ANALYSIS OF THE TEXAS HIGH PLAINS EVAPOTRANSPIRATION NETWORK DATA TO DETERMINE THE OPTIMUM PLANTING DATE FOR DRYLAND GRAIN SORGHUM

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ABSTRACT

Grain sorghum (*Sorghum bicolor* L. Moench) is a leading cereal in semi-arid regions. Lack of water constrains dryland production in the Texas High Plains. One of the important features in increasing its water use efficiency is seeding at an appropriate time to minimize water stress. The objective is to analyze data from the Texas High Plains Evapotranspiration Network (TXHPET) to determine the best time for seeding dryland grain sorghum. Daily data, namely growing degree days (GDD), precipitation, potential evapotranspiration (PET) and precipitation availability index (PAI) for short season grain sorghum seeded at four planting dates (1 May, 15 May, 1 June, and 15 June), were analyzed for 15 locations. Only 82 days were required at Chillicothe and Munday for sorghum to reach the black layer stage in contrast to 122 days at Dalhart for June 15 planting date. An important finding was that the amount of growing season precipitation was nearly the same regardless of the planting date, but the amount prior to seeding increased considerably as planting date was delayed. Since some of the precipitation that occurs before planting is stored in the soil profile and can be used during the growing season, delayed planting will likely result in more total water being available to the crop during the growing season and should result in higher grain yields. Therefore, it appears on average that planting sorghum in June will result in more total water being available to the crop than planting in May, but variation among years is high.

INTRODUCTION

Sorghum is a leading cereal in arid and semi-arid agriculture, ranking fifth in importance among the world's grain crops (Doggett 1988). It is one of the oldest known crops and its origin can be traced to Africa and India. It is an important food crop in regions where heat, drought and poor soils make other crop production systems unsuccessful, particularly in Africa and Asia. It has been commercially introduced in the United States (US) in the 1800's (Bennett et al., 1990) and is the third most important cereal crop in US after corn and wheat. Sorghum grain and silage are important sources of livestock feed in dryland areas with lowest potential for agricultural production in the US. Texas, Kansas and Nebraska are the leading dryland grain sorghum producers in the Great Plains region.

The climate in the Texas panhandle is characterized by limited annual rainfall of irregular seasonal distribution with a great loss of water due to runoff during torrential showers and a very high rate of evaporation. Most of the precipitation is received during April-September inclusive and is very irregular in its distribution. The monthly averages do not represent normalcy. However, in reality, a heavy torrential shower is followed by a severe drought. Evaporation of moisture from the soil and crops is very high reaching a maximum during periods of drought and high winds. Sorghum can be planted at any time during May-June. The early growth stages

Table 1. Years of available PET and yield data for various locations across the Texas panhandle.

Station	Years of PET data	Years of yield data
Perryton	1997-2005	1972-2004
Dalhart	1995-2005	1972-2004
Etter	1995-2005	1972, 73, 75-2004
Morse	1992-2005	1972-2004
White Deer	1995-2005	1972-2004
Bushland	1992-2005	1972-2000
Wellington	1996-2005	1972-2003
Dimmitt	1995-2005	1972-2004
Farwell	1997-2005	1972-2004
Earth	1996-2005	1972-2004
Halfway	1997-2005	1972-2004
Chillicothe	1999-2005	1972-85, 87, 91-2000
Lubbock	1997-2005	1972-80, 82-2004
Munday	2000-2005	1972-2000
Lamesa	1997-2005	1972-80, 82-2003

utilize most of the available soil moisture and also the growing season rainfall. This makes the later growth stages, particularly the anthesis and grain formation susceptible to water stress. Owing to its importance as a feed crop in the Texas High Plains, there is a need to plant the grain sorghum at an appropriate time where there will be minimal stress on the plant, especially during its critical stages of growth. The objective is to analyze the data from the TXHPET to determine the best time for seeding dryland grain sorghum in the Texas High Plains.

The number of days required to reach a particular growth stage are related to the air temperature and genetic background of the crop. A possible approach to predict the growth stage of a crop is to calculate the cumulative number of GDD. It is an index used to express crop maturity and it is computed by subtracting a base temperature of 50°F from the average of the maximum and minimum temperatures for the day. Minimum temperatures less than 50°F are set to 50°F and maximum temperatures greater than 100°F are set to 100. The black layer growth stage is assumed to be physiological maturity. The different growth stages identified for this study are 3-leaf, flag leaf, and flowering and black layer stages and the cumulative GDD required to reach each growth stage are 500, 1287, 1848, and 2673 respectively (Gerik et al., 2003).

MATERIALS AND METHODS

The study area includes 15 automated weather stations comprised in the Texas High Plains ET Network (North Plains and South Plains Networks). The stations extend throughout the Texas panhandle and include Perryton, Dalhart, Etter, Morse, White Deer, Bushland, Wellington, Dimmitt, Farwell, Earth, Halfway, Chillicothe, Lubbock, Munday, and Lamesa. The length of record varies with the locations and range from 14 years at Bushland and Morse to 6 years at Munday (Table 1). The stations were mapped on part of a Texas map using a geographical information system (Figure 1). Average annual precipitation ranged from a low of 16.2 in at Farwell to a high of 26.3 in at Munday. Elevation ranged from 1476 ft above sea level at Munday

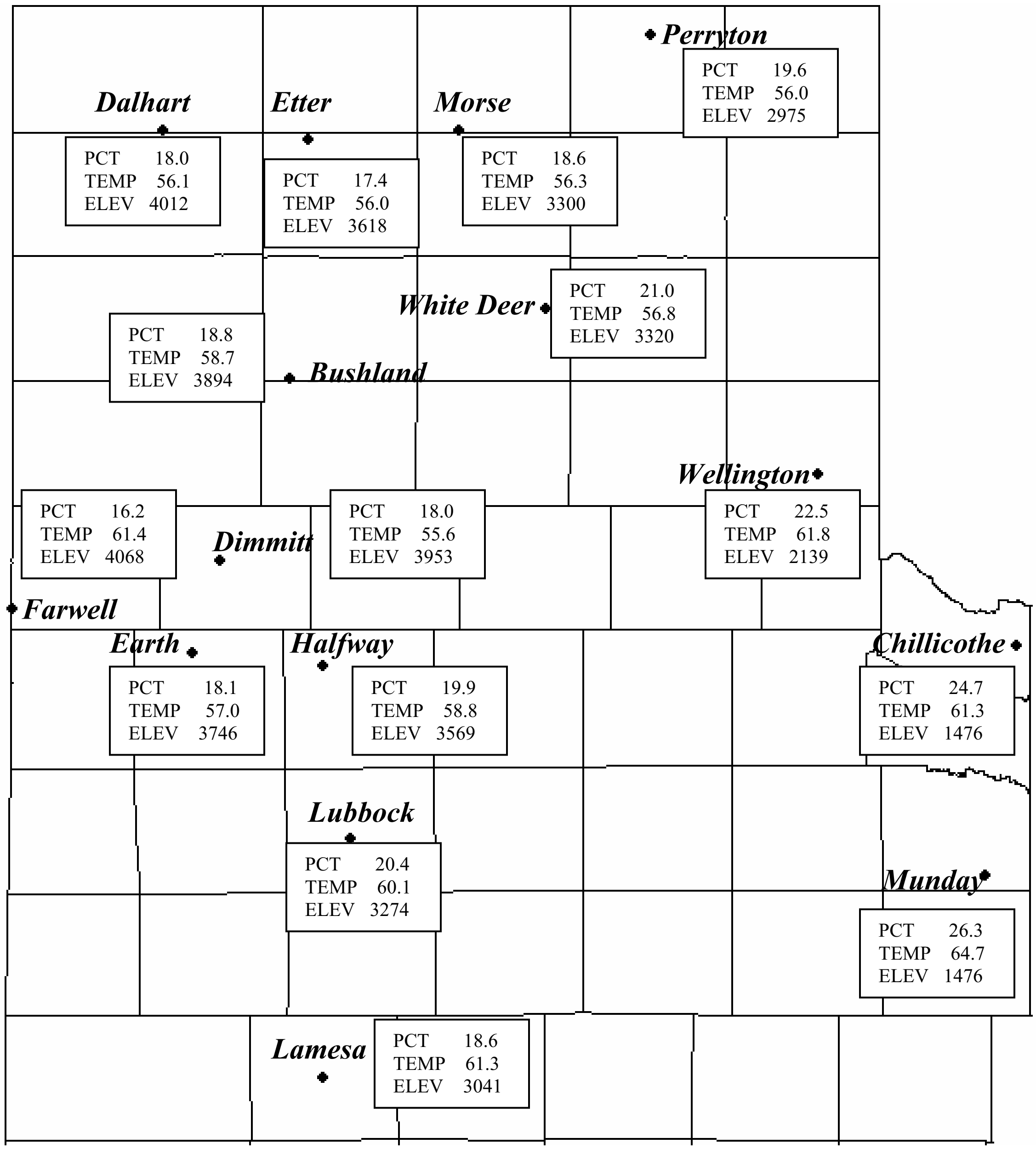

Figure 1. Texas Panhandle map showing various locations from the TXHPET, their 30-year average annual precipitation (in), average annual temperature (^{0}F), and elevation (ft).

and Chillicothe to 4068 ft at Farwell, and average annual temperature ranged from 55.6 °F at Dimmitt to 64.7 °F at Munday (Figure 1).

Daily data for short season dryland grain sorghum were collected from the TXHPET Network (TXHPET, 2005) for all the available years through 2005 for the four planting dates of 1 May, 15 May, 1 June, and 15 June. Number of years of available data varied from a maximum of 14 at Morse and Bushland to only 6 for Munday. The number of days from seeding to four different growth stages was calculated for each location. Also, the amount of precipitation occurring between 1 Jan. and the planting date, and the amounts of growing season precipitation that occurred during each of the four growth stages, as well as the total growing season precipitation, were summed for each location. Lastly, the precipitation availability index (PAI) was calculated for each period and season and shows the portion of the PET that was met by the growing season precipitation. Dryland grain sorghum also uses some of the precipitation that was stored in the soil profile at the time of seeding but the TXHPET Network does not provide any information about stored soil water. However, Jones and Johnson (1996) showed for a 9-yr study at Bushland that an average of 3.5 inches of water was used by dryland grain sorghum during the growing season. The PET is the amount of water required to fully meet the water demands of the growing crop and depends on the temperature, radiation, relative humidity, and wind conditions. The daily PET value can be measured by using a crop lysimeter, or calculated based on measurements of the climatic factors listed (FAO, 1999). The PET values for dryland grain sorghum will typically range from about 0.1 in per day or less at the 3-leaf stage to more than 0.35 in per day during flowering, and values greater than 0.5 in per day can occur on hot, dry, and windy days.

The average long-term grain sorghum yields (1972 to 2004 for most locations, Table 1) were calculated from yearly data obtained from the United States Department of Agriculture National Agricultural Statistical Service (USDA NASS, 2005). The calculated values represent the county average of all dryland grain sorghum acres harvested in the county where a TXHPET climatic site was located. The average ratio of acres harvested to acres planted for each county was also calculated. The 30-yr average monthly precipitation and annual precipitation amounts, and the average monthly temperature and annual temperature values, for each location was obtained from Intellicast (2005). Since the average precipitation and temperature records for Etter and Halfway were not available, the data of the nearest locations, Cactus and Plainview were respectively considered.

RESULTS AND DISCUSSION

The number of days required for grain sorghum to reach the black layer stage (physiological maturity) ranged from 82 to 122 d depending on date of planting and location (Figure 2). The 122 d requirement was for Dalhart and the same number of days was required for the earliest planting date, 1 May, and the latest planting date, 15 June. The shortest time of 82 d was for Chillicothe and Munday for the 15 June planting date. The elevation at Dalhart is much higher and the mean annual temperature considerably cooler than present at Chillicothe and Munday (Figure 1). The PET values, however, were higher at Dalhart than any other location in the network indicating Dalhart has the highest need for water to fully meet the water needs of grain sorghum for the entire growing season. This is because of the longer length of growing season required to accumulate enough growing degree days to mature the crop. Although the average amount of water required per day was less at Dalhart, the many more days that the crop required resulted in a higher total water use. In general, all of the southern locations had lower seasonal PET amounts than the northern locations. There was also a general trend at all locations for the seasonal PET amounts to decrease with the later planting dates. Again, this can mostly be explained by the later planting dates requiring fewer growing days. As the date of planting becomes later, the daily temperatures become higher, particularly during the early growth stages, and fewer days are required. However, the 15 June planting date required slightly more growing days than the 1 June planting date at nearly every location. Somewhat surprising, the PAI values were essentially equal for all locations regardless of the planting date. The northern locations had PAI values of about 0.35 indicating that precipitation during the growing season contributed only 35% as much water as would have been required to fully meet the needs of the crop. The PAI values were only about 0.25 for the southern locations but were generally 0.40 or higher for the eastern locations where the precipitation amounts and relative humidity values are generally higher.

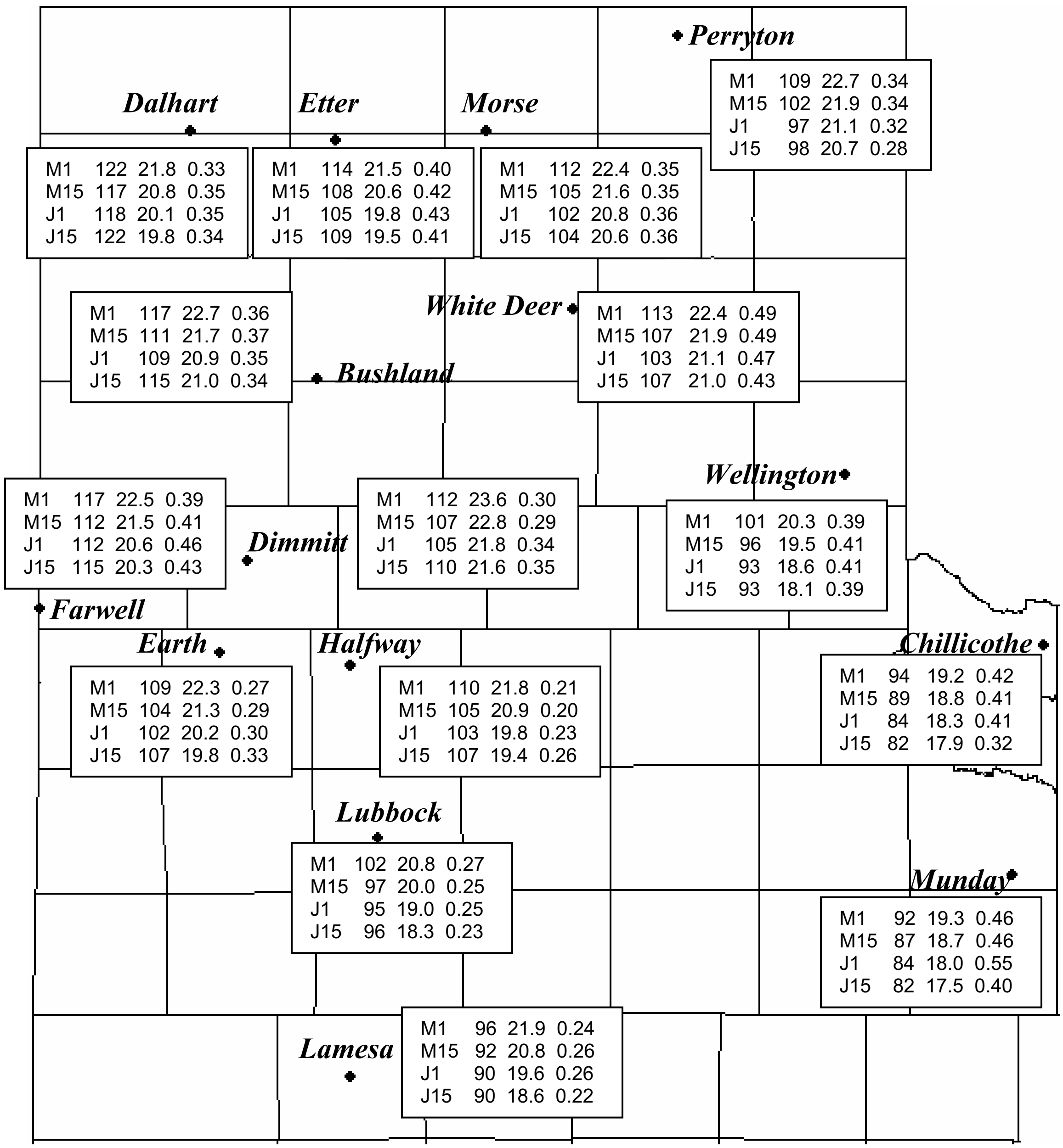

Figure 2. Texas panhandle map showing various locations from the TXHPET and the days taken to reach black layer, seasonal PET and PAI for years of available data for four planting dates (1 May, 15 May, 1 June, 15 June).

Dryland grain sorghum depends entirely on growing season precipitation and stored soil water that is present in the soil profile at the time of planting. Figure 3 shows the average amounts of precipitation that occurred between the time of planting and the black layer stage for each of the locations. The number of years that was averaged for different locations varied because the PET network began in 1990 with only Bushland and Morse. Table 1 shows the years that the PET network has obtained data for the various locations. It is important to note that the amount of growing season precipitation was largely independent of date of planting at essentially

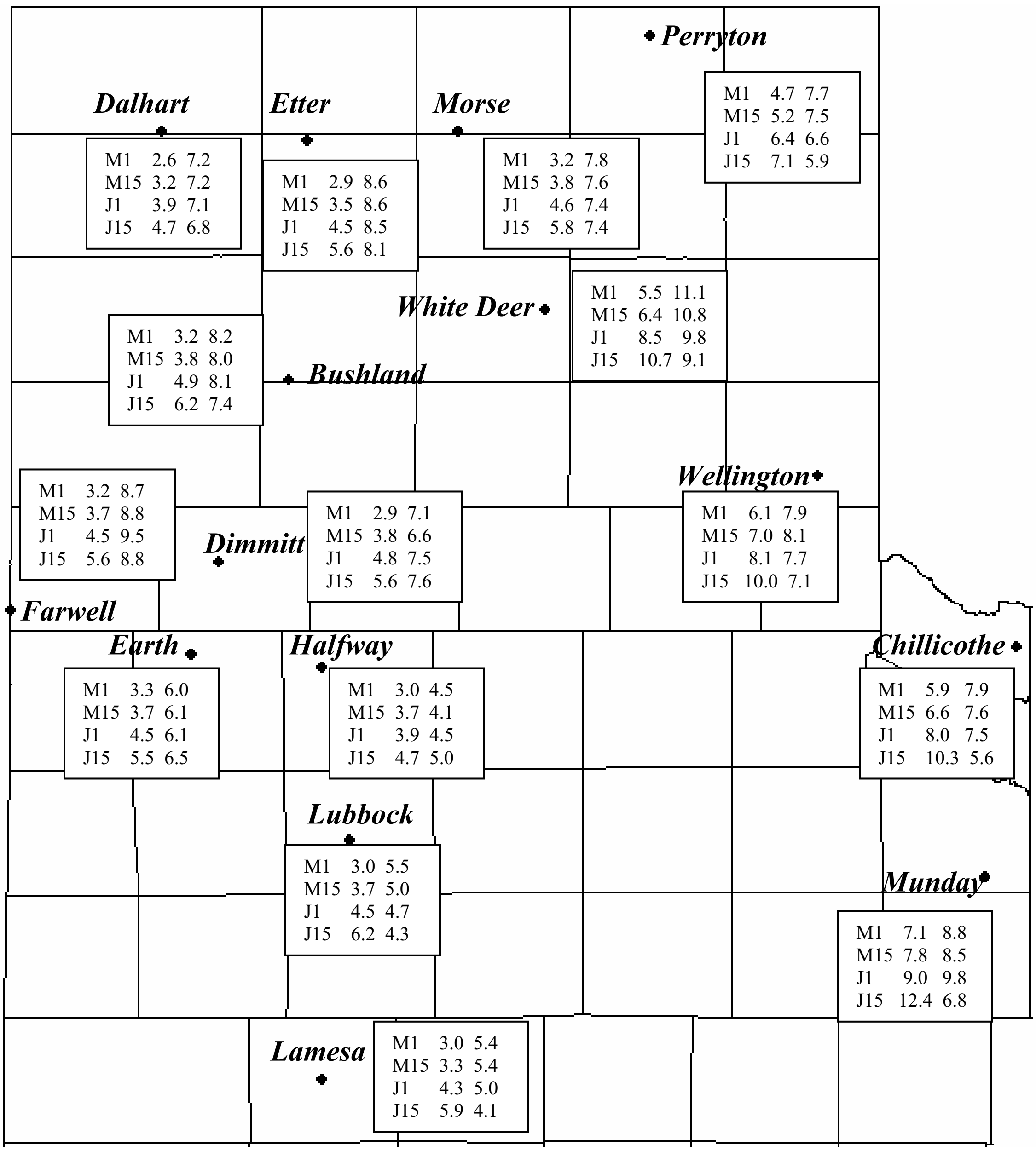

Figure 3. Texas panhandle map showing various locations from the TXHPET, their pre-plant and growing season precipitations (in) for four planting dates (1 May, 15 May, 1 June, 15 June) for years of available data.

all of the locations. The amounts of precipitation between 1 Jan. and the different dates of planting are also shown in Figure 3. As would certainly be expected, the amount of precipitation that occurred prior to planting increased as date of planting was delayed. The increased amounts between 1 May and 15 June ranged from about 2 inches at Dalhart to about 5 at Munday. It is well known and understood that some of the precipitation that occurs prior to planting a summer crop is stored in the soil profile and can be extracted by plants during the growing season. Dryland grain sorghum can extract soil water from a soil profile to a depth of four or more ft, and

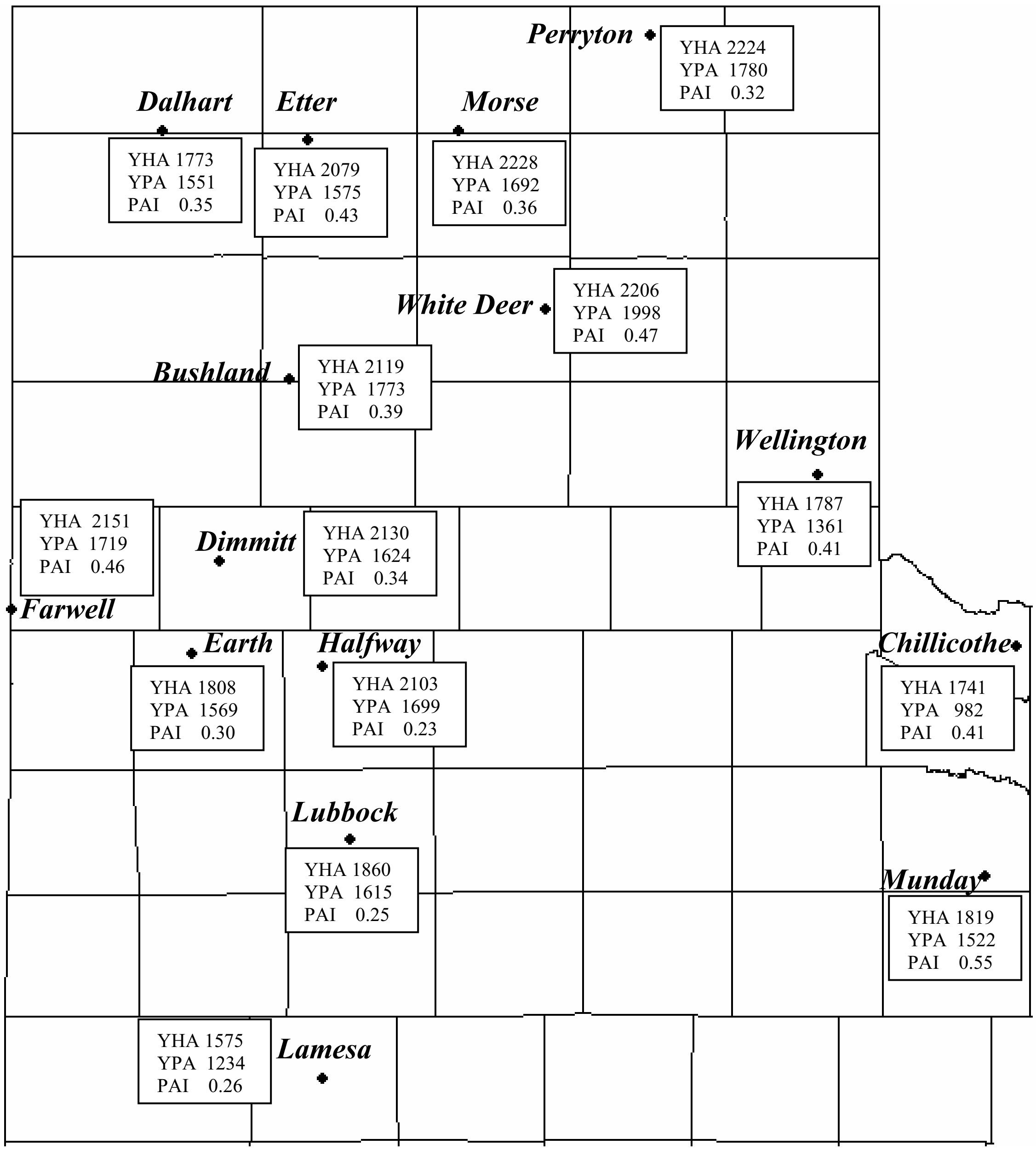

Figure 4. Average YHA and YPA for the county in which a PET Network site is located and PAI.

Jones and Johnson (1996) have shown that dryland grain sorghum at Bushland utilized an average of 3.5 inches of stored soil water during a 9-yr study. Even if only 20% of the precipitation that occurs prior to planting is stored in the soil for use by the grain sorghum crop, it could be important because small increases in stored soil water can result in significant increases in grain yield. Stewart and Steiner (1990) summarized several dryland grain sorghum studies and concluded that grain yields were increased 350 pounds for every inch of additional water use. Therefore, the information presented in Figure 3 indicates that more total plant available water will be available to a grain sorghum crop by delaying planting to 1 June or 15 June because there should be more stored soil water and growing season precipitation should be similar when compared to planting in May.

Grain sorghum is a major dryland crop in the Texas High Plains because it is one of the few crops that can be grown under severe drought conditions that occur almost every year. The long-term grain yields are shown in Figure 4 for the counties in which each of the network sites are located. Both the yield per harvested acre and yield per planted acre are shown. The yields were obtained from the USDA NASS (2005) and are the average for 1972 to 2004 for most locations, but for fewer years for some locations as shown in Table 1. On average, about 20% of the acres planted to grain sorghum are never harvested, so the yield per planted acre is considerably lower than the yield of harvested acre. For any location, the yield per planted acre can be divided by the yield per harvested acre to determine the proportion of planted acres that were actually harvested. For example, an average of 87% of the acres planted in the county where Dalhart is located was harvested compared to 78% for the county in which Lamesa is located. Average grain sorghum yields decrease from north to south, and the PAI values that represent only the years that the TXHPET network has been collecting data also decrease from north to south. Somewhat surprising is that the PAI values for the eastern counties where Wellington, Chillicothe, and Munday are located are also considerably higher than most of the other locations but the average yields are not higher. These locations are considerably lower in elevation and have higher mean annual temperatures than the other locations. The growing season temperatures are also higher as shown in Figure 2. The higher temperatures, particularly the higher night time temperatures, may have a negative effect on yields. As discussed earlier with Figure 2, the number of days required to grow grain sorghum at these locations is several days less than for the High Plains locations where the elevation is much higher (Figure 1).

The TXHPET network is used primarily for irrigation scheduling. The model assumes that the stage of growth changes with the same number of GDD regardless of the planting date. However Ottoman et al. (1997) showed that the number of GDD required for grain sorghum production was somewhat dependant on the planting date.

CONCLUSIONS

The amount of precipitation during the growing season was nearly the same regardless of the planting date, but the amount of precipitation prior to seeding increased considerably as planting date was delayed. Since some of the precipitation that occurs before planting is stored in the soil profile and can be used during the growing season, a later planting date will likely result in more total water being available to the crop during the growing season and should result in higher grain yields. Therefore, it appears on average that planting dryland grain sorghum in June will result in more total water being available to the crop than planting in May, but variation of precipitation among the years is high.

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