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Full Length Research Paper

Use of soil water content in deciding the sowing time in dry land agriculture

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Precipitation is the most important issue under dry land condition agriculture. However, soil water amount is the best parameter to decide the hydraulic stress level in crops. The main objective of this study was to determine a statistical model in deciding whether to plant or not under dry land condition. This model used soil water amount condition as the most important parameter. Two experiments were established in the summer of 2006 and 2007, respectively at the Francisco Villa community, in the estate of Durango, México. The two corn genotypes used in this experiment were White Hualahuises and H-412, soil water amounts were measured since the beginning in each plot. Also, grain yields were weighed for statistical analysis, which consisted of 2*2 contingency tables and X^2 interaction usage to estimate soil water amount for planting. The results indicated that the optimum soil water range for planting varies from 6.5 to 8.2 cm, for Blanco Hualahuises and 6.5 to 8.0 cm for H-412, in 2006; and 6.5 to 7.7 cm for Blanco Hualahuises in 2007. The main conclusion is that the X^2 interaction is a good tool to determine soil water ranges at the beginning of corn planting. Thus, farmer can decide whether to plant or not.

Key words: Genotypes, X^2 interaction, grain yield.

INTRODUCTION

Crop production in dry arid lands around the world depend on several factors which occur naturally in the environment and on weather distribution on time and space. Therefore, to achieve an integral resources utilize-tion and to diminish risks in the production it is necesary to develop methodologies that include factors such as, soil, weather, plant, and their interactions which can help on taking a decision in this type of agriculture (Hernandez et al., 1993). The limitant factor for agriculture in these areas, is not only quantity but also distribution of rain. However, rain is not always the best parameter used in the characterization of a specific region in regard to water availability for plants. Nix and Fitzpatrick (1969), Goos et al. (1984) and Villalpando (1985) reported water storaged in soil available for plants is a better parameter than rain used as an prediction element for crop success or failure Therefore, it can be used as a tool in taking desicion. The objective was to develop a statistical model based on water content storaged in soil which allows taking the decision of seeding.

MATERIALS AND METHODS

Experimental site

The experiment was established at the Francisco Villa Comunity, municipium of Ciudad Lerdo, Durango, México (Comarca Lagunera) Km 10 of the road Torreón-Nazareno. Geographycally located at 20°40'40'' North and 103°21'00'' West, with a elevation of 1110 m. It is located in the hydrologycal region No 36 were the predominant crops are maize (47.7%), and bean (35%), representing 82.7% of the tilled surface in the dry land area (Voisin and Orona, 1993).

According to Koppen's classification, modified by Garcia (1973), weather is arid with scarse precipitations throughout the year with an average of 240 mm. The rain period comprise from May to September, period during which 70% of precipitation occurs. The

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average annual temperature is 20.7°C. However, during the Spring and Summer (from May to August) the temperature raise to 40°C, causing hydric stress in crops.

Labor field

The experiment was conducted during Summer 2006 and 2007. Two maize genotypes were used (Blanco Hualahuises and H-412) under the following considerations: date of sowing, September 18 (2006) and August 23 (2007), seeding density in both cases was 12 kg ha^{-1} and the dose of chemical fertilizer was 80-40-00 of nitrogen, phosphorus and potasium respectively, at sowing time.

Evaluated field variables

1. Soil moisture content at sowing and after each precipitation date (cm). Soil moisture was measured once at sowing, using the Veimmheyer drill for this determination. Composite samples per plot were obtained, to evaluate moisture content at 0 - 30 cm and 30 - 60 cm depths. Moisture was calculated by gravimetric method (Martínez, 1971) using the Equation (1)

$$Pw = (Psh + tare) - (Pss + tare)/(Pss + tare) - tare \quad (1)$$

where:

Pw = gravimetric moisture content based on weight (g g^{-1}).
Psh = soil wet weight (g).
Pss = soil dry weight in oven at 105°C for 24 h (g).
To express the results in percent, the quantity obtained from the Equation (1) must be multiply by 100. Then, to express these values of moisture content in water amount (cm) the Equation 2 is used:

$$Lr = (Pw_3)*Da*Z \quad (2)$$

Where:

$Pw_3 = Pw_1 - Pw_2$; Where: Pw_1= Soil moisture (Pw) one week before the soil moisture was determined at sampling time (Pw_2) for each depth.
Lr = water lamina in soil (cm).
Pw = gravimetric moisture content based on weight (g g^{-1}).
Da = soil apparent density (g cm^{-3}).
Z = depth where moisture is estimated (m).

2. Grain yield per plot (t ha^{-1}).

Experimental design

Fourty eight plots were randomly distributed in a surface of three hectares, half of them were sown with the genotype Blanco Hualahuises (24 plots) and the rest with H-412 (24 plots). That distribution was performed to explore a large rank of moisture conditions based on micro relief. The surface on each plot was 5.6 m wide and 10 m long sowing at 0.80 m between furrows and at 0.20 m between plants, establishing seven furrows per plot and harvesting five furrows to obtain grain yield per plot.

Methodology

Moisture values (cm) in soil at sowing time and grain yield during 2006 and 2007 were used to estimate water content in order to determine the right time for planting, employing the analysis of the χ^2 methodology cited by Keisling and Mullinex (1979), whom applied the procedure to evaluate threshold of adequacy or toxicity on micro nutrients, and by Goos et al. (1984) whom used data of 53 years of grain yield in North Dakota and using that procedure to determine the adequate water content in soil to decide sowing on wheat (*Triticum aestivum* L.). These authors found out that water content in soil less than 6. 4 cm were not adequate for sowing and that moisture ranks of 6.4 to 9.4 cm showed the same quantity of success or failure on sowing, indicating that 9.4 cm of water content was required to be successful and to obtain yields higher than 1350 kg ha^{-1}. This methodology is possible to estimate the threshold (water rank in soil) most probable for crop, dividing the number of successes or failures based on the intercross zone (zone that divides the population in yields above and below the mean). Soil moisture after one precipitation is used to estimate water content that should be in soil to obtain yields equal or higher than the regional average (1000 kg ha^{-1}). The regional yield average (1000 kg ha^{-1}) considered in this study is similar to that in other areas in Mexico. Peña and Zapata (1990) reported yields of 645 to 835 kg ha^{-1} on maize in the central zone of Mexico using precocious genotypes under critical moisture conditions and late crops as occurred in 2006 and 2007 for Blanco Hualahuises and H-412. Value of χ^2 for each critical value was calculated using the Equation 3.

$$\chi^2 = \frac{(N11 * N22 - N12 * N21)^2 N..}{N1. * N2 - N.1 * N.2} \quad (3)$$

Where:

N11 = number of plots with grain yield below the regional average with deficient water content.
N21 = number of plots with grain yield above the regional average with deficient water content.
N12 = number of plots with grain yield below the regional average with sufficient water content.
N22 = number of plots with grain yield above the regional average with sufficient water content.
N1 and N2 = total number of plots on the respective row.
N.1 and N.2 = total number of plots on the respective column.
N = total of evaluated plots.

The parameters which integrate the Equation 3 were obtained by using contingency tables of 2*2. To perform the procedure of contingency tables of 2*2 the following critical values of moisture content were used: 6.5, 7.0, 7.5, 8.0, 8.5, 9.0, 9.5, 10.0 and 10.5 cm, plus the regional yield average of 1000 kg ha^{-1}. Values above and below of that yield determined the transition between successes and failures, arranging the equation parameters on the contingency table as shown:

			Sum
	N11	N12	N1.
	N21	N22	N.2
Sum	N.1	N.2	N..

Once the contingency table procedure was performed, the obtained values were substituted for each critical value in Equation 3 and the χ^2 values were calculated building up a dispersion diagram with the moisture critical values on the X axis and χ^2 values on the Y axis and point out in the graphic the intercross zone. These values (intercross zone) is obtained using the regional yield average of 1000 kg ha^{-1} in the χ^2 tables using a $\alpha = 0.05$ of significance level and one degree of freedom (column -1 and row -1) (Steel and Torrie, 1988). Thus, based on the diagram, rank moisture content can be defined. The χ^2 methodology was used because of previous

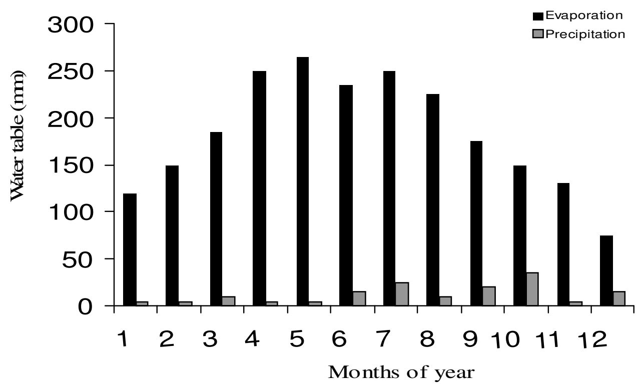

Figure 1. Climate behavior (evaporation and precipitation). Francisco Villa, Durango. México. 2006.

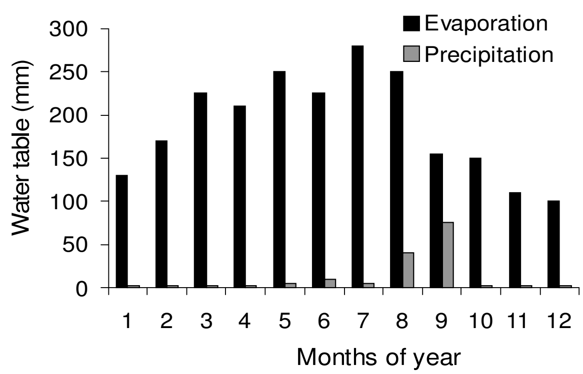

Figure 2. Climate behavior (evaporation and precipitation). Francisco Villa, Durango,México. 2007.

Table 1. Grain yield and soil water content at sowing time per plot in Blanco Hualahuises and H-412 maize. Francisco Villa, Durango, México 2006.

Blanco Hualahuises		H-412	
Grain yield (kg ha^{-1})	Soil water content (cm)	Grain yield (kgha^{-1})	Soil water content (cm)
976	6.05	1200.1	5.0
928	6.22	1482.2	7.0
1236.1	6.28	1282.1	7.5
1064.1	6.51	1141	7.5
1464.1	7.84	1229.6	9.7
988	7.93	1364.1	9.8
1156.1	8.01	1291.9	9.8
935	8.25	1265.7	9.8
1454.1	8.25	1439.5	10.0
962	8.38	1459.2	10.6
1304.1	8.48	1232.9	10.8
1500.1	8.5	1190.2	10.8
1600.1	8.95	1095.1	10.8
1450.1	9.29	1248.4	11.0
1112.1	9.53	1124.6	11.2
1120.1	10.08	1098.4	11.4
1468.1	10.08	995	11.4
1204.1	10.12	1042.6	11.4
1456.1	10.53	916.3	11.5
1039.5	11.6		

study, Lopez and Pissani (1996) showed a lack of fit by regression analysis for the data base analyzed, with an R^2 of 0.13, 0.49 for Blanco Hualahuises and of 0.32 and 0.29 for H-412 respectively.

RESULTS AND DISCUSSION

Weather conditions

Weather conditions for 2006 were limited, which got worse the drought conditions established since 1993 and 1998. Precipitation during this year was 182.6 mm and precipitation during the crop cycle was 118.5 mm (Figure 1). Figure 1 shows that during 60 days the crop was maintained only with the moisture of rain storage in soil during this period of time.This originated later problems on crop development mainly at grain fill stage, due to the high temperatures occurring in September and October which propitiated increased water lost due to evaporation, causing a limited grain yield due to limitations of grain fill stage.

In 2007 moisture conditions in soil were more critical than in 2006, precipitation was 145.6 mm, and precipitation during the crop cycle was 95 mm (Figure 2). However, unlike 2006 the precipitation was scarce during the crop cycle, in 2007 precipitation occurred mainly at sowing time (80 mm) and after that only 15 mm of precipitation occurred for the rest of the crop cycle. The scarce precipitation resulted on limited moisture in soil in both crop cycles resulting in low grain production. Our results are in agreement with Jordan (1983) and Qui and Redman (1993) whom reported a negative effect of moisture reduction on crop development.

In Tables 1 and 2 the information shown is related to water content in soil at sowing time and grain yield for both genotypes in 2006 and 2007. In those tables also, grain production is shown by plots. Four and five plots were lost in 2006 for Blanco Hualahuises and H-412, respectively, remaining 19 and 20. However, in 2007 only two plots were lost, remaining only 23 in both genotypes, respectively. Those plots were lost due to limited soil moisture during crop cycle, which caused grain or forage not to be produced. Based on grain yield and moisture values at sowing, the statistic of χ^2 was estimated allowing the study to calculate the ranks of moisture content at sowing time.

The results in Table 3 (values of χ^2 for both genotypes) showed the intercross zone for Blanco Hualahuises in both cycles (2006 and 2007) and values of water content from 6.5 to 8.2 cm and 6.5 to 7.7 cm, respectively. Also,

Table 2. Grain yield and soil water content at sowing time per plot in Blanco Hualahuises and H-412 maize. Francisco Villa, Durango, México 2007.

Blanco Hualahuises		H-412	
Grain yield (kg ha^{-1})	Soil water content (cm)	Grain yield (kg ha^{-1})	Soil water content (cm)
3090	6.36	2120	8.22
2440	6.42	2090	8.76
2400	6.75	2430	8.85
1080	7.26	1590	8.85
950	7.32	2250	8.88
950	7.32	1830	9.0
1010	7.50	2310	9.25
1870	7.53	2770	9.27
1030	7.59	2200	9.27
1620	7.65	2040	9.33
2010	7.81	2010	9.33
3060	8.13	1920	9.60
2730	8.67	3130	9.81
2150	8.73	2150	9.9
1700	8.79	2050	9.9
3030	9.0	1490	10.02
1500	9.18	1280	10.02
940	9.21	1440	10.08
2270	9.24	1640	10.35
2850	9.63	1370	10.47
2260	9.66	1200	10.47
850	9.75	1800	10.56
2520	9.96	1250	10.77

Table 3. X^2 interaction for grain yield in Blanco Hualhuises and H-412 maize. Francisco Villa, Durango, México 2006-2007.

Critical value of soil water content (cm)	2006		2007	
	Blanco Hualahuises	H-412	Blanco Hualahuises	H-412
	X^2 value	X^2 value	X^2 value	X^2 value
6.5	9.97	9.4	10.40	-
7	14.18	9.42	16.38	-
7.5	14.18	20.0	12.15	-
8	14.70	8.88	5.28	-
8.5	4.93	8.88	4.50	-
9	3.13	8.88	2.58	-
9.5	2.42	2.71	1.019	-
10	1.019	2.71		
10.5	0.95			
11.0	0.24			

values of 6.5 to 8.0 cm for H-412 in 2006 at an α level of 0.005; in 2007 moisture ranks for H- 412 were not reordered, because of yield field results (Table 2) exceeded the regional average (1000 kg ha^{-1}), therefore it was not possible to apply the methodology. In the study area 1000 kg ha^{-1} was the yield average used and based on that value the models must be generated. In 2007 the smallest value of water content registered at sowing time was 8.22 cm (Table 2), which surpass any rank of those calculated for Blanco Hualahuises. As graphic example for genotype H - 412 in 2006 (Figure 3) show the rank of moisture to define sowing time which varies from 6.5-8.3 cm.

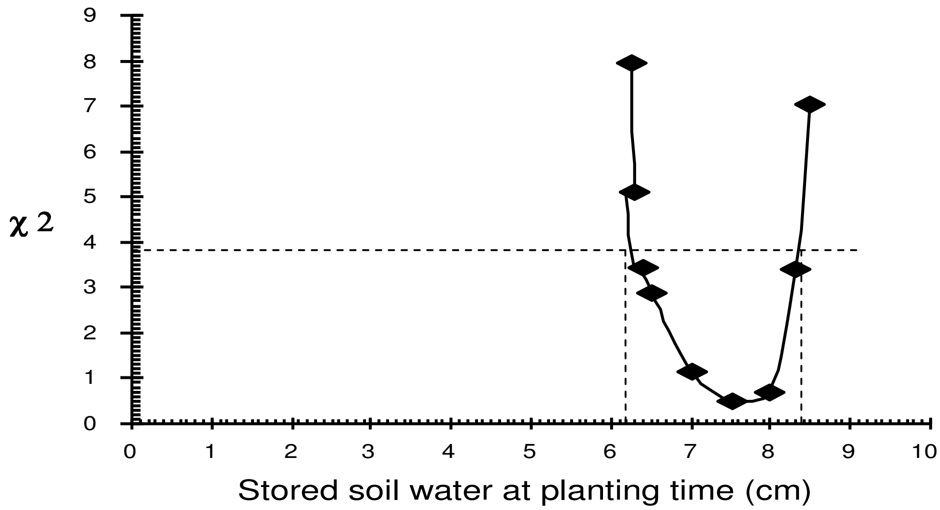

Figure 3. χ^2 interactions for both Blanco Hualahuises and H-412 maize. Francisco Villa, Durango, México. 2006.

Based on the previous results, it is feasible to obtain a yield similar to that higher than the regional average in both genotypes using the estimated ranks, and above these ranks of water content in soil yields higher than 1000 kg ha^{-1} are expected. The results are in agreement with Goss et al. (1984) whom reported that water content in soil at sowing time is a critical factor to be successful in the agricultural production in arid zones. The previous results vary due to the difference in water content in soil between plots. However, the results are reliable for both genotypes.

Conclusions

The χ^2 test is a good tool to identify initial moisture ranks in soil to decide either sowing or not. The results demonstrated that the ranks of moisture content in soil to determine sowing time should be from 6.5 to 8.2 cm for Blanco Hualahuises and from 6.5 to 8.0 for H - 412, respectively, in 2006; and from 6.5 to 7.7 cm for Blanco Hualahuises in 2007 at an α level of 0.005. These moisture values help the authors to obtain similar quantity of success or failures in grain yields similar or higher than the regional average (1000 kg ha^{-1}). Therefore, water content in soil suitable to be successful and to achieve yields higher than 1000 kg ha^{-1} should present values similar or higher than 7.8 and 8.3 cm, respectively, for Blanco Hualahuises and H-412 in both cycles. Validation of the methodology in other areas of Mexico is suggested, to amplify its perspectives of application and investigation under conditions of climatic risk.

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