Preplant Irrigation in the Central and Southern High Plains – A Review

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Abstract

Preplant irrigation has been widely practiced in the semi-arid High Plains since the early expansion of pump irrigation from the Ogallala Aquifer in the late 1930s. As groundwater storage continues to decline, the common practice of "heavy" water application to fully wet the root zone of graded furrow fields prior to planting is being questioned. Under some conditions, preplant irrigation is an essential practice for timely stand establishment and high yields. However, in many situations, the large application depths required for surface irrigation result in inefficient soil water storage and low yield response. With center pivot sprinkler systems, smaller and more precise preplant irrigation application amounts are possible resulting in more efficient preseason storage.

We conclude that the benefits of preplant irrigation are likely to be greatest (1) when the soil profile is dry before planting; (2) when seasonal irrigations are not applied to drought-tolerant crops or are reduced in amount; (3) when early planting limits soil wetting by precipitation by the desired date; and (4) when preplant irrigation plus seasonal precipitation on deep, high water storage soils can result in moderately high irrigated yields without seasonal irrigation. The benefits are likely to be low (1) when soil profiles are moderately wet at time of irrigation; (2) when planting dates are flexible and can follow precipitation events for stand establishment; and (3) when seasonal irrigation provides adequate water to meet plant requirements. As groundwater decline continues and precipitation becomes more important for supplying crop water requirements, the use of preplant irrigation as an irrigation water management practice will likely decline in importance in the High Plains.

Introduction

The Ogallala Aquifer in the High Plains is a major water resource for irrigation in the Texas High Plains, Oklahoma panhandle, and parts of eastern New Mexico, eastern Colorado, western Kansas, and central and western Nebraska. The four major field crops, (grain sorghum, corn, wheat, and cotton) account for about 90% of the irrigated area and groundwater pumped for irrigation. In surface irrigation systems, the preplant irrigation is normally the largest irrigation event and constitutes about one-fourth of the total irrigation applied for corn, about one-third for grain sorghum, and one-half for cotton.

Although preplant irrigation is widely practiced in the semiarid Central and Southern High Plains, it has not previously been the subject of a technical review. Results of many preplant irrigation tests were reported years ago in Experiment Station reports and other publications that are mostly no longer available. The significance of this early work along with the more recent work is summarized and interpreted in this review.

Irrigated soils in the High Plains are predominantly gently sloping. Most surface irrigation is practiced on slopes less than 1%. Soils are relatively deep with field crop extraction of available soil water (ASW) occurring to the 1- to 2-m depths. Graded furrow irrigation is used for 56% of the irrigated crop area in the Texas High Plains in 1989 (Musick et al., in press) and for about 50% of the area in the Central High Plains. Almost all preplant irrigation tests conducted in the High Plains involved water application to graded furrow or level border plots. Preplant irrigation mostly occurs during April and May for summer crops. Windy periods of warm, dry air and moderately high evaporative demand are common and contribute to the frequently low profile storage efficiencies.

The High Plains is both a major irrigated and a major dryland crop region. Long-term precipitation ranges from about 380 mm annually in the southwest to about 600 mm in the northeast. Precipitation occurs mostly from spring to fall and winters are relatively dry. The distribution pattern increases in bi-modal tendency from north to south as illustrated by transect data for Colby and Garden City, KS, and Amarillo, Bushland, Lubbock, and Big Spring, TX, in figure 1. During periods of major drought, very little effective soil water storage occurs from harvest to planting time, whereas in occasional wet periods, precipitation fully rewets the soil profile. In most years, the profile is partially rewet by preseason precipitation. Preplant irrigation is widely practiced to avoid the risk of inadequate precipitation prior to planting time which permits timely establishment of crops that are spring planted.

Advantages of preplant irrigation are that it (1) permits early planting without having to rely on unpredictable rainfall; (2) delays the need to begin seasonal irrigation and reduces seasonal irrigation water requirements; (3) improves soil conditions for seedbed preparation and germination of crop volunteer plants and weeds which can be killed by tillage before planting; and (4) allows

Article was submitted for publication in May 1990; reviewed and approved for publication by the Soil and Water Div. of ASAE in October 1990. Presented as ASAE Paper No. 87-2558.

Contribution from the USDA-ARS and Kansas Agricultural Experiment Station, Kansas State University. Contribution No. 90-419-J.

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This article is reprinted from the Transactions of the ASAE (Vol. 33, No. 6, pp. 1834-1842, 1990)
Published by the American Society of Agricultural Engineers, St. Joseph, MI 49085-9659 USA

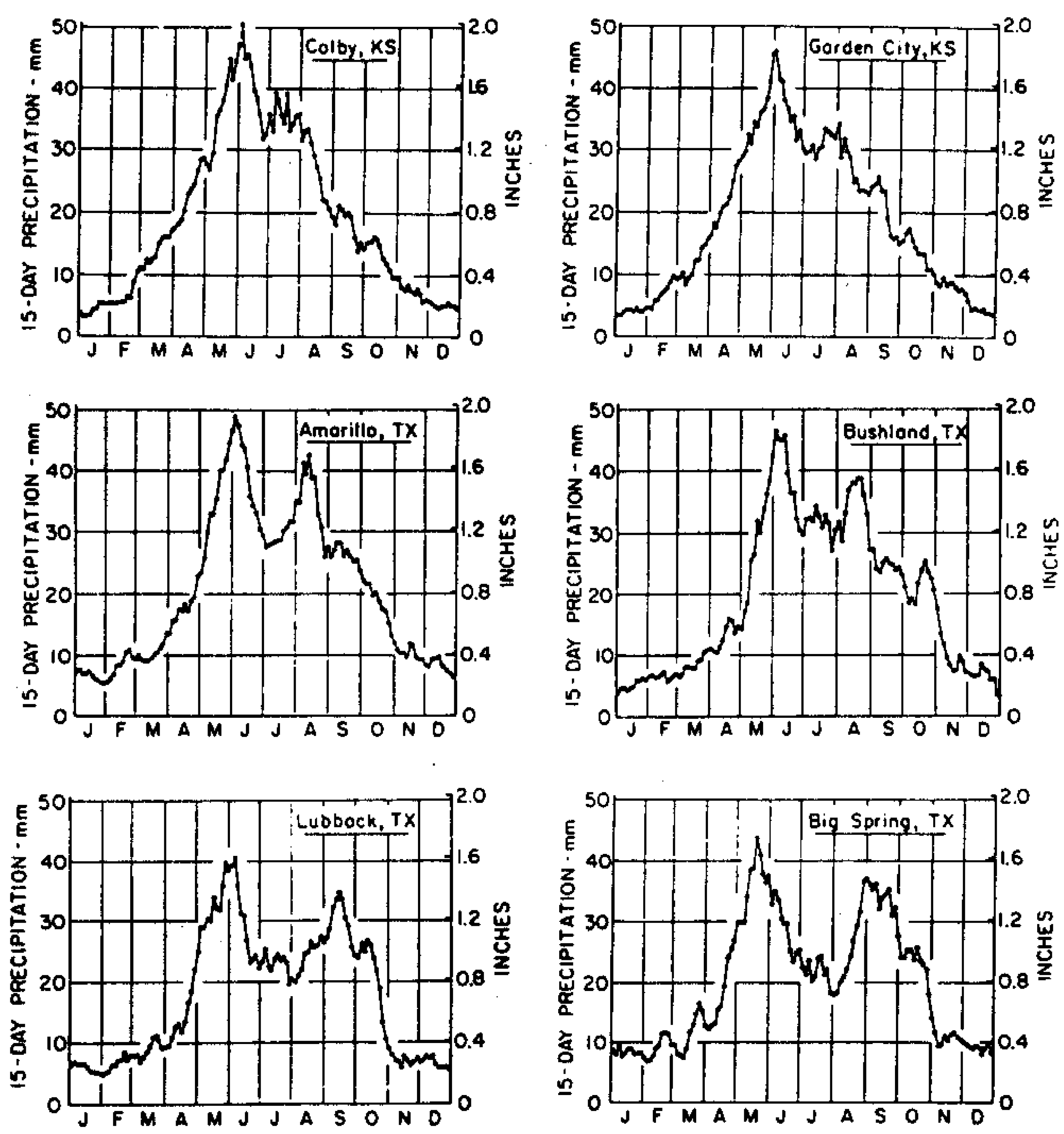

Figure 1–Average 15-day precipitation moving totals by 3-day periods, January through December, for north to south locations in the Central and Southern High Plains. The locations and length of record are Colby (1914-89) and Garden City (1908-89) KS, and Amarillo (1892-1989), Bushland (1939-89), Lubbock (1911-89), and Big Spring (1915-89), TX. Plotting points are centered for the 15-day periods.

additional land area to be irrigated from wells than can be adequately irrigated during the growing season, thus reducing the area in dryland crops and increasing total farm production. The disadvantages are that it often (1) increases cost of production; (2) increases total irrigation water requirements and accelerates depletion of groundwater storage; (3) reduces the efficiency of irrigation water use for crop production; and (4) lowers soil temperatures needed for timely stand establishment.

In this review, preplant irrigation is considered in relation to (1) water intake, storage, and storage efficiency; (2) field response for the major irrigated crops of grain sorghum, corn, winter wheat, and cotton; and (3) management in surface and sprinkler irrigation systems.

As groundwater supplies available from the Ogallala Aquifer continue to decline, pumping energy costs remain high or further increase, and the High Plains area continues a transition to dryland agriculture, the advisability of applying large preplant irrigations to fully rewet the soil profile before planting will be increasingly questioned. Eliminating the preplant irrigation when crops can be established without it is a practical approach to reducing irrigation water requirements. However, preplant irrigation for soil water storage before planting when the profile is dry or for stand establishment of early planted crops when precipitation is deficient is a practical and efficient management practice.

Water Intake, Storage, and Storage Efficiency

A common disadvantage of preplant irrigation of graded furrow fields is the large application depths compared with seasonal irrigations. Water intake is generally increased due to soil loosening effects of primary tillage, winter freezing and thawing effects on soil structure, and flow retarding effects of crop residues. In 5 years of tests on Richfield silty clay loam at Garden City, KS, preplant applications for grain sorghum averaged 220 mm compared with 153 mm for two seasonal irrigations (Hooker, 1985). In 3 years of tests with winter wheat on Pullman clay loam at Bushland, TX, preplant irrigations ranged from 140 to 238 mm applied, whereas seasonal irrigations ranged from 75 to 100 mm (Jensen and Sletten, 1965a). In a 3-year test of five tillage treatments on Sherm clay loam at Etter, TX, intake during a fall preplant irrigation of a graded furrow field following sorghum harvest and tillage averaged 208 mm, whereas a spring preplant irrigation treatment averaged 462 mm (Undersander and Regier, 1988). During spring preplant irrigation test, intake of water as it advanced across the field in wheel track furrows was one-half that in non-wheel track furrows. This indicates the importance of surface soil conditions on water intake. Also, Musick and Dusek (1971a, 1975) and Musick et al. (1981) found that deep tillage can greatly increase water intake during a preplant or initial irrigation for emergence. Practices that have reduced the large preplant irrigation in graded furrow systems are wheel traffic compaction of furrows (Musick et al., 1985, Musick and Pringle, 1986) and surge flow application (Musick et al., 1987).

For sprinkler irrigated fields, a common practice is to apply two to four preplant irrigations for a total depth of about 50 to 100 mm. Thus, total preplant irrigation depths are usually less than one-half the depths applied in furrow irrigation and profile drainage is substantially reduced. For crops other than cotton, a widely practiced alternative is to eliminate preplant irrigation and apply one or more small applications after planting for crop emergence. Emergence irrigation for cotton is not practiced because of adverse effects of lowered soil temperatures for stand establishment.

Without preplant irrigation, sprinkler-irrigated fields frequently have only partially wet profiles as the growing season begins. For corn, early-season irrigation for profile wetting is applied when plants are small and water use rates are low (May in the Southern High Plains and mid-May to mid-June in the Central High Plains). Cotton growth is adversely affected by irrigation at this early stage because of cool temperatures and seedling disease effects associated with wet surface soil. Irrigation for profile wetting is delayed until warmer growing conditions. A common practice for sprinkler irrigated cotton is to begin the irrigation season about two weeks earlier than normal (about beginning of fruiting squares). Soil probes and gypsum blocks are used to some extent to monitor subsoil wetting and the need for additional early-season irrigation for lower-profile wetting.

Planting dates for summer row crops coincide in general with periods of highest annual precipitation probabilities in the High Plains. Due to flexibility of small applications for emergence when precipitation is inadequate, sprinkler irrigation can be managed to effectively eliminate the preplant irrigation. This allows increased storage of preseason and early seasonal precipitation on soil that has not been preplant irrigated and allows management flexibility to apply early-season irrigation as needed for profile wetting ahead of the rapid plant growth and increasing ET demand period.

It is not uncommon for moderately wet soil profiles to occur after harvest of irrigated crops, either from late season irrigation or irrigation plus late season rainfall. In the Southern High Plains, corn is adequately irrigated to prevent substantial yield reductions associated with limited irrigation (Musick and Dusek, 1980). Adequate irrigation management normally leaves profile ASW storage in excess of 50% after harvest. Grain sorghum is grown under both adequate and limited irrigation and the timing of the last irrigation has a major effect after harvest on residual soil water storage, (Musick, 1970). Application of the last irrigation at late boot, flower, milk and dough stage of grain sorghum resulted in residual ASW storage in a 1.8-m profile of Pullman clay loam of 71, 118, 142, and 197 mm and deficit storage below field capacity of 156, 109, 85, and 30 mm, respectively. Sprinkler-irrigated fields usually have drier profiles after harvest than surface-irrigated fields (Lamm and Rogers, 1982).

Large preplant irrigation depths applied in surface systems and occurrence of average to above average preseason precipitation can dictate that water storage efficiency will be low. For example, a soil profile that has 100 mm of remaining water storage capacity receives 150 mm preplant irrigation plus an additional 150 mm of precipitation between harvest and planting. If the soil is fully wet at planting, storage efficiency cannot exceed 33% of the 300 mm of irrigation and precipitation. Slowly permeable clays, such as Pullman clay loam, are difficult to wet below about 0.6-m depth, and storage efficiencies have been measured in the 20% range (Musick et al., 1971). In the study by Undersander and Regier (1988), storage efficiency of preplant irrigation measured as increased ASW at planting averaged 22% for the fall irrigation and 18% for early spring irrigation.

A soil that is preplant irrigated early in the nongrowing season may lose more water than it gains from scattered rains before the crop season begins. Musick et al. (1971) measured a net loss in ASW storage for 2 years with 75 and 125 mm of rain after preplant irrigation and before planting. Gain or loss in ASW from rainfall following preplant irrigation in relation to rainfall amount is illustrated in figure 2. On deep uniform silt (loess) soil profiles in western Kansas, prolonged soil profile drainage occurs following fall preplant irrigation. Stone et al. (1987) determined rapid drainage losses from a 1.8-m profile of Ulysses silt loam following irrigation as about 60 mm during a 3-day period to the 640 mm upper limit water content. Slow drainage losses of an additional 60 mm continued over the extended time period between preplant irrigation and planting the next crop. Drainage losses equalled or exceeded soil evaporation losses at profile water contents above 80% ASW.

The most efficient condition for preplant irrigation storage is when the profile is relatively dry. Water applied as preplant irrigation is subject to losses as surface evaporation and deep percolation below the root zone. Musick et al. (1971) found that storage efficiency of 100 to 150 mm preplant applications to level border plots on five dates from fall to spring decreased in a linear relationship with time (fig. 3). When evaluated within one or two weeks after irrigation, the highest storage efficiency of 54% occurred during fall irrigation, and the lowest of 33% occurred during late spring irrigation. Early preplant irrigation reduced precipitation storage efficiency, and timing of preplant irrigation had little effect on storage efficiency of both preplant irrigation and preseason rainfall. Average storage efficiencies for the 20 preplant irrigations were 44% for irrigation water and any rainfall occurring following irrigation, 49% for additional soil water storage associated with irrigation, and 29% for irrigation plus precipitation from late fall harvest to sorghum emergence in late June. These data indicated that storage efficiency of preplant irrigation averaged (1) more than double the 20% for preseason precipitation reported by Unger (1972) for continuous cropping of dryland grain sorghum on a nearby site, but (2) less than one-half of the irrigation water applied was stored as ASW for subsequent plant use.

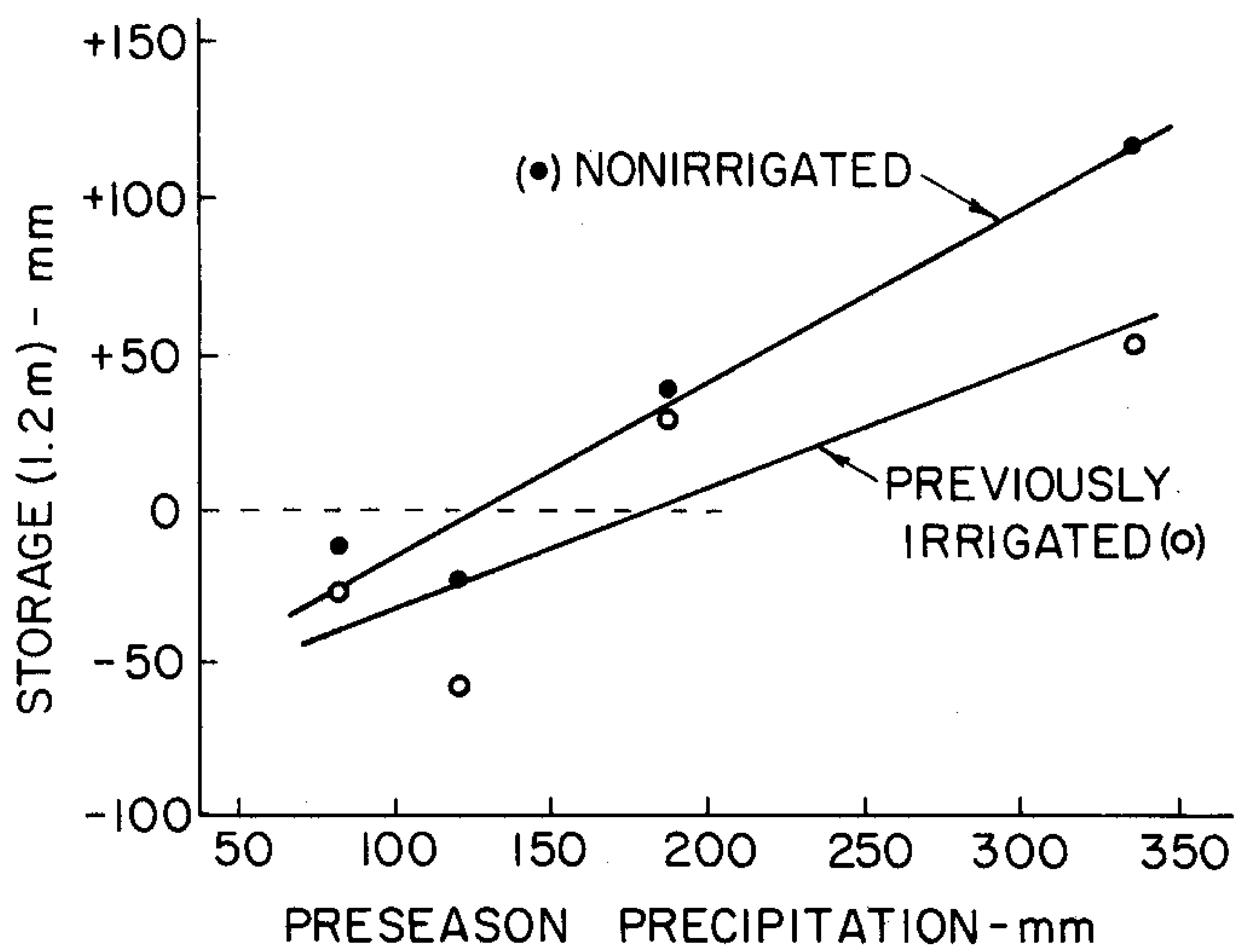

Figure 2–Precipitation storage after early preplant irrigation for annually grown sorghum compared with storage by nonirrigated plots of Pullman clay loam (adapted from Musick et al., 1971).

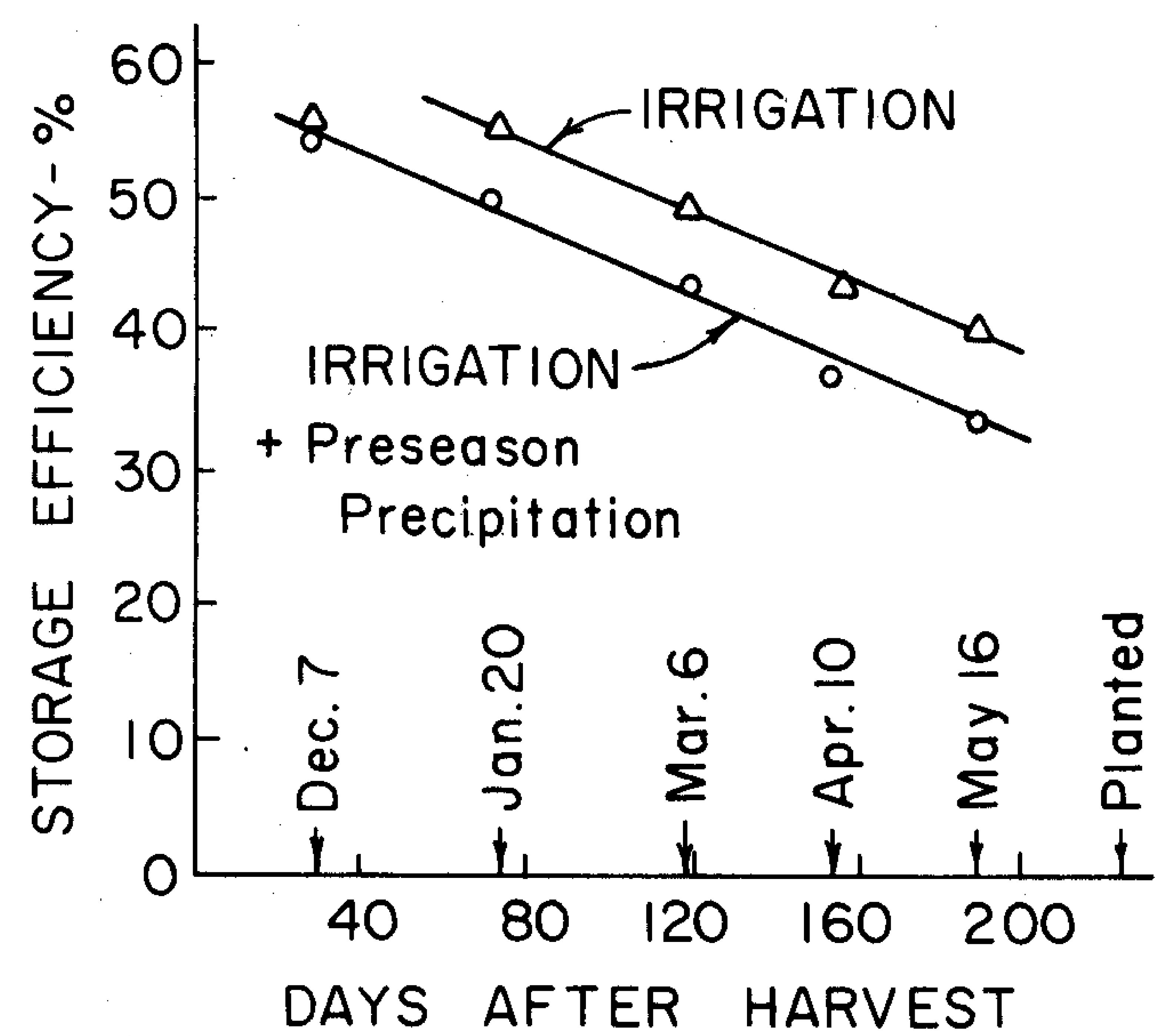

Figure 3–Storage efficiency of preplant irrigation and preplant irrigation plus preseason rainfall for annually grown grain sorghum on Pullman clay loam in relation to preseason irrigation date (from Musick et al., 1971).

Although storage efficiency of preplant irrigation (measured as additional soil water storage at planting) is relatively low, additional increments of water storage at planting are efficiently used for yield of grain sorghum that is not irrigated during the growing season. In 27 years of dryland research at Bushland, TX, grain sorghum yields were linearly related to ASW at planting, with additional storage resulting in an efficient average yield response of 1.5 kg/m^3 (O. R. Jones, unpublished). Stone et al. (1980) concluded from a 3-year study "that the most efficient use of irrigation water is made when water is applied as close as possible to the time of plant need".

A test of three application depths (125, 200, and 375 mm) of preplant irrigation only for continuous grain sorghum on Pullman clay loam indicated relatively low storage efficiencies at planting of 42 to 32% (fig. 4). However, the yield response to additional storage without seasonal irrigation was rather high and averaged 2.1 kg/m^3. The data illustrate the decline in storage efficiency as application depths were increased.

Significant relationships have been found between residual ASW storage after harvest and preseason soil water storage from precipitation on Pullman clay loam (Musick, 1970) and on Keith silt loam (Lamm and Rogers, 1985). The use of limited irrigation with an earlier-than-normal cutoff date increases soil water depletion, storage deficit after harvest, and potential storage efficiency of precipitation. Stone et al. (1983) indicated that on a Ulysses silt loam at Tribune, KS, a range of spring ASW in a 1.8 m profile from 30 to 70% was related to a linear decline in storage efficiency of fall preplant irrigation from 85 to 42%.

In the Texas High Plains, a winter survey of ASW contents to 1.5 m is conducted annually for a 15-county area by the High Plains Underground Water Conservation District No. 1, Lubbock, TX. Results are made available as contour maps of profile storage deficits in the District newspaper "The Cross Section". Early awareness of profile soil water deficits is useful information for the farmers in assessing the risk and making decisions concerning

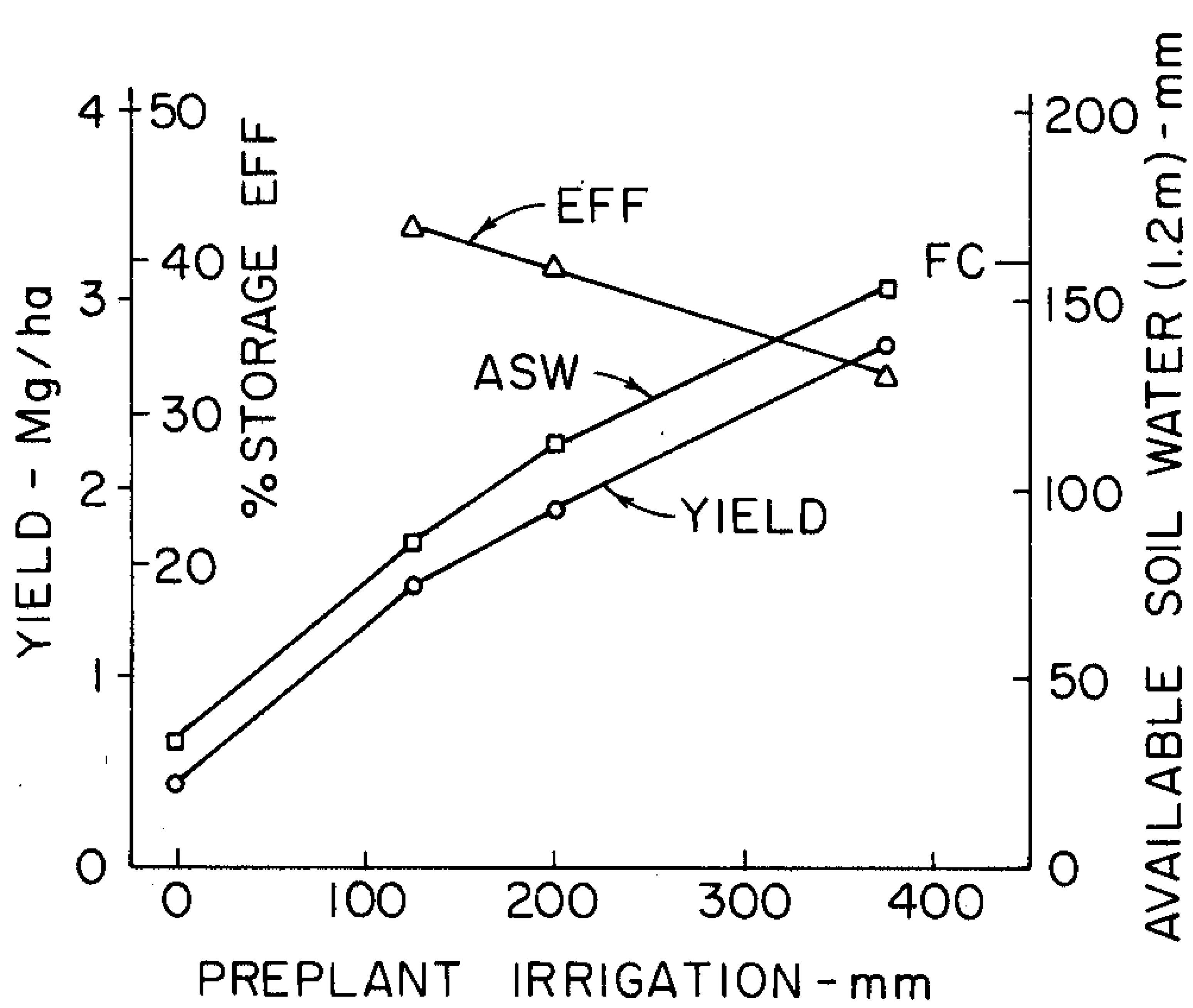

Figure 4–Effect of preplant irrigation amount for annually grown sorghum (Pullman clay loam) on available soil water, irrigation storage efficiency, and grain yield.

preplant irrigation for the next crop. When the profile ASW appears adequate, shallow tillage can be used to limit surface soil drying and reduce precipitation requirements for adequate rewetting of the surface soil before planting.

CROPS

GRAIN SORGHUM

The first irrigation water management research for grain sorghum occurred during early irrigation development in the southern part of the Texas High Plains. This work at Lubbock by Jones and Gaines (1941) emphasized the importance of preplant irrigation to provide a wet soil profile at planting and one seasonal irrigation during boot stage. This work preceded the introduction of hybrids and the use of fertilizers for grain sorghum; and yields of adequately irrigated crops were relatively low, less than 4 Mg/ha. Even though yields were relatively low during a period of major drought, irrigation water-use efficiencies (IWUE = irrigated minus dryland yields/irrigation water intake volume) for grain production were rather good, averaging 1.25 kg/m^3 for preplant irrigation, 2.29 kg/m^3 for the boot stage irrigation, and 1.42 kg/m^3 for two seasonal irrigations.

Dryland grain sorghum frequently failed during the major drought years of the 1950s, and Swanson and Thaxton (1957) stated, "A grain sorghum crop can be produced with a preplanting irrigation alone in very dry years when dryland crops are complete failures". Thus, yield reliability from preplant irrigation was considered important as irrigation developed in the traditional dryland environment of the Texas High Plains.

The use of limited irrigation changed during the 1960s as more emphasis was placed on adequate irrigation for high yields. However, declining groundwater supplies, low commodity prices, and high pumping energy costs have led to renewed interest in limited irrigation. In reducing water application, the need for and benefits of preplant irrigation need reevaluation. As water application for grain sorghum has declined, the production emphasis has shifted from longer maturity, high yield potential hybrids that require high production inputs to medium maturity-length (dryland type) hybrids that as a group have superior drought tolerance. These hybrids can be planted two to three weeks later than the medium-late and full season hybrids, which considerably enhances stand establishment reliability from rainfall and reduces the need for preplant irrigation.

The highest yield response to preplant irrigation has occurred for continuous cropping when yield response to preplant irrigation only was compared with dryland yields. In 7 years of tests at Bushland, TX, dryland yields averaged 2.08 Mg/ha, yields with preplant irrigation only averaged 3.23 Mg/ha, and preplant plus adequate seasonal irrigation averaged 7.98 Mg/ha (Jensen and Sletten, 1965b; Musick and Dusek, 1971b). The IWUE of preplant irrigation applied to level border plots without runoff averaged 1.08 kg/m^3, whereas that of seasonal irrigation averaged 1.81 kg/m^3. The reduced IWUE of preplant compared with seasonal irrigations is associated with the relatively low storage efficiency of preplant irrigation for later use by the crop and reduced storage of rainfall following preplant irrigation and before the beginning of crop growth.

When plant establishment can be obtained without preplant irrigation and a normal irrigation schedule is followed during the season, preplant irrigation may have little influence on yields. Eliminating the preplant irrigation in a 3-year study by Musick et al. (1971) increased IWUE from 1.26 to 1.68 kg/m^3 in 1964, from 1.44 to 2.25 kg/m^3 in 1966, and 250 mm of precipitation in June 1965 eliminated any soil water storage and yield benefit from the preplant irrigation. Bordovsky and Hay (1975), in a 3-year study at Colby, KS, found no additional yield benefit from preplant irrigation of grain sorghum when adequately irrigated during the growing season.

When preplant irrigation is not used for grain sorghum, planting in the Southern High Plains can be delayed if necessary from early or mid-May to mid- or late June for precipitation to rewet the seed zone. The probability of precipitation depths at Amarillo, TX, for continuous sorghum during preseason and approaching planting during May and May through 15 June are shown in figure 5. In 35 years of dryland research at Bushland, sorghum stand establishment was possible by late June in all but one season, the major drought year of 1956. Reduced tillage intensity and shallow operating depths enhance seed zone water content and stand establishment on dryland, and conservation tillage practices may be desirable for stand establishment without preplant irrigation (Allen and Musick, 1990). When sorghum follows irrigated wheat grown the previous year, a no-tillage system can be successfully used. The sorghum can be seeded in the old wheat beds which normally have very good soil water contents following fallow and stand establishment does not require preplant irrigation (Musick et al., 1977).

The northern part of the Southern High Plains and the Central High Plains have extensive areas of deep, fine-textured irrigated soils with silt (loess) subsoils that are high in water storage capacity and have the potential for relatively high yields from preplant irrigation plus seasonal rainfall. In an early bulletin on irrigation in western

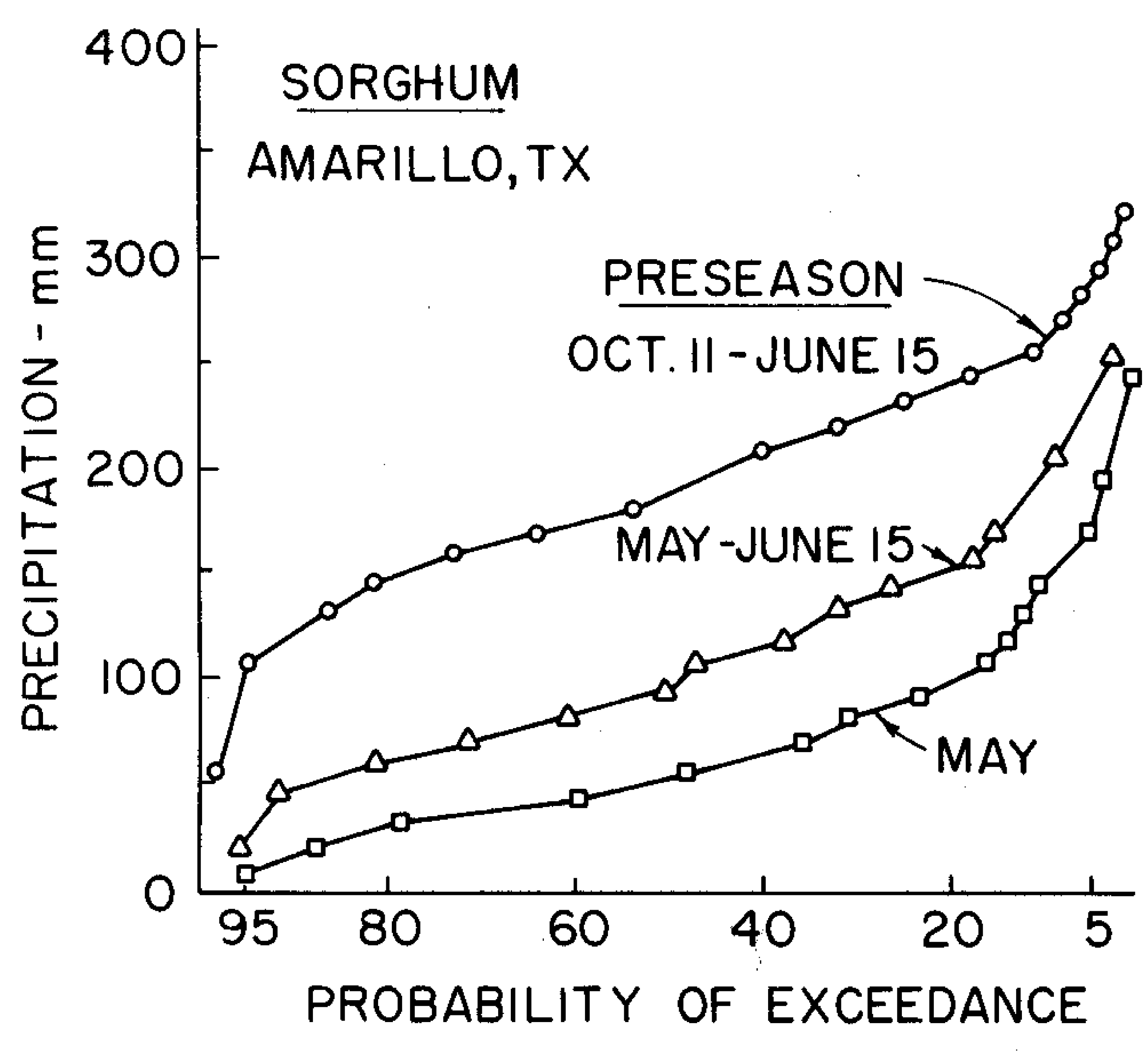

Figure 5–Probability of exceeding precipitation amounts for annually grown sorghum, Amarillo, TX, for preseason total through 15 June planting and for May and May-15 June in relation to providing surface soil water for planting.

Kansas, Erhart et al. (1958) stated, "It is possible to irrigate additional area in the winter when fields under full irrigation require little or no water. Such a practice can fill the root zone with water and result in crop yields equal to those under good summer fallow. Application of 8 to 12 inches (200 to 300 mm) of water may be required to fill the soil to capacity". In an 8-year test by Erhart (1970) on Ulysses silt loam, yields from about 300 mm of winter irrigation averaged 4.33 Mg/ha compared with 1.88 Mg/ha for dryland after summer fallow in a wheat-sorghum-fallow sequence. In a 6-year test by Musick and Grimes (1961) on Ulysses clay loam at Garden City, KS, yields from preplant irrigation only averaged 4.80 Mg/ha yields compared with 1.99 Mg/ha for dryland fallow sorghum. Three of the 6 years occurred during the major drought of the 1950s. During the three years following the drought, yields with preplant irrigation only averaged 6.37 Mg/ha compared with 2.52 Mg/ha for dryland fallow.

Ratio of grain sorghum yields from preplant irrigation plus precipitation to yields under adequate irrigation increases from south to north across the Southern and Central High Plains for locations having similar seasonal and annual precipitation. Yield from preplant irrigation as a percent of yield under adequate irrigation at Bushland, TX, averaged 40% during 7 years of tests (Jensen and Sletten, 1965b; Musick and Dusek, 1971b); at Garden City, KS, it averaged 66% during 6 years of tests (Musick and Grimes, 1961) which included 3 years of major drought, 79% for 3 years after the drought ended, and 57% in 8 years of tests (Erhart 1970); at Tribune, KS, it averaged 81% in 3 years of tests on Ulysses silty clay loam (Stone et al., 1978); and at Colby, KS, it averaged 95% in 3 years of tests on Keith silt loam (Bordovsky and Hay, 1975). At all locations, yields under adequate irrigation were generally similar and were mostly in the 7 to 8 Mg/ha range. Evapotranspiration demands that require seasonal irrigations for high yields decrease from south to north in the Southern and Central High Plains. Also, as yields from preplant irrigation without seasonal irrigation increase from south to north, this practice becomes more efficient as the only irrigation applied for soils having major profile storage capacity at the time of irrigation. Comparative differences were reported for Pullman clay loam at Bushland, TX, and Richfield clay loam at Garden City, KS, by Musick and Sletten (1966).

Corn

The corn hybrids grown have longer growing seasons, germinate at cooler soil temperatures, and are planted two to four weeks earlier than the grain sorghum hybrids. Normal tillage for seedbed preparation frequently results in dry surface soil, and the low precipitation prior to the late April to early May planting dates may necessitate preplant irrigation for germination and stand establishment. Corn is mostly irrigated and managed for high yields. Because of critical stage sensitivity to plant water stress, it is seldom grown without seasonal irrigation.

The irrigation cutoff dates used for high yields result in residual storage of ASW which frequently exceeds 50% of available capacity in a 1.5 to 1.8-m profile depth. A 2-year study of irrigated corn fields in Thomas County, KS, indicated ASW storage to a 1.5 m depth after harvest averaged 80% (Lamm and Rogers, 1982). Tests at Colby, KS, indicated that irrigation was not needed for stand establishment from early to mid-May planting (Lamm and Rogers, 1982, 1985). In these tests on Keith silt loam, ASW after harvest averaged about 60%. They stated, "In most years, fall preseason irrigation is not needed to recharge the soil profile in northwest Kansas". They further stated that, "Most irrigation systems have excess capacity in June and could add a significant amount of water to a deficit soil profile before the peak water use period of July through August".

Corn is mostly planted following corn or grain sorghum and, to a lesser extent, after harvest of wheat the previous summer. Preplant irrigation to recharge the profile may not be needed when corn follows corn because of residual ASW after harvest and preseason precipitation and also when corn follows wheat because of fallow season soil water storage. Preplant irrigation is more likely to be needed following sorghum when irrigation is managed to allow major depletion of ASW by harvest.

Fall or winter irrigation after harvest, following tillage and reforming of bed-furrows, developed as a preplant irrigation practice in western Kansas. Benefits from fall irrigation for corn in the Central Plains have been debated since the early 1900s. Knorr (1914) reported yield benefits on sandy loam soils with deep wetting at Scottsbluff, NE, but Farrell and Aune (1917) reported no benefit from moderate wetting depths on Pierre clay at Belle Fourche, SD. Knapp (1919) recommended winter irrigation for most of western Kansas with the exception of areas with sandy subsoils. Off-season utilization of labor was one of the major factors in promoting winter irrigation.

More recent studies with corn in the Central High Plains have shown little or no response to preplant irrigation over a wide range of conditions. Stone et al. (1987) found no significant yield increase from preplant irrigation that substantially increased total water application. In a 3-year study at Colby, KS, Banbury et al. (1977) found no yield benefit from preplant irrigation over a wide range of treatments from limited to full irrigation. Lamm and Rogers (1983) found no statistically significant differences in corn yields as affected by preplant irrigation even though average yields were slightly higher for the fall irrigation treatment.

Stand establishment without preplant irrigation can be enhanced by:

1. Using fall tillage and reforming bed-furrows to allow a relatively long time interval for the bed seed zone to become rewetted by precipitation.
2. Delaying planting up to about two weeks in the Central Plains and three weeks in the Southern Plains to enhance surface soil wetting from precipitation.
3. Planting on summer fallow after irrigated wheat with no-tillage management and seeding into old beds (using furrow openers to clean out furrows if needed before the first seasonal irrigation).
4. Applying, if necessary, a smaller irrigation after planting for rewetting of beds to ensure emergence.

Stone et al. (1980) concluded, "Spring irrigation amounts sufficient for germination and early-season corn growth is obviously a necessary and efficient use of irrigation water. Beyond this necessary use, and if the irrigation system and capacity can supply sufficient in-season irrigation to corn, the application of water in the noncrop season to fill the soil profile to field capacity appears to be an inefficient use of water supplies".

Wheat

Irrigated wheat is mostly grown after wheat, after summer fallow, or to a lesser extent, soon after harvest of a summer crop such as corn. The time interval for preplant irrigation overlaps the late season irrigation of summer row crops, and the priority for water supplies is normally given to the summer crops. Therefore, preplant irrigation for wheat is not extensively practiced. The probability of precipitation at Amarillo, TX, between maturity of one crop and planting time for another and approaching planting time (September to 10 October) is shown in figure 6. Wheat is frequently planted into moist soil after precipitation and may be irrigated for emergence or to improve stand establishment after the crop has partially emerged. When soil water conditions are adequate for a period of growth after emergence, the initial irrigation may be delayed or deleted. Preseason precipitation storage, particularly after summer fallow, reduces the need for irrigation until after a period of substantial water use by the crop.

Studies involving preplant irrigation of wheat were conducted on Pullman clay loam at Bushland, TX, by Jensen and Sletten (1965a) and on Richland clay loam at Garden City, KS, by Musick et al. (1963), two locations having similar seasonal and annual precipitation. At Garden City, seasonal evapotranspiration is about 100 mm lower than at Bushland, and the available water storage to 1.8 m on Richfield clay loam is about 100 mm higher than on Pullman clay loam. These differences resulted in preplant irrigation only at Garden City yielding 90% of the fully irrigated plots compared with 58% at Bushland. The tests on Richfield clay loam indicated that preplant irrigation only was an efficient water management practice on a high water storage soil that had major ASW soil water storage capacity at time of irrigation. However, preplant irrigation contributed to low yield response and water-use efficiency

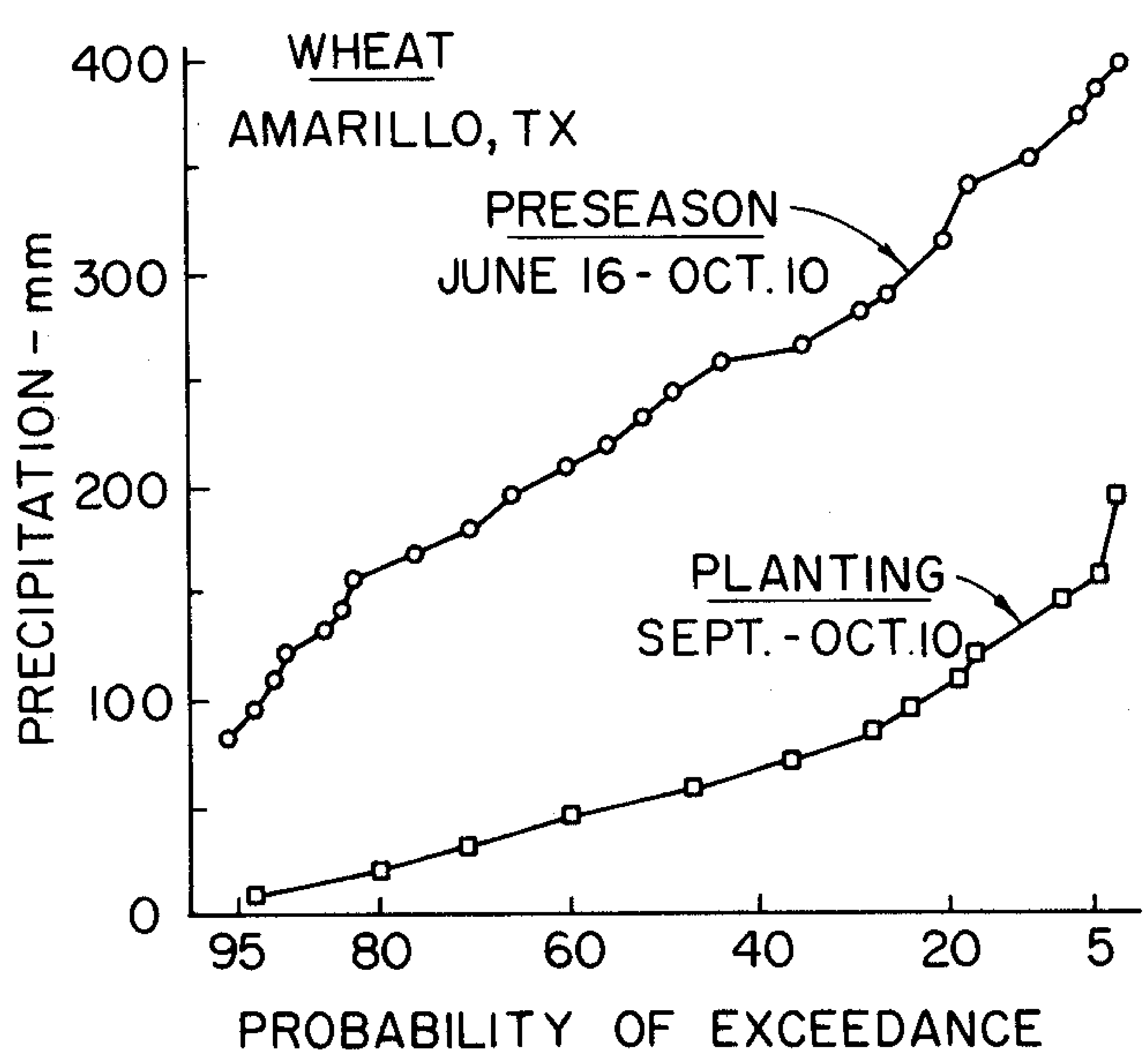

Figure 6–Probability of exceeding precipitation amounts for annually grown winter wheat, Amarillo, TX, for preseason totals through 10 October and for September-10 October in relation to providing surface soil water for planting.

from seasonal irrigation. Stone et al. (1980) in tests of continuous cropping of irrigated wheat at Tribune, KS, concluded that, "Fall irrigation of winter wheat for stand establishment and early growth is a very efficient and worthwhile use of irrigation water. Additional irrigation in the spring produced yield increases, but the usefulness and profit of the additional irrigations could be questioned".

Winter wheat is planted over a relatively wide range of dates from early September to mid-October. In many years, precipitation is adequate to provide surface soil water for stand establishment. When precipitation is inadequate, irrigation after planting to improve stands is more common than preplant irrigation. If beds and furrows are reestablished following major tillage in July after late June harvest, July-September precipitation in most years is adequate for rewetting of beds and furrows. Because of previous wetting by precipitation, only a modest amount of precipitation is needed to provide adequate seed-zone soil water at planting. Irrigation to rewet the soil profile can be delayed until late fall or early spring when it is likely to be used more efficiently for increasing yields.

COTTON

Because of limitations in heat units and length of growing season, cotton is grown only in a 25-county area in the central and southern parts of the Texas High Plains. Preplant irrigation is usually applied during late March to early May. Irrigated cotton is mostly planted during mid- to late May, whereas dryland cotton is planted during mid-May to early-June following seed zone wetting from precipitation. Planting dates correspond to the most predictable precipitation period of the year, and in many years, precipitation can be relied upon for stand establishment of irrigated cotton. Even though stands can be normally established from precipitation, Walker and Onken (1969) stated, "Where available, a preplant irrigation is usually applied to cotton land with subsequent summer irrigations to supplement rainfall". Cotton is most often grown in monoculture systems, and preplant irrigation is used to rewet the soil profile and to ensure favorable soil water conditions for early planting.

Irrigation inventories conducted by the Soil Conservation Service for the Texas Water Development Board at about 5-year intervals since 1958 indicate that groundwater use for cotton has ranged from about 488 mm in the driest season to 196 mm in the wettest season and averaged 299 mm for eight inventory years (Musick et al., In press). The most common surface application schedules are preplant-only, preplant plus one seasonal application at about peak bloom, and preplant plus two seasonal applications, at about early bloom and late bloom. Irrigated cotton lint yields in a 25-county production area averaged 472 kg/ha during 1968-89, whereas dryland yields averaged 321 kg/ha (Texas Agricultural Statistics Service annual reports). Assuming irrigation water application for cotton has averaged about 300 mm, IWUE for lint yields has averaged about 0.05 kg/m^3, substantially lower than has been obtained from research field plot tests.

A review of cotton preplant irrigation research at Lubbock, TX, revealed 21 years of test data during 1937-74 (Jones and Gaines, 1941; Thaxton and Swanson, 1956; Thaxton, 1957; Newman, 1960, 1967a, 1967b; Quisenberry and Roark, 1976). Thaxton and Swanson (1956) concluded that, "The preplant irrigation is the most important one". However, later data indicated that irrigation before planting was less important for yield than irrigation during the critical bloom stage (Newman, 1967a).

For all the preplant irrigation test data, dryland cotton lint yields averaged 285 kg/ha compared with 423 kg/ha for preplant irrigation only and 606 kg/ha for preplant plus one seasonal irrigation during bloom. Data for 10 years included water application to level plots without runoff, permitting calculation of IWUE values for lint yields. Dryland lint yields averaged 308 kg/ha compared with 412 kg/ha for preplant irrigation only and 594 kg/ha for preplant plus one seasonal irrigation. For the first study conducted during 1937-41, IWUE was higher for preplant irrigation than for an additional seasonal water application during bloom, 0.115 kg/m^3 compared with 0.080 kg/m^3. As a 10-year average, the IWUE of preplant irrigation only averaged 0.107 kg/m^3 compared with 0.110 kg/m^3 for the additional water applied during bloom. In a 3-year study by Newman (1967a), a seasonal irrigation only during bloom on plots that were not preplant irrigated resulted in a very high IWUE value of 0.235 kg/m^3, much higher than the 0.062 kg/m^3 for preplant irrigation only.

The study by Newman (1967a) is the only one in the literature that reports the response of increased cotton yields to seasonal irrigation applied without preplant irrigation. The results suggest that the limited groundwater supplies available for irrigation in the Texas High Plains may be used more efficiently for seasonal irrigation during bloom than for preplant irrigation. W. M. Lyle (personal communication) indicated that the most efficient time to rewet the profile for water use by cotton is prior to the major growth and water use period rather than prior to planting.

Newman (1967a) evaluated preplant and seasonal irrigation of cotton in both solid planted and skip-row systems (1-m rows and bed-furrow spacing). In a 3-year test of the popular two-in-and-one out planted skip-row system, the preplant irrigation amount was reduced by one-third and IWUE values were increased to 0.212 kg/m^3 for preplant irrigation only and to 0.270 kg/m^3 for seasonal irrigation only during bloom. This study indicated that reduced water application in skip-row systems is an efficient use of preplant irrigation and soil water storage at planting. In the two-in-and-one-out system, irrigation of one furrow between two cotton rows substantially reduces water application compared with solid planting and every-furrow irrigation.

Yield probabilities of dryland and preplant irrigated only cotton by Bilbro (1974) at Lubbock, TX, indicated a declining yield response to preplant irrigation as yield levels increased. When yields exceeded 600 kg/ha, irrigated and dryland yields were similar. Production data for a 25-county area since 1968 indicated that irrigated and dryland yields were similar only in 1979, a cooler and wetter than normal season. (Texas Agricultural Statistics Service annual reports).

Much of the cotton production area has limited groundwater storage and relatively small well yields. Preplant irrigation can be applied over a longer time period than the normal irrigation season, which is limited to about six weeks because of the short growing season. Thus, a practical aspect of preplant irrigation is that small wells can be used to irrigate larger land areas than can be irrigated during the growing season.

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