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SMALL GRAIN PRODUCTION MANUAL PART 5

Irrigation and Water Relations

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This publication, *Irrigation and Water Relations*, is the fifth in a fourteen-part series of University of California Cooperative Extension online publications that comprise the *Small Grain Production Manual*. The other parts cover specific aspects of small grain production practices in California:

- *Part 1: Importance of Small Grain Crops in California Agriculture*, Publication 8164
- *Part 2: Growth and Development*, Publication 8165
- *Part 3: Seedbed Preparation, Sowing, and Residue Management*, Publication 8166
- *Part 4: Fertilization*, Publication 8167
- *Part 6: Pest Management—Diseases*, Publication 8169
- *Part 7: Pest Management—Insects*, Publication 8170
- *Part 8: Pest Management—Vertebrates,* Publication 8171
- *Part 9: Pest Management—Weeds*, Publication 8172
- *Part 10: Small Grain Forages*, Publication 8173
- *Part 11: Small Grain Cover Crops*, Publication 8174
- *Part 12: Small Grains in Crop Rotations*, Publication 8175
- *Part 13: Harvesting and Storage*, Publication 8176
- *Part 14: Troubleshooting Small Grain Production*, Publication 8177

The majority of California's small grain acreage is irrigated, although rainfed grain production is also important, particularly in coastal growing areas and foothill regions of the Central Valley. The wide range of geographic locations and climate where small grains are produced determine the length of the growing season, crop water consumption, and irrigation requirements. Planned end use of the crop and stage of growth at harvest (grain or forage) also affect irrigation requirements. Recognizing and anticipating important stages of small grain growth and development is key to successfully managing irrigation.

SOWING AND SEEDLING EMERGENCE

Irrigation may be required at the onset of the growing season if residual soil moisture from the previous crop and rainfall are insufficient for germination and establishment. A grower must decide whether to preirrigate and then sow the seed into moist soil, to sow the seed and irrigate to germinate the seed, or to sow the seed into dry soil and rely on rainfall for germination. Timely preirrigation during warm, dry weather provides soil moisture for rapid seedling emergence and growth. Preirrigation a month or so before planting (depending on soil type and cropping sequence) is often used in low-rainfall areas such as the southern San Joaquin Valley and the Imperial Valley where soil moisture is likely to be low at planting time. However, preirrigation fol-

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lowed by extensive rainfall can result in inefficient water use, less efficient nitrogen uptake, and higher irrigation costs. If extensive rainfall follows preirrigation, soils may become waterlogged and anaerobic and in turn reduce seedling establishment. In a worst-case scenario, farmlands preirrigated late in the fall and then followed by extensive rainfall may require delayed planting past optimal dates or not be able to be planted at all. Sowing to a dry seedbed and then irrigating risks poor germination and crop loss, particularly on slow-draining soils and if irrigation is followed by an extended period of rainfall. Irrigation can saturate and cool the seedbed to the extent that seed will not germinate and may rot. Where sprinkler irrigation is used and amounts of applied water are more easily controlled, there is less risk of oversaturating the soil. If irrigation is used to germinate the seed, it should be timed for when the chance of rainfall occurring for several days after irrigation is low, thereby giving the soils a chance to drain, aerate, and warm. In general, sowing seed into a dry seedbed and relying on rainfall for germination is more commonly practiced than pre-irrigation or irrigating immediately after planting. Optimal planting dates in late November and December coincide with a time frame when it is reasonable to expect enough rainfall to germinate shallow planted seed and establish sufficiently rooted seedling plants that can then be irrigated in January or February with less risk to crop health. The greatest risk to this approach is that in severe drought years, germination may be substantially delayed and result in a shorter growing season and reduced yields. In fall-sown areas in the northern part of the Central Valley, the Central Coast, and in Northern California intermountain valleys, reliability and quantity of rainfall is usually sufficient to germinate small grains and irrigation is not a concern.

MOISTURE STRESS

Moisture Stress at Vegetative Growth Stages

Early moisture stress may cause the crop to head about 7 to 10 days prematurely; the shortened growth period can reduce yield. Plants tend to increase tillering under early moisture stress, but many tillers die without producing grain-bearing heads. If severe moisture stress occurs during the initiation of tillers, those tillers never develop and plants may produce only the main stem (i.e., one head per plant). The spike that emerges from each tiller is formed during the tillering stage, and by the time the fifth vegetative leaf is visible on each stem, the potential number of spikelets that can grow into mature kernels has been determined. Plants at this stage are sensitive to moisture stress. Plants under moisture stress between the double-ridge stage (the stage in apical development when the primordia that differentiate to become spikelets are visible) and terminal spikelet formation (see Part 2, *Growth and Development*) are likely to form fewer spikelets. Plants under moisture stress during stem extension form fewer florets. Plants sacrifice tillers, spikelets, and/or florets if moisture stress develops after these parts have formed but before development of the parts is complete. As a rule of thumb, the most recently formed tillers, spikelets, or florets are sacrificed first. Small grains are also sensitive to moisture stress at the boot stage.

Moisture Stress at Reproductive Growth Stages

Moisture stress during pollination results in underdeveloped kernels or sterility. The milk stage of kernel development is not as sensitive as the pollination stage, but severe moisture stress should be avoided. Moisture stress during the soft dough stage may result in smaller or shriveled kernels. Adequate moisture extends the grain development period and results in higher grain yields and kernel weights. The kernels begin to dry by the time plants reach the soft dough stage. The hard dough stage signifies the end of grain filling. Plants reach physiological maturity at the end of the hard dough stage. Accurately anticipating this stage of development is important for determining irrigation cutoff and minimizing irrigation costs without compromising yield.

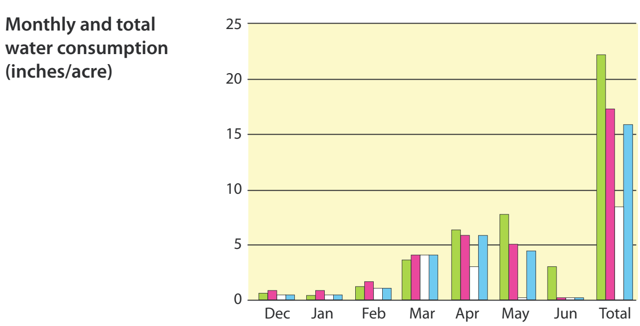
Recognizing Symptoms of Moisture Stress

Early symptoms of moisture stress include dark blue-green leaf color, wrinkled leaf margins, and slight rolling or cupping of leaves. More severe symptoms include a deep blue-green canopy, dead tissue along leaf margins, obvious leaf rolling, shortened and spindly stems, and small immature heads. By the time symptoms of severe moisture stress are apparent, the adverse effect on production is irreparable. Moisture-stressed plants are more susceptible to common root rot and damage by Russian wheat aphid and greenbug. Irrigation before critical growth stages assures that moisture is present when plants reach those critical periods. Checking soil moisture at different depths and different growth stages and knowing crop water needs at critical growth stages are important to avoid yield loss. Among the most common methods for checking soil moisture in the root zone are

- soil feel and appearance
- gravimetric sampling
- tensiometers
- resistance blocks
- neutron scattering
- time domain reflectometry (TDR)

PATTERNS OF WATER CONSUMPTION

Understanding general patterns of crop water consumption is important for anticipating when to irrigate and avoiding moisture stress. Small grain water consumption varies depending on grain type, cultivar, geographic production region and climate, and end use for the crop. Figure 1 provides historical estimates of crop water consumption for fall-sown semidwarf wheat cultivars grown for grain, barley grown for grain, and small grains grown for forage (harvested at boot stage or harvested at soft dough stage) in the Sacramento and San Joaquin Valleys. These historic averages are typically within 20 percent of the actual crop water use in a given year. Despite the inexactness, these estimates represent important patterns of water consumption from germination through maturity and can assist with irrigation decisions, especially if rainfall is monitored and consideration is given to root zone depth and water-holding capacity of the soil. Total crop water consumption is defined here as the quantity of water consumed from germination to harvest or maturity by a healthy, productive small grain crop by plant transpiration and evaporation from the soil surface. Crop water consumption also is referred to as crop evapotranspiration (ETc). Crop water consumption is lower than the irrigation requirement because more irrigation water must be applied to ensure that all parts of the field are adequately irrigated. Typically, an efficiently designed and managed flood, furrow, or sprinkler irrigation system applies about 15 to 35 percent more water than the estimate of crop water consumption.



	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Wheat grain, Dec. 15 emergence	0	0.5	1.1	3.5	6.2	7.8	3	22.1
Barley grain, Dec. 1 emergence	0.5	0.7	1.6	4.1	5.8	4.6	0.1	17.3
Wheat/triticale boot forage, Dec. 1 emergence	0	0.5	1.1	4.1	2.9	0	0	8.6
Wheat soft dough forage, Dec. 1 emergence	0	0.5	1.1	4.1	5.8	4.4	0	15.9

Figure 1. Historical average water consumption by irrigated small grains for the central San Joaquin and Sacramento Valleys.

Water consumption by wheat or triticale in the Central Valley can range from as little as 8 to 9 inches per acre (50 to 56 cm/ha) if the crop is harvested at the boot stage for forage to as high as 22 inches per acre (139 cm/ha) if harvested for grain (see fig. 1). Barley consumes less water than wheat or triticale because it has a shorter growing season, resulting in a seasonal estimate of water consumption in the Central Valley of about 17 inches per acre (107 cm/ha). Crop water consumption on a monthly basis increases gradually, reflecting use during developmental stages from germination through dough stage. When normal or above-normal rainfall occurs, precipitation may be sufficient to meet the crop water consumption needs without irrigation from December through March in the Sacramento and San Joaquin Valleys and other regions of fall-sown small grains, except for desert areas. The months of April and May (corresponding to boot stage through soft dough) are the primary months when irrigation is needed in those areas, but the amount of irrigation depends on rainfall patterns and crop development stage.

ROOT ZONES OF SMALL GRAINS

Small grains have a fibrous root system. Most roots in a fully developed small grain plant's root system are in the top 2 feet (0.6 m) of soil. Under ideal conditions small grains can root to 7 feet (2.1 m) deep by the end of the season. Generally, rooting depths will be deeper in uniform soils than in soils with distinctly different soil layers. The soil layers are physical barriers to both root growth and drainage of water and aeration. Digging backhoe pits to evaluate soil uniformity, soil textures, and evidence of roots following a small grain crop is an effective way to characterize root zone depths for specific fields. Soil texture and structure and the depth of the root zone influence irrigation frequency and the ability to irrigate efficiently. Crops with deeper root zones and finer soil textures require less-frequent irrigation and sometimes less total applied water. Less-frequent irrigation is needed because these conditions provide more stored water for crop consumption between irrigations. Irrigation efficiency is generally greater on deep, fine-textured soils because less of the applied water is lost to percolation. More rainfall can be stored within the root zone and can contribute to the seasonal water consumption, postponing the first irrigation and enabling earlier irrigation cutoff. Table 1 illustrates the available soil water for a range of soil textures.

Table 1. Amount of water available for selected soil textures at field capacity

Soil texture	Average available soil water capacity (in/ft of depth)	(cm/m of depth)
sand	0.7	5.8
loamy sand	0.9	7.5
sandy loam	1.4	11.7
fine sandy loam	1.5	12.5
loam	2.0	16.7
silty loam	2.2	18.3
clay loam	2.2	18.3
sandy clay	2.3	19.2
silty clay	2.3	19.2
clay	2.3	19.2
peats and mucks	2.5	20.9

TIMING THE FIRST IRRIGATION

As discussed earlier, the first irrigation may have to be applied before or near the time of sowing to ensure timely seed germination and stand establishment. If rainfall is relied upon for germination, the first crop irrigation can be delayed. Timing largely depends on seasonal rainfall patterns and amounts. Since one growing season is seldom like the next, what is appropriate timing one year may not be for another. Once the rainfall season has ended, stored soil moisture will provide the water for crop consumption until the reserve is depleted. How long this reserve will sustain crop growth before irrigation is needed depends on soil texture and root zone depth. The first postemergence irrigation is needed after about 40 to 50 percent of the stored soil moisture in the crop root zone is consumed. Using a rain gauge to monitor rainfall and a soil sampling tube or auger to estimate soil moisture content (soil moisture depletion), understanding crop water consumption patterns and root development, and recognizing how soils feel as they dry can be used to time the first crop irrigation and avoid crop moisture stress.

DETERMINING IRRIGATION FREQUENCY AFTER THE FIRST IRRIGATION

The small grain root system usually is near full development by about 60 to 70 days after germination, and it reaches maximum development at about boot stage. Only one irrigation is normally needed during that period in most areas. Once the root zone is fully developed, the interval between irrigations is fairly consistent up to irrigation cutoff. Depending on soil texture and water-holding capacity, there are 3 to 10 inches (7.5 to 25.5 cm) of available stored water in a root zone 2 to 4 feet (0.6 to 1.2 m) deep. About 1.5 to 5 inches (4 to 12.5 cm) of soil moisture is available to sustain the crop between irrigations since about one-half of the stored water can be consumed from the crop root zone before moisture stress occurs. This amount is enough to sustain an irrigation frequency ranging from about 7 to 10 days for sandy and sandy loam soils, 12 to 18 days for loam soils, and up to 25 days for silt loams, clay loams, clays, peats, and mucks. Warm, windy spring days deplete soil moisture quickly, so it should be replenished more frequently under such conditions, especially if the crop was previously exposed to wet soil conditions that limited root development. Irrigation frequency should be verified by checking soil moisture and watching for the earliest signs of crop stress, possibly in a particularly sensitive area of a field.

IRRIGATION METHODS, IRRIGATION UNIFORMITY, AND AMOUNTS

Several methods are used to irrigate small grains in California, including border check, furrow, and sprinkler systems. For border check irrigation, the optimal strip width and check length depend on soil type and slope of the field. Shorter and narrower strips with steeper slopes are used on light-textured soils, while longer and wider strips with lesser slopes are used on heavy-textured soils. The check length can range from 200 feet (61 m) for a sandy soil with a slope of about 1 percent to more than 1,200 feet (366 m) for a clay soil with a 0.3 percent slope. Strip width can range from 20 to 100 feet (6 to 30 m) for the above soil types and slopes, respectively. Borders or furrows should be made at planting time. When border flood or furrow irrigation systems are used, extra irrigation water is usually applied near the head of the field to prevent underirrigation in the middle and the tail end of the field. Subirrigation with spud ditches is used in the Sacramento–San Joaquin Delta. Spud ditches are the smallest ditches in the irrigation system used in peat soils, about 12 inches (30 cm) wide and 24 inches (60 cm) deep and connected to larger 4-foot (1.2-m) ditches, placed about 100 feet (30 m) apart. Table 2 gives the number of irrigations recommended for small grains in the main growing regions of California.

Irrigation practices that ensure ample soil water storage during early stages of crop development promote a deep, extensive root system. In general, flood or furrow irrigation should bring the upper 3 feet (1 m) of the soil profile to field capacity. Usually about 4 to 8 inches (10 to 20 cm) of water is applied per flood or furrow irrigation event. Less water, usually 2 to 4 inches (5 to 10 cm), may be applied per sprinkler irrigation. Table 3 provides a general guide for the amount of water needed to bring soil moisture to field capacity for different soil types.

Table 2. Number of irrigations recommended for small grain regions of California

Region	Number of irrigations
Central Coast	1–3
Sacramento Valley	1–3
Intermountain Area	1–4
San Joaquin Valley	3–6
Imperial Valley	5–7

DETERMINING IRRIGATION CUTOFF

Timely irrigation cutoff prevents yield losses and assures adequate kernel weight. It also helps minimize irrigation costs and prevents irrigating too late, avoiding problems with field access by heavy combines. Irrigation that continues too late in the season results in more severe lodging and black point disease, stimulates late-season weed growth, causes yield reductions, slows harvest, and delays ground preparation for the sub-

Table 3. Approximate amount of water needed to bring selected soil textures to field capacity

Available soil water remaining (%)	Inches of water needed for soil texture (in/ft)*				
	Loamy sand	Sandy loam	Silt loam and clay loam	Sandy clay and silty clay	Peats and mucks
0–25	0.9–0.7	1.4–1.1	2.2–1.7	2.3–1.7	2.5–1.9
25–50	0.7–0.5	1.1–0.7	1.7–1.1	1.7–1.2	1.9–1.3
50–75	0.5–0.2	0.7–0.4	1.1–0.6	1.2–0.6	1.3–0.6
75–100	0.2–0	0.4–0	0.6–0	0.6–0	0.6–0
At field capacity	0.9	1.4	2.2	2.3	2.5

Note: *1 in/ft = 8.33 cm/m.

sequent crop. The appropriate irrigation cutoff date depends on the soil water-holding capacity and root zone depth. The optimal irrigation cutoff is determined by patterns of dry matter accumulation in the grain after heading, crop water consumption during grain filling, and weather. Sufficient moisture must be available from the last irrigation to carry the crop through the late dough stage (the end of dry matter accumulation). For sandier soils and crops with shallow root zones, this period may be 7 to 10 days before the late stages of dough development. For finer-textured uniform soils and crops with deeper root systems, the irrigation cutoff may be 14 to 21 days or more before the late stages of dough development.

BIBLIOGRAPHY

Clement, L. D., L. F. Jackson, T. E. Kearney, J. P. Orr, R. L. Sailsbery, and J. F. Williams. 1982. Wheat production in the Sacramento Valley. Oakland: University of California Division of Agricultural Sciences Leaflet 21323.

Flint, M. L., ed. 1990. Integrated pest management for small grains. Oakland: University of California Division of Agriculture and Natural Resources Publication 3333.

Ley, T. W., R. G. Stevens, R. R. Topielec, and W. H. Neibling. 1994. Soil water monitoring and measurement. Pullman: Washington, Oregon, and Idaho State Universities, Pacific Northwest Publication PNW0475. Available online from the Washington State University Extension Web site, http://cru.cahe.wsu.edu/CEPublications/pnw0475/pnw0475.html.

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