Growth and Yield Development of Some Pearl Millet Cultivars During the Spring Season in Nuevo Leon, Mexico[1]

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ABSTRACT

In the present study 20 pearl millet cultivars were grown in Nuevo León in the Spring of 1985 for growth and development studies. The results showed that while a significant difference occurred for days to flowering, no significant difference was found for variation in days to panicle initiation or days to maturity. Differences were found among varieties for durations of various growth stages but not for grain yield. The difference among cultivars in the numbers of heat units or accumulated sunshine hours required from planting to 50% flowering was also significant. A significant correlation was found among heat units and accumulated sunshine hours required for different growth stages but no significant correlation was observed among durations of growth stages and yield components. Significant correlation existed between some vegetative traits and yield. These indicate that high temperature, long photoperiod and a large difference between day and night temperature during the growing season favoured growth and adaptation of pearl millet in semiarid Nuevo Leon, Mexico.

COMPENDIO

En el presente estudio 20 cultivares de mijo perla fueron sembrados en Nuevo León para estudiar su crecimiento y su desarrollo durante la primavera de 1985. Los resultados mostraron que aunque existe una diferencia significativa entre cultivares para los días a floración, no se encontró diferencia estadística en los días a la iniciación de la panoja o días a madurez fisiológica. Se obtuvieron diferencias entre variedades para diferentes etapas de crecimiento, pero ninguna para el rendimiento de grano por hectárea. La diferencia encontrada en el número de unidades calor y horas luz acumuladas requeridas para una etapa se encontró también para el 50% de floración. Se obtuvo una correlación significativa entre las unidades calor y horas luz requeridas para diferentes etapas, pero no se encontró correlación significativa entre las etapas de crecimiento y los componentes del rendimiento. Hubo algunas correlaciones entre la etapa vegetativa y el rendimiento. Estos resultados indican que las altas temperaturas, fotoperíodos largos y la gran diferencia de temperatura entre el día y la noche prevalente durante la estación, favorece el buen crecimiento y adaptación del mijo perla en Nuevo León, México.

INTRODUCTION

Pearl millet (*Pennisetum americanum* L. Leeke) is one of the important cereals for grain and forage in rain-fed agriculture in the arid and semiarid tropics of many countries in Africa, India, Pakistan, Bangladesh, Burma, Sri Lanka and others. The adaptations of crops in the semiarid tropics are clearly defined, being limited to those sites with rainfall ranging between 200 and 600 mm annually, spread over 2-4 months, high evapotranspiration rate and edaphic conditions of shallow or sandy soil (3, 6). Rachie and Majmudar (13) and Bidinger *et al.* (2) have suggested that the adaptation of pearl millet to these conditions might be due to its short duration and tolerance to high temperature. Because north east Mexico exhibits a climate that resembles the zones of adaptation of pearl millet as described, an attempt is being made to introduce this crop in the area where other crops fail, mainly due to frequent droughts. Lack of rainfall at critical times often leads to a scarcity of grain and forage production in this zone. In order to successfully introduce a crop it is necessary to study its growth, development and phenology (8).

This paper describes an evaluation of 20 pearl millet cultivars for growth, development and adaptation during the spring season in semiarid Nuevo Leon, Mexico.

MATERIAL AND METHODS

Field trials described herein were conducted at the experimental station of the Agronomy Faculty of Universidad Autónoma de Nuevo León at Marin, N.L. (Lat 25°53' N, Long 100°03' West, altitude 367 m) during the spring of 1985 (February-June); this planting date coincides with the planting season of this region. The following pearl millet cultivars were sown on 23 February, 1985:

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WC–C–75	C	ICMS–7835	S
ICMS–7703	S	NELC–P–79	V
IVS–5454	S	ICMS–7857	S
IVS–A–82	S	WS–P–78	V
ICMS–7704	S	ICMS–8008	S

C = Compositae; S = Synthetic;

NELC–H79	V	ICH–433	H
ICMS–8021	S	ICH–451	H
ICMV–81237	V	ICH–440	H
ICMV–81111	V	ICMH–415	H
ICMV–81235	V	ICMH–423	H

H = Hybrid

These genotypes include varieties, synthetics and hybrids which have been generated by the Pearl Millet Programme of the International Crops Research Institute for Semi-Arid Tropics (ICRISAT) located at Patancheru, India This constitues a part of the international adaptation trial of pearl millet distributed by INCRISAT

The cultivars were evaluated in the field in a randomized complete block design with an experimental plot of 4 rows, 5 m long, with 80 cm between rows, in three replications Two irrigations were given, one at planting and another supplemental, one month later Seeds were treated with the insecticide Aldrin (dimetanonaftalene) at 3 g/kg seed, and the fungicides ridomil (metal oxil) and thiram (tetramethyl) both at 2 g/kg seed. Plants were thinned to 10 cm spacing within rows. Insects, such as thrips (*Frankliniella occidentalis*) and aphids (*Myzus persicae*) were observed and controlled with an application of Lannate (metomil) at 300 g/ha, diluted in 350 l of water.

Data on phenology (e g GSI = days from emergence to panicle iniciation; GS2 = days from panicle initiation to 50% flowering; GS3 = days from 50% flowering to physiological maturity) were recorded according to methods described by Maiti and Bidinger (8). Plant height (from stem base to tip of panicle of main stem), leaf number (marked with China ink) on main stem, panicle exsertion length, number of productive and non-productive tillers, grain yield (of two central rows leaving 30 cm on both sides, 3 2 m^2) and 1 000 seed weight (dried in oven for two days at 65°C) were recorded on 10 tagged plants from the central two rows at random, per replicate, at maturity

Temperature (maximum, minimum), precipitation, hours of sunshine and heat units (HU) calculated, were recorded daily at various growth stages. Weather records were taken from Meteorological Station, Agricultural Experiment Station, Agronomy Faculty Campus, UANL.

Heat units were calculated following the formula of Arnold from the daily mean (max ϕ min) temperature with a base of 10°C.

$$HU = \frac{(\text{Maximum} + \text{Minimum})}{2} \ T°C - 10°C$$

RESULTS

Growth stages and growth duration

Analysis of variance indicates that no significant differences were observed among cultivars and days from planting (GS1) Results indicate, however, that a significant difference existed for days from planting to flowering, which ranged from 58-70 days (Table 1). The 20 cultivars had mean times to GS1 and GS3 of 64 and 92 days, respectively. GS1 in different cultivars ranged from 28 to 31 days, GS2 from 31 to 40 days and the duration of GS3 in different cultivars ranged from 24 to 32 days (Table 2) Although no significant differences were observed among cultivars in growth stages and growth duration, some cultivars are identified which were very early and some were late in different growth stages. All the pearl millet cultivars flowered in the long days (13-14 hours day length), indicating their photosensitive nature.

With respect to the environmental factors no significant differences were observed among cultivars for HU required for GS1 and GS3 However, in the GS2 a highly significant difference ($P < 0.01$) was found to occur among cultivars for the accumulated heat unit sum (Table 1). The cultivars requiring minimum heat units for GS2 were IVS-5454, ICMH-423, WS-P78 and ICMH-415. All cultivars reached anthesis with heat sum units ranging from 746-933

A similar pattern emerged with accumulated hours of bright sunshine; there was no significant difference in GS1 and GS3 but significant differences among cultivars were observed for GS2 ($P < 0.01$) The early flowering cultivars received less hours of bright sunlight during each growth phase (Table 1). The hours of bright sunshine accumulated at anthesis by cultivars averaged 423h

Yield components and grain yield

A significant difference ($P < 0.01$) was observed among different yield components, number of leaves, plant height, total tiller number, productive tiller number, non-productive tiller number, length of

Table 1. Variability in growth parameters and yield components of 20 pearl millet cultivars grown in Marin, Nuevo León, Mexico, 1985.

	Mean	Range	C.V. %	Significance
Days to panicle initiation	29.90	28–32	3.69	NS
Days to 50% flowering	64.43	58–70	3.05	++
Days to physiological maturity	92.67	91–94	1.49	NS
Heat units at GS1	332.0	320–370	3.27	NS
Heat units at GS2	841.0	746–933	3.76	++
Heat units at GS3	1 296.0	1 267–1 320	1.88	NS
Accumulated hours of bright sunlight, GS1	186.0	177–210	4.56	NS
Accumulated hours of bright sunlight, GS2	423.0	371–477	4.37	++
Accumulated hours of bright sunlight, GS3	645.0	683–650	0.80	NS
Leaf number	8.0	6.4–9.4	5.4	++
Plant height (cm)	146.0	125–170	5.7	++
Panicle exsertion length (cm)	2.69	0–7.63	49.23	NS
Panicle length (cm)	23.0	17–27	4.0	++
Tiller number (total)	4.78	4–7	11.89	++
Productive tiller number	1.0	0–3	30.8	++
Non-productive tiller number	3.59	2–6	16.51	+
1 000 seed weight (g)	5.27	3–7	8.10	++
Grain yield (kg/ha)	1 234.0	572–1 935	18.95	NS

NS = Non-significant
+ = $P < 0.05$
++ = $P < 0.01$

exsertions, panicle length and 1 000 seed weight (Table 1). No significant difference was observed in grain yield/ha (Table 2). The 20 cultivars had mean plant height, tiller number, panicle length, 1 000 seed weight and grain yield of 146.4 cm, 4.8 cm, 23 cm, 5.3 g and 1 234.2 kg/ha respectively.

Some cultivars were short (c. 1.40 m) (e.g. ICMH-415, ICMH-423, ICMH-7703). The cultivars which produced reasonably high yields were WS-P78 (1 540 kg/ha), ICH-451 (1 486 kg/ha, IVS-5454 (1 484 kg/ha), ICMV-81 253 (1 459 kg/ha), and all of these were approximately 1.5 m in height. The cultivar which was least well adapted was ICMH-423 (Table 2).

Correlations

a) Growth stages: the duration of GS1 did not show any correlation with the duration of advanced growth stages, although a significant correlation was found between the duration of GS2 and the duration of GS3 (Table 3).

b) Environmental requirements: a highly significant correlation was observed among the duration of some of the growth phase and the heat units accumulated for these stages. For example, the duration of GS2 was significantly correlated with the heats sums required for the same growth stage. There was no significant correlation between HU requirements in GS2 and HU required for GS3. The purpose of calculating HU is to integrate those fluctuations over time in a way that directly and linearly related to the rate of development of the crop.

While considering the relation among the principal growth phases, a significant correlation was found among HU requirements of GS2 and GS3 (r = 0.36).

c) Yield components: there were good correlations among plant characters. There was a significant but weak negative correlation between the duration of the vegetative growth stage (GS1) and leaf number (r = 0.33) and between panicle development and leaf number (r = 0.22). One thousand seed weight showed significant positive correlation with panicle length (r = 0.32) and yield (r = 0.33).

Heat units required for GS1 showed a negative correlation with leaf number (r = 0.31). Yield components did not show significant correlation with the duration of GS1 at this phase but HU required for GS2 showed significant correlation with leaf number (r = 0.39), panicle exsertion (r = 0.35), number of non-productive tillers (r = 0.39) and panicle length (r = 0.24). The sunshine hours accumulated in the vegetative growth stage were highly negatively correlated with leaf number (r = –0.45). The accumulated sunshine hours were also correlated with different

Table 2. Duration of various growth stages (days and grain yield of 20 cultivars grown in Marin, Nuevo Leon, Mexico, 1985.

Genotype	Panicle initiation	Flowering	Physiological maturity	GS1	GS2	GS3	Grain yield kg/ha
	Days						
WC-C75	29	64	93	29	35	29	1 161
ICMS-7703	31	66	93	31	35	25	1 248
IVS-5454	29	62	93	29	33	31	1 484
IVS-A82	29	65	93	29	36	28	1 277
ICMS-7704	29	69	93	29	40	24	1 035
ICMS-7835	28	63	91	28	35	28	1 247
NELC-P79	29	64	92	29	35	28	1 337
ICMS-7857	29	68	94	29	39	26	1 152
WS-P78	29	62	92	29	33	30	1 540
ICMS-8008	29	63	92	29	34	29	1 151
NELC-H79	29	64	93	29	35	29	1 209
ICMS-08021	29	64	92	29	35	28	1 270
ICMV-81237	29	66	93	29	39	27	1 079
ICMV-81111	29	65	94	29	36	29	1 312
ICMV-81235	29	64	93	29	35	29	1 459
ICH-433	29	64	94	29	35	30	1 068
ICH-451	28	67	93	28	39	26	1 485
ICH-440	30	68	92	30	38	24	1 186
ICMH-415	29	60	91	29	31	31	1 177
ICMH-423	30	62	94	30	32	32	797
S E	0 066	0 244	0 024	0 066	0 239	0.226	15.815

yield components, e.g. with panicle exsertion (r = 0.45), but there was no correlation between parameters associated with GS3 and yield components.

There was significant correlation among some yield components, e g. panicle length with plant height (r = 0.62) and productive tiller number with total tiller number (r = 0 55). Grain yield was significantly correlated with plant height (r = 0 42), with panicle length (r = 0 33), leaf number (r = 0 24) and 1 000 seed weight (r = 0 33) Pearson and Coaldrake (11) did not find any correlation between individual seed weight and any other characters but in the present study seed weight showed positive correlation with panicle length (r = 0 32) and yield (r = 0 33).

Variation in climatic variables in relation to phenology

During the growing period of the crop climatic factors varied greatly. The maximum temperature varied between 12°C and 30°C and the daily minimum temperature ranged between 5 5°C and 29°C. Daily bright sunshine hours ranged from 0 to 10 7 and the rainfall from 0 to 10.6 mm. There were large fluctations of temperature during this phase. It was observed that emergence was delayed (nine days) due to the prevailing cool soil temperature (4 5°C-9°C). The panicle initiation occurred when the minimum temperature exceeded 10°C, maximum temperature ranged between 32°C and 36°C, and sunshine hours ranged from 0 to 10 7 hours

During GS2 daily maximum temperature ranged from 14 1°C to 38°C, daily minimum temperature ranged from 11°C to 25°C, sunshine hours ranged from 2 3 to 11 5 hours and daily rainfall from 0 to 65 mm. This phase was characterized by a fluctuating daily maximum temperature

In GS3 the daily maximum temperature ranged from 32°C to 38°C and the minimum daily temperature from 22°C-28°C. The duration of GS3 in different cultivars ranged from 26 to 32 days. The time from planting to physiological maturity in different cultivars was 95 days; on average ICRISAT cultivars matured in about 102 days.

DISCUSSION

This study reports the performance of different pearl millet cultivars evaluated for grain production in the semiarid environment of Marin, Nuevo Leon, in northeastern Mexico. Field experiments with

20 ICRISAT genotypes have showed that pearl millet was well adapted during the spring season and that there was significant variability in some of the growth stages and many of the yield components studied. Some of the cultivars were well adapted and gave acceptable grain yields. Pearson and Coaldrake (11) also reported acceptable performance by some ICRISAT genotypes in temperate eastern Australia. The temperature which prevalied during the present study was high (12°-39°C) with a high rate of evapotranspiration in the summer months. Pearl millet is likewise well adapted to temperate eastern Australia where temperature ranges during the major growing period were 30-35°C.

The vegetative phase terminates with the initiation of the panicle phase (7, 8).

The panicle development stage (GS2), during which there is growth of floral organs, is affected by adverse factors such as drought or nutrient deficiency (7, 8). High insolation and moderate to high temperatures produced excellent growth of the crop. There was a highly significant variation among cultivars for duration of GS2, with a range of 31 to 40 days being observed; ICMH-415 was identified as an early maturing cultivar requiring 31 days from panicle initiation to flowering, while ICH-415, a late cultivar, required 39 days for this phase. The early flowering genotypes gave a grain yield of 1 178 kg/ha and the late genotype gave a grain yield 1 486 kg/ha, though this difference was not statistically significant. Most of the genotypes were earlier in maturity with a reasonably higher yield in comparison to their performance in India. This might be correlated to longer photoperiod and higher temperatures in Mexico compared to those in India and Africa.

Ong and Monteith (10), Fussel *et al.* (4), Ong (9) and Pearson and Coaldrake (11) stated that genotypes showed differences in the requirements of light and temperature. The results obtained with respect to the requirements of heat units and accumulated hours of bright sunlight indicate that there was no significant difference among cultivars in the vegetative and grain filling phases, while in the panicle development phase a significant difference was observed. This phase depends much on temperature and photoperiod (1, 4, 5) thus indicating that the time to flowering shortens and panicle development accelerates with an increase in temperature. Fussell *et al.* (4) demostrated that high temperatures shortened and low temperature lengthened the grain filling period. Hence the variability in the grain filling periods was among genotypes. ICMH-423 required 32 days for grain filling while ICMS-7857 needed only 26 days. This indicates that late genotype gave a lower yield compared to the early genotype showing poor adaptation of this cultivar. All the cultivars were well adapted to long photoperiods. A long photoperiod and a large difference between the day and night temperature (10-28°C) probably favored higher photosynthetic production of pearl millet cultivars during the spring season in Marin, Nuevo Leon. Some of the early maturing cultivars could be cultivated up to three times per year in this region.

Correlation among variables

There were significant correlations between durations, heat units and accumulated sunshine hours of GS2 and GS3. This estabilished a weak but possibly important relationships between these phases. A significant correlation between GS1 and GS2 indicates a relationship between leaf area per plant and the rate of panicle development.

Table 3. Correlation among yield components, duration of growth stages, heat units and accumulated hours of bright sunlight for each growth stage of pearl millet (*Pennisetum americanum*) Marin, Nuevo Leon, Mexico, Spring 1985

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 Leaf no	1.00																	
2 Plant height	0.45^{++}	1.00																
3 Length exsertion	0.50^{++}	-0.02	1.00															
4 Panicle length	0.32^{++}	0.62^{++}	-0.31^{++}	1.0														
5 Tiller no.	0.20	-0.22^{+}	-0.07	-0.23^{+}	1.00													
6 Productive tiller	0.17	-0.14	0.43^{++}	-0.32^{++}	0.55^{++}	1.00												
7 Non-productive tiller	0.36^{++}	-0.10	-0.37^{++}	0.09	0.57^{++}	-0.28^{+}	1.00											
8 Yield	0.24^{+}	0.42^{++}	0.07	0.33^{++}	0.03	0.06	-0.07	1.00										
9 Phase 1	-0.33^{++}	-0.15	0.19	-0.11	-0.10	0.10	-0.27^{+}	-0.12	1.00									
10 Phase 2	0.22^{+}	-0.05	-0.19	0.08	0.03	-0.08	0.14	-0.16	0.12	1.00								
11 Phase 3	0.15	0.01	0.03	0.02	0.06	0.07	0.07	-0.18	0.06	0.29^{+}	1.00							
12 1 000 seed weight	0.10	0.14	-0.19	0.32^{++}	-0.08	-0.17	0.05	0.33^{++}	-0.07	-0.08	0.03	1.00						
13 Heat unit phase 1	-0.31^{++}	-0.15	0.17	-0.11	-0.07	0.11	-0.27^{+}	-0.10	0.99^{++}	0.11	0.04	-0.05	1.00					
14 Heat unit phase 2	0.39^{++}	-0.04	-0.35^{++}	0.24^{+}	0.14	-0.20	0.39^{++}	-0.23^{+}	0.09	0.59^{++}	0.36^{++}	0.11	0.09	1.00				
15 Heat unit phase 3	0.15	0.00	0.03	0.02	0.06	0.08	0.07	-0.18	0.06	0.30^{++}	1.00^{++}	0.03	0.04	0.36	1.00			
16 Light hours phase 1	-0.32^{++}	-0.15	0.18	-0.11	-0.08	0.10	-0.27^{+}	-0.11	0.99^{++}	0.12	0.05	-0.06	0.99^{++}	0.09	0.05	1.00		
17 Light hours phase 2	0.35^{++}	-0.01	-0.45^{++}	0.35^{++}	0.05	-0.31^{++}	0.37^{++}	-0.16	0.04	0.54^{++}	0.26^{+}	0.20	0.05	0.91^{++}	0.26^{+}	0.04	1.00	
18 Light hours phase 3	0.17	-0.01	-0.01	0.04	0.07	0.06	0.10	-0.20	0.06	-0.32^{++}	0.99^{++}	0.03	0.04	0.41^{++}	0.99^{++}	0.05	0.31^{++}	100

+ = Significance ($P < 0.05$)
++ = Significance ($P < 0.01$)

While analysing the relationship among yield components, the duration of vegetative phase (GS1) showed a negative correlation with leaf number which indicates the genotypes with higher leaf number experience a delay in panicle initiation. The duration of GS1 did not show any correlation with other yield components. The duration of panicle development phase (GS2) showed a weak but significant positive correlation with leaf number, which suggests that higher leaf numbers are associated with slower panicle development. The yield components did not show any correlation with the duration of GS2

Phul (2) demonstrated association of some yield components such as leaf number and plant height with grain yield. Gupta showed a significant correlation of panicle length and tiller number with grain yield. Pearson and Coaldrake (11) showed significant correlation between panicle length, plant height and days to anthesis among ICRISAT genotypes. Similarly the present study shows significant correlations of some of yield components with grain yield.

The present study, unlike that of Pearson and Coaldrake (11), showed a weak but significant correlation between seed weight and panicle length and grain yield. This indicates that the expression of characters and the degree of correlation among yield components varies in different environments.

LITERATURE CITED

1. BEGG, J.E.; BURTON, G.W. 1971 Comparative study of five genotypes of pearl millet under a range of photoperiods and temperatures. Crop Science 11:803-805

2. BIDINGER, F.R.; MAHALASKSHMI, V.; TALUKDAR, B.S.; ALAGARSWAMY, G. 1981. Improvement of drought resistance in pearl millet. ICRISAT.

3. COCHEME, J.; FRANQUIN, P. 1967 Rapport technique sur une étude agroclimatique de l'Afrique sèche au sud du Sahara Rome, FAO 326 p.

4. FUSSELL, L.K.; PEARSON, C.J.; NORMAN, M.J.T. 1980. Effects of temperature during various growth stages on grain development and yield in *Pennisetum americanum*. Journal of Experimental Botany 31(121):621-633

5. HELIMER, H.; BURTON, G.W. 1972. Photoperiod and temperature induces early anthesis in pearl millet Crop Science 12:198-200.

6. KOWAL, J.M.; KASSAM, A.M. 1978. Agricultural ecology of savanna. Oxford, Oxford University Press 403 p

7. MAITI, R.K.; BISEN, S.A. 1978. Studies on growth and development of panicles and grains in two contrasting genotypes of pearl millet (*Pennisetum typhoides* S. & H). In "Physiology of sexual reproduction in flowering plants" Ed. by R.K. Maiti *et al.* Kalyani Publishers. p. 115-125.

8. MAITI, R.K.; BIDINGER, F.R. 1981 Growth and development of the pearl millet plant. Patancheru, India, ICRISAT Research Bulletin no. 6

9. ONG, C.K. 1983. Responses to temperature in a stand of pearl millet (*Pennisetum typhoides* S. & H) vegetative development. Journal of Experimental Botany 34:322-336

10. ONG, C.K.; MONTEITH, J.L. 1984 Response of pearl millet to light and temperature. In Agrometeorology of Sorghum and Millet in the Semi-arid Tropics. ICRISAT. p. 129-142 Presented at International Symposium (1982, Patancheru, India). Proceedings.

11. PEARSON, C.J.; COALDRAKE, P.L. 1983. *Pennisetum americanum* as a grain crop in Eastern Australia Field Crops Research 7:265-282.

12. PHUL, P.S. 1971. Association of some leaf and stem characteristics with grain yield in pearl millet Current Science 41:89-90

13. RACHIE, K.O.; MAJMUDAR, J.V. 1980 Pearl Millet. Pennsylvania State University Press 307 p.