic matter require 25 lb. of additional nitrogen per acre to provide a nutrient level capable of 100 bu/a (See Table 3). On the other hand, soils with 0-6 ppm NO_3-N and less than 0.5% organic matter will require up to 130 lbs. of nitrogen per acre for the 100 bu/a yield level. Soil testing is highly recommended and the best way to accurately determine fertilizer requirements.

Table 3. Nitrogen recommendations for wheat with 100 bu/a yield goal.

NO_3-N soil test ppm	Soil Organic Matter - % 0-0.5	0.6-1.0	1.1-1.5	1.6-2.0	>2.0
	Fertilizer N - lbs/a				
0-6	130	120	105	90	75
7-12	110	100	85	70	55
13-18	90	80	65	50	35
19-24	70	60	45	30	20
25-30	50	40	25	0	0
31-36	30	20	0	0	0
>36	0	0	0	0	0

Adjust N recommendation for yield goal different from 100 bu: add 15 lb N for each 10 bu above 100 bu; subtract 10 lb N for each 10 bu below 100 bu.

Special Note: Increase above recommendations for wheat and barley by 40 lb N in the following counties: Alamosa, Conejos, Costilla, Rio Grande and Saguache.

With furrow irrigated fields, it is desirable to apply nitrogen during or after pre-plant irrigation to avoid leaching losses. For sprinkler irrigated fields, some of the nitrogen can be applied through center pivot irrigation systems. Nitrogen, phosphorus and other fertilizers nutrient should be applied on the basis of the fertilizer test.

Continuous Cropping vs. Rotations

Continuous irrigated wheat in a rotation is not a successful practice because of the consistent yield decline over a period of years. This decline occurs because of the difficulty in deep water penetration from center pivot sprinklers. Nutrient deficiencies disease problems and insect or weed pressures may become significant problems in continuous irrigated wheat. It is recommended that irrigated wheat be incorporated into a rotation where possible. Wheat fits quite well in rotations because peak irrigation times for wheat do not coincide with peak demand times for other crops, i.e., corn, beans, etc.

Varieties

The results from irrigated variety trials located throughout Colorado should be used to aid in selecting a variety for a particular location. For irrigated fields, the short semidwarf varieties have had consistently high yields and are preferred to avoid lodging.

Important Points to Consider:

1. Fill the soil profile to a depth of 2-4 feet in the fall.

2. With adequate surface moisture and soil fertility, adventitious root formation and subsequent tillering will be promoted.

3. Avoid irrigations during March and April as this practice encourages rank growth that may cause lodging.

4. With normal conditions on fine textured soils, apply the second irrigation when the wheat plants are in the late boot stage to early heading.

5. More frequent irrigations are needed on sandy soils since they hold less water per foot of storage.

6. The number of irrigations (amount of water) is a function of water needed and type of irrigation equipment (sprinkler, flood, furrow).

7. The use of some soil moisture monitoring device such as a soil probe is necessary to aid in determining available soil moisture.

FILE: WATER ANALYSIS
MAY, 1986

DOMESTIC WATER QUALITY CRITERIA

BY

R. H. FOLLETT AND S. M. WORKMAN[1]

The appearance, taste, or odor of water from a well or some other source offers some information on obvious contamination but it must be realized that chemical analysis is needed to detect most contamination in water. Obvious contaminates include silt (turbidity) and hydrogen sulfide which can be detected by smell, but as a rule, your senses will not detect impurities that cause hard water, corrode pipe, and stain sinks. Two types of tests--bacteriological and chemical--are used to assess water quality. The two tests are separate and distinct, and normally are not made in the same laboratory at the same time. The Colorado State University Lab is equipped to analyze chemical tests rather than bacteriological tests. The analysis is for determining chemical constituents of water as they relate to drinking or irrigation purposes. Questions about testing water for bacterial or microbial contamination, including Giardia, should be directed to your local health department.

Bacteriological Test

Bacteriological tests are used to determine if water is bacteriologically safe for human consumption. There are tests based on detection of coliform bacteria, a group of microorganisms that are recognized as indicators of pollution from human or animal wastes. Coliform bacteria are found in the intestinal tracts and fecal discharges of humans and all warm-blooded animals. Anyone desiring to have a bacteriological test performed on their drinking water should contact the local County Health Department to obtain the specially prepared bottles and instructions for taking a water sample. It is important to note that special techniques are required to collect samples because you could contaminate the samples if procedures are improper. If the county does not offer a bacteriological test for water, you can contact the following address: Colorado Department of Health, 4210 E. 11th Avenue, Denver, CO 80220, Phone 303-320-8333.

Chemical Tests

Chemical tests are used to identify impurities and other dissolved substances that affect the use of water for domestic purposes. Water begins to decrease in palatability when the amount of minerals, i.e., dissolved salts, exceeds 500 to 1000, but, this does depend on the nature of the minerals. Note that sea water contains 30,000 ppm of dissolved salt. Beyond these limits, the water becomes increasingly unpalatable. Table 1 lists the constituents and parameters that are routinely determined on a water sample by the

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[1]R. H. Follett, Professor, Extension Specialist (Soils) and S. M. Workman, Research Associate.

Colorado State University Soil Testing Laboratory. Table 2 is a list of additional constituents that can be determined on request in water by the CSU Soil Testing Laboratory.

Table 1. The parameters determined for the routine domestic water analysis test.

Parameter	Recommended[a] Limits-mg/l
Conductivity (Micromhos/Cm)	*
pH	*
Calcium	*
Magnesium	*
Sodium	20
Potassium	*
Carbonate	*
Bicarbonate	*
Chloride	250
Sulfate	250
Nitrate	45[b]
Total Alkalinity as $CaCO_3$	400
Hardness as $CaCO_3$	*
Total Dissolved Solids	500
Boron	*

[a]Limits recommended for good quality domestic water. Limits suggested by U.S. Environmental Protection Agency; National Academy of Science. 1980. Vol. 3, Washington, D.C.
[b]Mandatory upper limit for nitrate (NO_3).
*Limits not established.

Table 2. Additional tests that can be determined in water on request.

Constituent	Mandatory Upper Limit-mg/l[a]
Arsenic	0.05
Selenium	0.01
Chromium	0.05
Fluorine	2.4
Barium	1.0
Cadmium	0.01
Mercury	0.002
	Non-Mandatory Suggested Limits-mg/l
Zinc	5.0
Iron	0.3
Manganese	0.05
Copper	1.0
	Limits Not Established
Aluminum	--
Ammonium	--
Phosphorus	--
Nickel	--
Molybdenum	--

[a]Mandatory upper limits suggested by U.S. Environmental Protection Agency.

The Laboratory Report-What Do The Numbers Mean?

Most testing laboratories report quantities of chemical substances by weight in volumetric units such as milligrams per liter (mg/l). For all practical purposes, 1 ppm = 1 mg/l.

The factors reported on a water analysis report are discussed below and represent the parameters that are considered in the evaluation of domestic water quality.

pH is a measure of intensity of alkali or acid contained in the water. Absolutely pure water has a pH value of 7.0. In Colorado, the pH of well water will normally be between 6.5 and 8.0. Water with pH less than 5 may cause problems due to corrosion since many metals become more soluble in low pH waters. Water with pH values higher than 8.5 indicate that a significant amount of sodium bicarbonate may be present.

Calcium and Magnesium cause water hardness and result from limestone-type materials in underground soil layers. Separate values are of minor concern but they are combined for calculating hardness.

Hardness is the soap-consuming capacity of water; that is, the more soap required to produce lather, the harder the water. Hard water also causes greasy rings on bathtubs, greasy films on dishes or on hair after washing, and poor laundry results. Problems caused by hard water in bathing or washing may be overcome by the use of synthetic detergents or packaged "softening" compounds. The hardness of water may be removed by a water softening unit containing exchange resins, but this results in the exchange of calcium and magnesium (Ca + Mg) by sodium so it may be a concern to persons on a low-salt diet for medical reasons. Such water should not be used for gardens, lawns or plants. Hardness is reported as calcium carbonate in milligrams per liter (mg/l). A commonly used classification for hardness is given in the following table:

Table 3. Hardness expressed as mg/l of $CaCO_3$.

mg/l or ppm[a]	Water hardness
0-75	Soft
75-150	Moderately hard
150-300	Hard
Over 300	Very hard

[a]When expressed as grains of hardness, 1 grain = 17.1 mg/l (ppm).

Sodium may be of health significance to persons on a low-salt diet for medical reasons. Sodium can be reduced or removed by expensive treatment systems, but when Ca + Mg are removed from water by passing through a water softener, sodium replaces it.

Potassium is an essential nutritional element, but its concentration in most drinking water is trivial and quantities seldom reach 10 mg/l.

Carbonates and Bicarbonates are the major contributors to the "total alkalinity" that may be determined in a routine water-test. The alkalinity of a water sample is a measure of its ability to neutralize acids. Although this property may be of interest to technicians and scientists concerned with water treatment, the numbers that appear on the water-test report usually have little meaning for the farmer or homeowner.

Chloride concentrations in drinking water may be important to persons on low salt-diets. Most persons will detect a salty taste in water containing more than 250 mg/l of chloride. Expensive treatment methods are needed to remove chloride from water.

Sulfate content in excess of 250 to 500 ppm (mg/l) may give water a bitter taste and have a laxative effect on persons not adapted to the water. Expensive treatment methods are necessary to remove or reduce sulfate in a private water system.

Nitrate in excess of 45 mg/l (or in excess of 10 mg/l if reported as nitrate-nitrogen) is of health significance to pregnant women and infants under six months of age. High nitrate water should not be used for infant formulas or in other infant foods. Considerably higher nitrate content apparently is tolerated by most adults. Nitrate can be removed from private water supplies, but the equipment is expensive and not commonly used.

Total Dissolved Solids also called "total mineral content" or "total residue," is merely the total amount of material remaining after evaporation of the water. Values of less than 500 ppm (mg/l) are satisfactory and up to 1,000 ppm (mg/l) can be tolerated with very little effect.

Fluoride is important in the development of teeth in infants and youth. The optimum fluoride content to assist in the control of tooth decay is 0.9 to 1.5 ppm (mg/l). Excessive amounts are rarely found in Colorado waters, but a concentration over 3.0 ppm (mg/l) may cause darkening of the tooth enamel and possibly other undesirable effects.

Iron and Manganese are nuisance chemicals which cause troublesome stains and deposits on light-colored clothes and on plumbing fixtures. Iron causes yellow, red or reddish-brown stains and deposits, while manganese stains and deposits are gray or black. Excessive amounts may also cause dark discoloration in some food and beverages and cause an unpleasant taste. Iron and manganese can be removed or reduced in a softener equipped with special resins or by small treatment systems involving aeration, filtration and chlorination.

Copper and Zinc will cause an undesirable taste if concentrations are above the recommended limits. A water softening system should significantly lower the levels of these elements.

Arsenic, Selenium, Barium, Cadmium, and Mercury are potentially toxic elements. Fortunately, these elements rarely exceed the mandatory limits in most Colorado well water. If high concentrations are found, it would be necessary to remove these elements using expensive treatment methods.

Aluminum, Ammonium, Phosphorus, Nickel, and Molybdenum are additional constituents that can be determined by the Colorado State University Soil Testing Laboratory. Although no limits have been established for these parameters, pollution of some sort would be indicated if significant concentrations are detected in a water sample.

Taste and Odor problems are difficult to solve. Some inorganic compounds may impart detectable tastes without odor. Hydrogen sulfide (rotten egg smell), when present, will impart an undesirable odor and taste. Generally, undesirable tastes may be caused by any of numerous organic compounds. These may be present naturally in the water, or may be due to sewage or other surface contamination sources. These may impart disagreeable taste and odor in minute concentrations (a few parts per billion or a few milligrams per kiloliter) and specialized chemical tests are needed to detect such small levels.

Water Treatment Systems

Some water constituents can be removed or reduced by ion-exchange resins, distillation, reverse osmosis or a combination of these methods. Other treatment processes might involve aeration or chemical oxidation followed by filtration. Organics can be removed by filtration through charcoal. Treatment methods are specific to the type of chemical problems and are generally quite costly. For additional information on water treatment systems, refer to SIA Fact Sheet No. 9.728 and 9.729 listed below.

For More Information:

Follett, R. H. and P. N. Soltanpour. 1985. Irrigation water quality criteria. Colo. State Univ. Service in Action No. .506.

Hallaway, Joann. 1983. Drinking water treatment devices:filters. Colo. State Univ. Service in Action No. 9.728.

Hallaway, Joann. 1983. Drinking water treatment devices:distillers. Colo. State Univ. Service in Action No. 9.729.

Soltanpour, P. N., and W. L. Raley. 1982. Evaluation of drinking water quality for livestock. Colo. State Univ. Service in Action No. 4.908.