901

YIELD COMPARISONS OF PEARL MILLET (PENNISETUM AMERICANUM (L.) LEEKE) AND GRAIN SORGHUM (SORGHUM BICOLOR (L.) MOENCH)

by

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B. S., University of California, Davis, 1978

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

Approved by:

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TABLE OF CONTENTS

LIST OF TABLES

Table Page

Table | Page

INTRODUCTION

Pearl millet (*Pennisetum americanum* (L.) Leeke) is grown on more than thirty million hectares of the world's land (66). It is the principle food source for many millions of people in the semi-arid tropics of Africa and India. Following sorghum (*Sorghum bicolor* (L.) Moench) it is the second most important crop in India (54). In the United States, however, large scale cultivation of pearl millet has been limited to the southern coastal plain where about 200,000 hectares are grown annually as temporary summer pasture (48).

Of domesticated plants, pearl millet is one of the most tolerant to drought (8, 9, 54). No other cereal grows so well in areas of high temperature, low rainfall, and infertile, light, sandy soils (4, 39, 43, 55). Throughout most of it's distribution, mean annual rainfall varies between only 250 and 800 mm (9).

Pearl millet yields traditionally have been low. Even as of 1978, yields in farmer's fields in Africa and India averaged only 400 to 500 kg/ha (35). However, using hybrids, fertilizers, and some irrigation, Indian farm demonstrators reported yields of 3500 to 8000 kg/ha (14).

To aid plant breeders working with pearl millet, yield evaluations were conducted at several locations in Kansas for two summers. Commercial grain sorghum hybrids were included for comparison. Attention was focused on grain yield, plant height, seed weight, grain protein content, head number per unit area and plant population.

In addition, heterosis among several pearl millet inbreds and their F_1 hybrid offspring was studied.

LITERATURE REVIEW

YIELD EVALUATIONS

Pearl millet yield trials were conducted as early as 1936 in Sudan (40). Three Nigerian cultivars were compared with local cultivars at Dilling and Lagawa. Based on three years of testing at Dilling (1936-38) all three Nigerian cultivars were superior to the local cultivar. 'Nigerian unawned black' was the best cultivar; it produced a mean yield of 1556 kg/ha compared to 1327 kg/ha for the local cultivar. Likewise, at Lagawa in 1937, Nigerian unawned black was the top entry with 951 kg/ha. Yield of the local cultivar was not reported. The Nigerian cultivars were less susceptible to bird and locust attack.

Initial improvement of open pollinated populations of pearl millet employed some form of mass selection in indigenous and introduced populations (27). In all, about twenty-five cultivars improved by mass selection were released in India (27).

In the 1950's, pearl millet cultivar 'Punjab Type-55' had a three year average yield of 1135 kg/ha (43). In a "fair sized" trial in 1960, pearl millet cultivar 'Improved Ghana' significantly outyielded Punjab Type-55 by 22.5 percent (41). Improved Ghana produced 1830 kg grain/ha. Both cultivars were quite tall, about 300 cm each. The 1000-seed weight of Improved Ghana (15.3 g) was substantially higher than that of Punjab

Type-55 (6.7 g). When Improved Ghana was supplied to farmers in sixty Indian villages, the average yield increase due to new seed was 24 percent (44).

In 1968-69, performance studies were conducted at Lyallpur, West Pakistan (71). Of ten pearl millet cultivars tested, 'Ex Bornu' was the highest yielder with 1433 kg/ha. It was also the tallest cultivar (222 cm) and produced the most leaves (12 leaves/plant), but produced the lowest number of tillers (1.2/plant).

In addition to varietal improvement, attempts were made to exploit heterosis in pearl millet by building "chance hybrids," which are mixtures of 40 percent hybrid and 60 percent parental seed (27). These hybrids were produced by planting parental inbred lines in equal proportions and allowing them to mate in isolation. Chance hybrids were released in India in the early 1950's and outyielded standard cultivars by 10 percent. However, because of their limited productivity, narrow range of adaptability, and lack of seed production programs, improved cultivars and chance hybrids did not become popular (27).

Discovery of cytoplasmic male sterility in pearl millet by Burton in 1955-56 (11) made possible the large scale production of hybrids. The development of hybrids in India can be divided into three phases based on seed parents, years of release, and disappearance of the hybrids from cultivation (27).

In the first phase, 1965-1972, five hybrids, 'HB-1' through 'HB-5', were released (27). Of these hybrids, 'HB-3' was popular until 1974-75. "Tift 23A', a cytoplasmic male sterile line developed by Burton (12) and introduced to India in 1962, was the common female parent of these hybrids. These hybrids gave high grain yields, showed better adaptation to drier conditions, tillered profusely and synchronously, exhibited medium early maturity, and responded better to fertilization than local cultivars (27).

HB-1 (Hybrid Bajra-1) developed by Athwal (5), was tested throughout India under the Coordinated Millet Improvement Program (2). HB-1 produced 100 percent more grain and 30 percent more fodder than the standard cultivars of the respective regions (2). Under rainfed conditions, yields of 2471 kg/ha were obtained (5). In a demonstration at Ludhiana in the rainy season (Kharif) of 1964, HB-1 yielded 4645 kg/ha of grain compared to 2570 kg/ha of the standard cultivar, 'A 1/3' (5). Athwal suggested that head numbers and not head size contributed to it's high yield potential. HB-1 was susceptible to ergot and soon went out of cultivation (27).

The second hybrid, HB-2, was released in India in 1966 (15). Though it was early maturing and high yielding, it never spread widely (27) because a superior hybrid, HB-3, was released in 1968 (42).

HB-3 had superior grain quality as compared to HB-2 (15), and had shorter maturity, larger grains, and was better adapted to moisture stress conditions (27). HB-3 also tillered better than local types (15). In the All India Coordinated Trials from 1969 to 1975, HB-3 yielded an average of 1600 kg/ha under rainfed conditions (27). It was popular in all the pearl millet growing areas of India (15). In Gujarat, HB-3 covered 66 percent of the pearl millet hectarage in 1973. As a result of this, the average yields in farmers' fields rose from 310 kg/ha (1960-61) to 719 kg/ha (1973-74) (15).

HB-4, a hybrid recommended for irrigated areas and areas with adequate rainfall, was also released during this period (27, 50). In comparative performance trials (1965-68), HB-4 out-yielded HB-1 by an average of 26 percent and by as much as 126 percent in some locations. In these same trials, HB-3 out-yielded HB-1 by an average of 11.2 percent and local cultivars by 50 percent (50). Average yields for HB-4, HB-3, and HB-1 were 3296, 2539, and 2101 kg/ha, respectively. The local cultivar yielded 1514 kg/ha. In a separate experiment with rows spaced 46 cm apart and 80 kg N/ha applied, HB-4 yielded 4020 kg/ha compared to 3360 kg/ha for HB-1 (50).

In the second FAO Regional Cooperative Pearl Millet Nursery held at nine locations in eight countries in 1973, HB-4 and cultivar 'Ex Bornu 70' gave the highest average grain yields of 4500 kg/ha and 3960 kg/ha respectively over all locations (7).

Due to heavy downy mildew infestation, HB-4 was subsequently withdrawn (27). The incidence of downy mildew in HB-3 likewise increased until by the year 1974-75, it was totally susceptible (15, 27). Thus the first phase of hybrids, based on Tift 23A, came to an end.

During this same period, other pearl millet hybrids and varieties were evaluated in the East African Regional Trial at Botswana (1971-72) (8). There was no significant difference between hybrids and varieties tested. Yields of open pollinated varieties ranged from 2558 kg/ha (Serere 30) to 3352 kg/ha (Serere Composite 3). Yields of hybrids ranged from 2987 kg/ha (10LA x Serere 3A) to 3652 kg/ha (Tift 23A x Serere 2A).

Yields in farmers' fields at this time in Botswana (1968-69 to 1972-72) ranged from only 64 kg/ha to 251 kg/ha for pearl millet and from 65 kg/ha to 455 kg/ha for sorghum (8). Sorghum outyielded millet in every year but by only one kg/ha in 1969-70.

The second phase of the hybrid era was characterized by attempts to diversify the female background for downy mildew tolerance (27). '5071 A', a hybrid with low downy mildew incidence, was developed by mutation breeding. During 1975, HB-3 and HB-5 were reconstituted using 5071 A as New HB-3 (NHB-3) and New HB-5 (NHB-5). These hybrids did not become popular due to low yields, and because seed production did not catch up with the demand for new hybrid seed (27).

In Gujarat, India, millet hybrid 'GHB J 1399' was found to have high downy mildew resistance and acceptable agronomic characteristics (15). It was released in 1975 for Gujarat. In large scale state trials at five locations from 1972 to 1974, GHB J 1399 yielded an average of 2738 kg/ha compared to 2538 kg/ha by HB-3. In 1975 it yielded 2921 kg/ha compared to 2595 kg/ha for NHB-3 and 1955 kg/ha for HB-3

Two more hybrids, based on the cytoplasmic male sterile line 'Pb 111A' from Ludhiana, were found to have downy mildew resistance (19, 27). These hybrids, PHB 10 and PHB 14, were tested in four yield trials in India and Africa from 1972 to 1975 (19). Mean yields of PHB 10 ranged from 1901 kg/ha to 3008 kg/ha and mean yields of PHB 14 ranged from 1978 kg/ha to 3156 kg/ha. Yields of HB-1 ranged from 978 kg/ha to 1893 kg/ha. These hybrids were given the new designations HB-6 and HB-7 (PHB 10 and PHB 14 respectively) and were released in India in 1977 (19). However, seed production problems arose due to the occurrence of pollen shedders (27), though the problem was later reportedly corrected.

During the growing season (Kharif) of 1975, the International Crops Research Institute for the Semi-Arid Tropics, (ICRISAT), divided fifty-seven hybrid combinations into three trials on the basis of height and tested them at three locations in Africa and India (29). Though none of the hybrids were totally free of downy mildew, the best ICRISAT entries outyielded the check, HB-3, by 7 to 61 percent. The highest yielding hybrid, 'ICH-73', produced 3780 kg/ha averaged over locations (37.9 percent more than the mean of HB-3).

In a separate trial conducted by ICRISAT in "Rabi" 1975, ten new hybrids out of nineteen tested gave higher yields than HB-3 (29). 'ICH-101' was the highest yielder with 4059 kg/ha. HB-3 yielded 2740 kg/ha.

During Kharif 1975, four additional yield trials were conducted at ICRISAT (29). The first was a population/composite trial under high fertility conditions at Hyderabad and Hissar in India (29). At Hyderabad the highest yielder, 'Serere Composite 2(m)' produced 3370 kg/ha compared to 2350 kg/ha for the HB-3 check. At Hissar, a hybrid, PHB 10, was the best entry with 2720 kg/ha. 'Serere Composite 2' was second best with 2490 kg/ha and the HB-3 check produced 1990 kg/ha.

The second study was a population/composite trial under low fertility at Hyderabad (29). 'Early Composite' was the top yielder with 1180 kg/ha compared to 550 kg/ha for HB-3/

The third study was the All India Coordinated Millet Improvement Project, (AICMIP), Trial II at Hyderabad (29). The highest yielding hybrid, 'ICH-11', produced 1510 kg/ha, however it was partly susceptible to downy mildew and ergot.

The fourth study was a released hybrids trial also at Hyderabad (29). The best entry was hybrid 'HB-3-2' with 1263 kg/ha. Downy mildew affected most entries and ergot affected all entries.

Another yield trial was held at ICRISAT, with irrigation, in the summer of 1976 (29). Downy mildew and ergot which are common during the rainy season did not appear. The highest yielding hybrid, 'ICH-35', produced 4039 kg/ha. HB-3 yielded 3660 kg/ha and HB-4 yielded 3410 kg/ha. Two Senegalese synthetics (GAM-73 and Senegal Dwarf Synthetic) and variety Ex Bornu (from Nigeria) gave respective yields of 2577 kg/ha, 2330 kg/ha, and 2399 kg/ha, all lower than the trial mean of 3060 kg/ha.

The third phase of hybrid breeding began in 1976, and was based on new male steriles developed by backcrossing (27).

Two Indian hybrids, 'BH 104' and 'BK 560-230,' were relatively resistant to downy mildew and were comparable to HB-3 and HB-7 in productivity. In 1168 and 654 demonstrations in 1975 and 1976 respectively, BJ 104 and BK 560-230 produced respective mean yields of 1590 kg/ha and 1670 kg/ha representing increases of 40.7 percent and 47.8 percent over the mean yield of local checks (1139 kg/ha).

'BD 111', another hybrid, also showed potential (27). During two years of testing it gave a mean yield of 1880 kg/ha, a 17.5 percent increase over BJ 104. BD 111, BJ 104, and BK 560-230 were all based on the same female parent, '5141A', which had Tift 23A cytoplasm.

Despite proven high yield potentials, hybrids failed to achieve widespread coverage in India (27). Coverage in Rajasthan never exceeded 10 percent, and in Gujarat and Maharashtra, hybrids were only used on up to 40 percent of the cultivated area (27).

In addition, pearl millet hybrid yields in farmers' fields did not approach their demonstrated potential (42). The primary causes of low pearl millet productivity in Haryana, India appeared to be: (1) inadequate supply of hybrid seed, (2) low plant population, (3) natural hazards such as drought, erratic rainfall distribution, and diseases, and (4) poor management practices including low fertilizer application and poor weed control (42). In Botswana, birds were cited as the biggest obstacle to pearl millet production (8).

But inspite of the above, and although the area planted to millet remained relatively constant, average pearl millet production in India in the 1970's increased nearly 50 percent over that of 1965-66 (27). This increase was principally due to the development, release, and cultivation of hybrids as no improved varieties were released since 1965 (27).

However, composite varieties as well as hybrids are important in the improvement of pearl millet for several reasons (19): (1) it may not be possible to saturate all pearl millet growing areas with hybrids due to limitations in seed production, (2) genetically heterogeneous populations can withstand disease hazards better than uniform hybrids, and (3) farmers can produce seed from varieties once supplied them.

Harynarayana (27) reported that yields of the best populations were as much as 93 percent of that of hybrids. Inspite of their 10 percent lesser yields, populations have an edge over hybrids in situations of natural epiphytotics though hybrids have an advantage under stress conditions (27).

Work on the development of composite populations in pearl millet was taken up at Ludhiana in 1971 (19). Six composites were developed, and the first of these, 'PSB-3', was tested in the All India Coordinated Trials in 1975 where it gave the highest yield (1980 kg/ha) among composite varieties, although the best hybrid, PHB-14, yielded 2130 kg/ha. All six composites were tested in the All India Coordinated Trials in 1976. 'PSB-8' ranked first among composites yielding 1530 kg/ha compared to 1640 kg/ha for the best hybrid, PHB-14.

In 1976, the FAO Cooperative Pearl Millet Trial was conducted at Wad Medani, Sudan (40). Three Nigerian entries, 'Nigerian Composite', 'Ex Bornu', and 'World Composite S_1 (C_1)' were better than others. Their respective yields were 3361 kg/ha, 3059 kg/ha, and 2990 kg/ha.

A pearl millet synthetic, HS-1, developed at Haryana Agricultural University in India, was tested in four trials conducted under different environments at Indian research farms (42). In 1975 it produced a mean yield of 2341 kg/ha compared to hybrid PHB-14 with 2715 kg/ha and local cultivars with 1903 kg/ha. In 1976, HS-1 yielded 3232 kg/ha, only slightly less than PHB-14 (3270 kg/ha) and much greater than locals (1886 kg/ha) again averaged over four trials (42). In the 1976 All India Coordinated Trials, HS-1 yielded 1390 kg/ha (mean of sixteen trials) compared to 1640 kg/ha by PHB-14 (42). In twenty-two minikit trials, HS-1 had a average yield of 1147 kg/ha, PHB-14 averaged 1347 kg/ha, and locals averaged 790 kg/ha (42). HS-1 was reported to have disease and lodging resistance.

The Andhra Pradesh Agricultural University released it's first composite, 'Vijay', in 1971 (57). It was suitable for growing in regions of adequate rainfall or with irrigation, and it's average grain yield was 1800 kg/ha compared to 1700 kg/ha for HB-1. Vijay deteriorated with time in yield, and in uniformity of height and maturity but was improved through additional breeding and again was reported to have been performing well.

Three additional composites were released by millet research stations in Andhra Pradesh in 1976 (57). In the All India Coordinated Trials conducted at eight locations in Kharif, 1975, these composites, 'Visakha', 'Balarji', and 'Nagarjuna', recorded grain yields of 1870 kg/ha, 1750 kg/ha, and 1700 kg/ha respectively, occupying second, third, and fourth ranks among composites (57). 'PSB 3' from Ludhiana was first with a yield of 1910 kg/ha.

An experimental varieties trial consisting of twenty-two derived varieties was conducted by ICRISAT at six locations in India during Kharif, 1976 (25). Eighteen out of nineteen experimental varieties were statistically equivalent to hybrid PHB-14 in yield (2070 kg/ha). 'Super Serere Composite-CX75' was best with a yield of 2240 kg/ha. Most varieties were superior to PHB-14 in downy mildew resistance.

Among varieties tested for three years (1977-79) in the All India Coordinated Trials, 'WC-C75' (an ICRISAT variety) was first with a mean yield of 1731 kg/ha (94 percent of released hybrid BJ 104) (36).

ICRISAT breeding materials were tested in Senegal during the off-season in 1977 (46). In an advanced progeny test, 'AP-23' (which was 197 cm tall with non-compact heads) gave the highest yield of 2660 kg/ha. The second best entry, 'AP-98,' yielded 2580 kg/ha, had compact heads, and was 130 cm tall.

In another trial, downy mildew free lines were evaluated for yield (however, there was no downy mildew pressure in the off-season) (46). The best line, 'DM 30', yielded 2630 kg/ha, had compact heads, and was 170 cm tall.

Drought tolerant lines were also evaluated (46). The best, 'DN 1', yielded 2930 kg/ha (under control conditions) and 2820 kg/ha under stress, a three percent reduction. DN 1 was 80 cm tall.

In hybrid experiments, 'ICH 105' was the best entry yielding 2690 kg/ha (46).

Experimental varieties also performed well. The best was 'IVSA x 75', (2555 kg/ha) (46).

In the summer of 1974, ICRISAT tested 166 variety cross F_1 hybrids (38). Hybrids involving Indian and African parents yielded over 25 percent more than the best hybrids made with cytoplasmic male sterile lines growing in the same field. The best variety cross hybrid, 'J 1249 x 700544', yielded 6668 kg/ha.

In Pearl Millet Inbred Trial 1 held at ICRISAT in 1976, 43 inbreds were evaluated (38). Three inbreds performed as well as the check, PHB-14, which had a four location mean yield of 2220 kg/ha. The best inbred was an F_5 inbred derived from the cross 'Souna D_2 x Ex Bornu-161'. It's mean yield was 2649 kg/ha, and it showed a high level of downy mildew resistance in India and Senegal.

In Pearl Millet Inbred Trial 2 (1976) forty-six inbred progenies were evaluated (38). Four inbreds had yields equivalent to the best hybrid check, PHB-14 (2254 kg/ha, averaged over four locations). The best inbred was 'J 1270 x 700623' with a mean yield of 2241 kg/ha. These inbreds had low incidences of downy mildew.

In the main season of 1976, ICRISAT conducted three advanced pearl millet hybrid trials, (PMHT's 1, 2, and 3), at six locations in Africa, India, and Pakistan (39). Entries were allocated to PMHT 1, 2, or 3 on the basis of height determined the previous season. Of twenty-five hybrids tested in PMHT 1, six entries had average yields higher than the best check, BK 560-230 (2420 kg/ha). 'ICH 110' was the highest yielder with 2895 kg/ha (though this was not significantly higher than the check).

In PMHT 2 (39) four hybrids, of twenty-five tested, yielded better than the best check, BK 560-230 (2962 kg/ha) though again none were significantly better than the check.

Twenty-three hybrids were tested in PMHT 3 (39). 'PHB-12' from Ludhiana was the top entry with 2880 kg/ha compared to the check, BK 560-230, with 2857 kg/ha.

Three ICRISAT hybrids were tested at thirty-two locations in the 1976 AICMIP Advanced Yield Trial III for limited moisture conditions (39). 'ICH 105' ranked second with a mean yield of 2240 kg/ha. The check, BK 560-230 ranked first with 2270 kg/ha.

In the AICMIP - Advanced Hybrids Trial at Ludhiana and Faridkot, India (1978), twenty-three pearl millet hybrids were evaluated under irrigated and rainfed conditions (20). With irrigation, 'MH-1' was the top yielding hybrid with a two location mean yield of 3732 kg/ha. The HB-7 check yielded 3008 kg/ha. MH-1 was also best under rainfed conditions with a mean yield of 3500 kg/ha, well above HB-7 (2698 kg/ha).

AICMIP - Initial Hybrids Trials were also at Ludhiana and Faridkot (20). Thirty-three entries were evaluated under irrigated and rainfed conditions. 'MH-33' was the best hybrid under irrigated conditions with a mean yield of 3102 kg/ha.

HB-7 yielded 2888 kg/ha and BJ 104 yielded 2534 kg/ha. The top ranking hybrid under rainfed conditions was 'MH-31' with a mean yield of 3129 kg/ha compared to HB-7 with 2411 kg/ha and BJ 104 with 1941 kg/ha.

Open pollinated populations of pearl millet also were evaluated at Ludhiana and Faridkot in 1978 (20). Twelve entries were tested under irrigated and rainfed conditions. With irrigation, a hybrid, PHB-14, was the top entry with 2902 kg/ha. But the best population, PSB-3, followed closely with 2816 kg/ha. Hybrid BJ 104 yielded 2585 kg/ha. Under rainfed conditions, hybrid PHB-14 was again the highest with an average yield of 2795 kg/ha. 'MP-6' was the best population with 2718 kg/ha. BJ 104 yielded 2455 kg/ha.

The AICMIP - Initial Population Trials was also held at Ludhiana and Faridkot in 1978 (20). Twenty entries, including hybrids HB-7 and BJ 104, were evaluated under irrigated and rainfed conditions. With irrigation, HB-7 and BJ 104 were first and second with respective average yields of 3233 kg/ha and 2785 kg/ha. The best population was 'PSB-8' with a mean yield of 2707 kg/ha. Under rainfed conditions, PHB-14 and BJ 104 were again first and second with mean yields of 2472 kg/ha and 2459 kg/ha, respectively. PSB-8 was the best population with an average yield of 2396 kg/ha (97 percent of HB-7, the best check).

In an experiment conducted at Agra, India, in Kharif 1977-78, yields of grain sorghum and pearl millet were compared (3). Both crops were planted 13 July 1977. The millet (hybrid

BH 104), was harvested 5 October 1977 and the sorghum (CSH-6) was planted 14 November 1977. The millet yielded 2480 kg/ha, somewhat less than the sorghum which yielded 2614 kg/ha.

Since 1975, International Pearl Millet Adaptation Trials have been conducted annually by ICRISAT (30, 34, 35, 36, 37). In these extensive yield trials, twenty promising pearl millet genotypes representing hybrids, synthetics, population bulks, and experimental varieties derived from populations are evaluated against local cultivars in many countries throughout the pearl millet-growing regions of the semi-arid tropics.

In International Pearl Millet Adaptation Trial -2, (IPMAT-2), in 1976, yield data were returned from thirty-three locations in twelve countries (30, 35). The top grain yields ranged from 1183 kg/ha ('LC-SX75' at Ukiriguru) to 6843 kg/ha ('ICH 13' at Serere). The top hybrid was 'ICH 105' with a mean yield of 2346 kg/ha, however, it was susceptible to downy mildew at certain critical West African locations (35). Among populations and population products, 'Ex Bornu' was best with a mean yield of 2062 kg/ha.

In IPMAT-3 (1977) grain yield data were received from twenty-nine locations in seven countries (34). The highest grain yields ranged from 696 kg/ha ('Ex Bornu' at Ouahigouya) to 3988 kg/ha ('PSB-8' at Ludhiana). The top yielding hybrid over all locations was 'ICH 118' with a mean yield 1917 kg/ha. The best experimental cultivar was 'SSC-CX75', which yielded 1828 kg/ha over locations.

Yield results were received from thirty-seven locations in thirteen countries in IPMAT-4 (1978) (36, 37). The top grain yields ranged from 659 kg/ha ('PHB-47' at Anantapur) to 3154 kg/ha ('NHB-3' at Rahuri). The best hybrid over all locations was 'MHB 110', which yielded 2238 kg/ha. The best cultivar was 'SSC-H76' with a mean yield of 2119 kg/ha. Poor plant stands, dry periods at critical stages of plant growth, insect attack, excessive weed growth, and bird damage were the reasons for low yields (37).

YIELD COMPONENTS

A number of researchers have attempted to determine the contribution of various morphological characters to yield in pearl millet.

Gupta and Nanda (26) studied genetic variability of grain, head, and plant characters in four groups of pearl millet germplasm. They reported that head weight, tiller number, earliness, and grain size and density appeared to be important characters influencing grain yield. Inclusion of head weight improved the efficiency of selection indices and was an important selection criterion in all groups of germplasm examined.

Singh and Ahluwalia (58) studied the influence of spike length, spike girth, 500-grain weight, number of ear-bearing tillers, and grain density on grain yield. They found that ear-bearing tiller number was the most potent character in determining yield of S_0 and S_1 populations.

Singh and Singh (60) found that in seventy-two diverse lines of pearl millet, days to flowering, total tiller number, and number of leaves were positively correlated with grain yield.

Egharevba (17) examined the effect of tiller number on grain yield. Stands of pearl millet cultivar 'Ex Bornu' with one, three, and five tillers per plant were maintained and compared with a control (no tillers removed). Maintaining three and five tillers per plant increased yield by about 20 percent over the control. Maintaining one tiller per plant reduced yields. It was suggested that the grain yielding advantage of few tillers was probably because not all tillers formed in the control stand produced heads, and those that did not were parasitic on the main shoot for nutrients and water. Egharevba related Ramond's findings (56) that some late pearl millet cultivars produced up to forty tillers per plant and that only 25 percent of the tillers produced viable heads. Egharevba also stated that intraplant competition for nutrients increased as more heads were formed per stand and this was detrimental to grain yield. It was suggested that grain millet should be bred by reducing tillering capacity.

Harinarayana (28) reported that unless 175,000 to 200,000 plants per hectare were maintained, the full potential of pearl millet hybrids could not be realized. Egharevba (17) found that when pearl millet variety 'Ex Bornu' was grown at 50,000, 65,000, and 80,000 plants per hectare, the lowest population density resulted in the most tillering.

Burton and Powell (13) reported that correlation studies by many researchers indicated that none of the characters considered (other than yield itself) would be a good selection index for yield of forage or grain if taken alone. They stated that of greater importance perhaps was the evidence that a number of plant characters may be altered by selection without materially affecting forage or grain yield. However, they later stated that the ability to develop many grain producing, lodging-resistant tillers (characters known to be related to high grain yield) will be sought in future grain varieties.

As regards plant height, Burton and Powell (13) speculated that even with hand harvesting, dwarf types will be used in pearl millet, as in wheat, rice, and sorghum, to permit the application of fertilizer, irrigation, etc. to maximize grain yields. However, ICRISAT (31) reported that reduction in plant height is sought only as necessary for optimal harvest index and to reduce lodging (not normally serious at farmer production levels).

HETEROSIS

Pearl millet is particulary well suited for research on heterosis (13). The best hybrids can produce twice as much grain as adapted open pollinated cultivars (13). Heterosis may also manifest itself in greatly increased size and yield of the whole plant (13).

To study the inheritance of eight spaced plant characteristics in pearl millet, F_1 and F_2 populations of crosses between some widely different lines were grown with populations of their parents (10, 13). Heterosis was shown for plant yield, plant height, head length, stem diameter, and internode length, but not for number of stems per plant, maturity, leaf width, nor number of leaves per stem.

Significant heterosis for grain yield was measured by Ahluwalia and Patniak (1) in six of nineteen F_1 hybrids between nine inbred lines and two open pollinated testers. The hybrids produced 33 to 77 percent more grain than their better parent.

Crosses of 184 elite pearl millet inbreds with Tift 23A and Tift 18A were studied by Murty et al (51). Of 93 inbreds crossed with Tift 23A, there was an increase of 6.7 percent for tiller number and 10.2 percent for ear length in hybrids compared to the inbreds. There was a 4.8 percent decrease for ear girth. The overall analysis, however, revealed a reduction of 7.1 percent in tiller number, and an increase of 36.9 percent for ear length and 1.6 percent for ear girth.

Using two S_7 lines, Lal and Singh (45) conducted studies to determine the extent of heterosis in F_1 hybrid millets for fifteen grain and fodder yield contributing characters. Highly significant heterosis was observed for plant height, number of internodes, number of branches, number of spike bearing branches, and days to flowering. However, significant heterosis was not found for stem diameter, number of tillers, number of spike bearing tillers, leaf length, leaf width, peduncle length, peduncle thickness, spike length, spike thickness, nor 250 grain weight.

Mahadevappa (47) studied heterosis among ten pearl millet inbreds crossed in all possible combinations (including reciprocal crosses) and their F_1 hybrid offspring. Significant heterosis was shown by the greatest number of hybrids for peduncle length and plant height. An appreciable number of hybrids showed heterosis for primary ear surface, primary ear yield, straw yield, and grain yield. Twenty-five percent of the hybrids had significant heterosis for grain yield with respect to mid-parents, nineteen percent with respect to better parent, and eight percent with respect to the best parent in the study. Few hybrids showed significant heterosis for peduncle diameter, density of grain, and tillering capacity. Only the characters peduncle length, plant height, and straw yield exhibited marked reciprocal differences.

In a heterosis study involving six pearl millet inbred lines crossed in all possible one way combinations (fifteen crosses) Phul et al. (52) found that all hybrids surpassed the mid-parental values by considerable margins for grain yield. Increases over mid-parental yield values ranged from 104 to 896 percent. However, in the case of protein content, F_1 values ranged from 42.8 to 6.6 percent less than the mean of the parents in all crosses.

Singh and Lal (59) calculated gene effects for fifteen grain and fodder yield contributing characters of pearl millet using P_1, P_2, F_1, F_2, B_1, and B_2 generations of a cross between two inbred lines. Significant heterosis was observed for plant height, number of internodes, number of branches, and number of spike bearing branches.

Heterosis in growth rates of pearl millet inbreds and hybrids was studied by Yadav and Singh (70). Superiority for growth was shown by hybrids only during the first ten days after sowing.

In crosses involving pearl millet male sterile Tift 23A and nine inbreds along with the male fertile Tift 23B, Singh (61) studied heterosis for several traits. The maximum heterosis over the superior parents was in the number of nodal heads (190 percent), followed by plant height (132.21 percent), leaf width (48.30 percent), number of nodes (46.80 percent), seed size (42.42 percent), yield per plant (37.49 percent), and earliness in flowering (9.09 percent). Negative heterosis was observed for basal tillers.

Tewari (64) studied heterosis in twenty-one F_1 hybrids involving seven inbreds. Positive heterosis for number of spike bearing tillers over the superior parent was found in six hybrids, however, only one hybrid combination displayed significant heterosis over it's better parent. The range of increase in these crosses varied from 0.11 to 47.22 percent.

In a later experiment, again with twenty-seven F_1 hybrids involving seven inbreds, Tewari (65) studied heterosis for length of spike, grain yield of the main stem spike, and number of grains in one square centimeter. For spike length, four hybrids showed positive heterosis as compared to their respective superior parents, though none were significantly superior. One hybrid showed significantly superior grain yield than it's better parent. Hybrids in general showed a decreased number of grains per unit area.

PROTEIN

A wide range of protein (8 to 23 percent) occurs in pearl millet (31).

In 1961, Joshi et al (41) found that pearl millet cultivars 'Improved Ghana' and 'Punjab Type-55' contained 12.03 and 12.47 percent protein respectively.

In comparisons of released hybrids with local pearl millet cultivars, HB-3 and HB-4 contained 9.3 and 15.7 percent protein, HB-1 ranged from 9.0 to 12.3 percent protein and local cultivars averaged 12.2 percent protein. HB-3 was grown under limited moisture conditions, whereas HB-1 and the local cultivars were grown under assured moisture conditions with 80 kg N/ha.

Goswami et al (21) studied protein content in pearl millet genotypes of diverse geographical origin for two years. Thirty-five pearl millet inbreds of African origin contained 9.82 to 15.25 percent protein. Forty-two inbreds of American origin contained 10.50 to 14.44 percent (22). Fifty-eight Indian inbreds contained 9.39 to 14.40 percent protein (23), and twenty-eight Indian varieties contained 10.26 to 13.22 percent protein (24).

In experiments at Agra, India, 55 kg N/ha at sowing (half as ammonia sulfate, half as compost) gave the highest grain protein content of 9.5 percent in an isolated variety of pearl millet (67).

Deosthale et al (16) analyzed several cultivars of pearl millet from diverse sources for grain protein content. In twenty-two Senegal cultivars protein ranged from 12.1 to 17.2 percent. Protein content was lower in fourteen Nigerian cultivars (6.4 to 13.2 percent) and fourteen hybrids from Jamagar (11.5 to 14.9 percent).

A number of pearl millet cultivars and hybrids grown under identical conditions of moisture stress in advanced yield trials were higher in protein than the released hybrids HB-1, HB-3, and HB-4 (16). Under limited moisture, protein ranged from 7.2 percent in HB-3 to 14.8 percent in an experimental hybrid. Under adequate moisture, protein ranged from 7.6 percent in HB-4 to 13.4 percent in an experimental hybrid.

In a dwarf hybrids trial held in 1969 at Delhi (16), the lowest yielder, cultivar 'D 174', contained the highest percentage of protein (14.9 percent). An experimental hybrid contained the lowest percentage of protein (11.7 percent). The HB-1 check contained 12.8 percent protein.

In 180 pearl millet inbred lines grown at Tifton, Georgia, protein ranged from 8.8 to 20.9 percent with a mean of 16.0 percent (14). The variation among lines suggested that protein in millet grain could be increased by breeding.

Grain of fourteen high yielding pearl millet hybrids grown at Delhi in 1970-71 was analyzed for various chemical constituents (68). Protein content ranged from 11.31 to 19.62 percent. Among the four popular hybrids HB-1, 3, 4, and 5, HB-3 was highest in protein content (15.11 percent). Two of the hybrids tested had relatively low protein contents (12.57 and 13.69

percent), however, they were superior to a number of hybrids in the amount of protein contained per 1000 seeds due to their higher seed weights. But the hybrid with the highest percentage of protein also had the highest protein content per 1000 seeds.

Freeman and Bocan (18) compared the protein content of commercial corn and commercial sorghum with pearl millet variety 'Tiflate' and line 'Tift 23DB' (the dwarf maintainer of 'Tift 23DA'). Commercial corn and sorghum contained 9.5 and 10.7 percent protein respectively, compared to Tiflate with 17.4 percent protein and Tift 23DB with 14.2 percent protein.

Rachie (55) reported that three years of testing hybrid pearl millets at the Indian Agricultural Research Institute, New Delhi, indicated crude protein levels ranged from 12 to 18 percent. Hybrids based on cytoplasmic male sterile line Tift 18A ran somewhat higher in protein than those utilizing Tift 23A as the seed parent. One white pearly inbred, 'Bichpuri', (discovered in two independent analyses), contained up to 23 percent crude protein.

At Kansas State University in 1976, a random mating population of pearl millet, derived from the cross 'Serere 17 x Tift 239', was found to contain 12.3 percent protein on a whole grain basis (6).

Pearl millet composites 'Visakha', 'Balaji', and 'Nagarjuna', released in 1976 from millet research stations in Andhra Pradesh, were reported to contain 10.69, 11.6, and 13.3 percent protein respectively (57).

Variano-Marston et al (69) analyzed four bulk populations of pearl millet ('RMP-1 (S) C_1', 'HMP 1700', 'Serere 3A', and 'HMP 550') and seventeen 'HMP 1700' S_1 lines for protein content. Protein percentages ranged from 11.1 to 14.1 percent on a 14 percent moisture basis.

In fourteen samples of pearl millet seed analyzed at ICRISAT in 1975-76, protein content ranged from 5.1 to 18.2 percent (29). In field trials in 1974-75, protein content varied from 7.9 to 12.6 percent and did not appear to be affected by yield levels, but was markedly affected by season, location, soil fertility, and other biological and environmental factors (29).

In a replicated trial in three different environments (1976) ICRISAT planted a number of high and low protein lines to determine the stability of protein content (31). Results indicated that protein percentages were high under low fertility conditions. The report stated that environment seemed to play a major role in influencing protein content and that differences in grain filling periods at different locations may have altered protein content.

From analyses on the same cultivar at different yield levels, ICRISAT found that the relationship between yield and protein content was not as strongly negative as expected (31). Eleven percent protein at yields of 3000 kg/ha seemed feasible (31).

ICRISAT also reported that using the pearl millet working collection, no relationship was indicated between grain weight

(2.4 to 14.0 grams per 1000 seeds), and protein content, (6.0 to 14.5 percent) (31).

During 1976-77, 4646 pearl millet samples were screened for protein at ICRISAT and the range was 5.8 to 20.9 percent (33). In a separate analysis, inbreds were identified that consistently gave 14 percent protein (compared to the average of 12 percent) (32).

The 1978 ICRISAT Annual Report (32) stated that from a large number of protein analyses of pearl millet seed from variety trials and from germplasm grown in several environments, it was established that at yields up to 3500 kg/ha, the relationship between protein content and yield in pearl millet, though negative, was weak, ($r = -0.2$). At these yield levels, it would be possible to select concurrently for protein level and yield (32).

MATERIALS AND METHODS

Three locations were selected in Kansas in 1978 for hybrid yield trials, (1) Ashland Experiment Field, Manhattan; (2) Fort Hays Branch Experiment Station, Hays; and (3) Sandyland Experiment Field, St. John.

Eight pearl millet hybrids developed at the Coastal Plains Station, Tifton, Georgia by Dr. Glenn W. Burton (Research Geneticist USDA, SEA), were planted at Manhattan along with twelve pearl millet hybrids developed at Kansas State University by Dr. A. J. Casady (Research Agronomist, USDA, SEA, ret.). An open pollinated pearl millet synthetic, 'RMP-1 (S) C_1' (also developed by Dr. Casady) and two commercial sorghum hybrids, Dekalb C42A+ and C46+ were included for comparison.

At Hays and St. John, twelve hybrids developed at the Fort Hays Branch Experiment Station by W. D. Stegmeier (Research Agronomist) were evaluated. DeKalb sorghums C42A+ and C46+, pearl millet synthetic RMP-1 (S) C_1, and an open pollinated population of pearl millet, 'Senegal Bulk', were included for comparison. Due to poor stand establishment at St. John, the study was replanted, however, stand establishment was again unacceptable and this site was abandoned.

An F_1 diallel yield test was also planted at Hays in 1978. In this study, 46 F_1 pearl millet hybrids developed by W. D. Stegmeier were evaluated. Dekalb sorghums C42A+, E59+, and F67 were included for comparison.

Planting and harvesting dates, soil types, plot layouts, and fertilizer and pesticide treatments can be found in Table 1.

At Manhattan and St. John, plots were planted with a two row vacuum pick-up planter designed for experimental plot work. At Hays, a four row planter equipped with cone units was used. All experiments were planted in randomized complete block design. Seeding depth was 2.5 cm except at St. John where this depth was doubled to place seeds in moist soil when re-planting the hybrid study. Thirteen seeds were planted per meter of row. For early season chinch bug protection at Manhattan, Furadan granular insecticide was placed with the seed at planting. Later, due to heavy chinch bug infestation, a carbaryl insecticide spray also was applied (Table 1). However, control was not completely effective and some entries were severely damaged. To control weeds, propazine herbicide was preplant applied at Manhattan and Hays. Some mechanical cultivation and hand hoeing also was necessary for weed control at all locations.

Within each plot, the best representative portion of the row(s) was hand harvested, avoiding skips. Harvested heads were threshed with an Ames experimental plot thresher. Data obtained on each entry included: grain weight, five hundred seed weight, plant height, number of heads, grain protein content (at Hays only) and average head length of ten heads selected at random (at Manhattan only). Grain moisture was determined using a Burrows automatic moisture meter unless insufficient grain samples made it necessary to determine

Table 1. Summary of locational and procedural data.

Study	Year	Location	Soil Type	Date Planted	Date Harvested	No. Reps.	No. rows per plot	Row Spacing (cm)	Row Length (m)	N fert applied (kg/ha)	Pesticides applied
1. Hybrid Yield Trial, (Burton and Casady entries)	1978	Manhattan	Reading silt loam	5 June	4 Sept.	3	2	76	6.1	67.3	Propazine @ 3.4 kg/ha, Furadan 10G @ 1.1 kg a.i./ha, Carbaryl @ 2.2 kg/ha.
2. Hybrid Yield Trial, (Stegmeier entries)	1978	Hays	Harney silt loam	14 June	15 Oct.	4	1	91	7.3	44.8	Propazine @ 2.2 kg/ha, 2,4-D @ 0.84 kg/ha.
		St. John	Naron loamy fine sand, and Pratt loamy fine sand	31 May, Replanted 28 June	Not harvested	3	1	76	9.1	none	none
3. F_1 Hybrid Diallel Study	1979	Hays	Harney silt loam	9 June	15 Oct.	3	1	91	7.3	44.8	Same as #2 above (Hays).
4. Hybrid Yield Trial, (Stegmeier entries)	1979	Manhattan	Muir silt loam	30 May	25 Sept.	3	2	76	9.1	67.3	Propazine @ 2.8 kg/ha, Furadan 10G @ 1.1 kg/ha, Carbaryl @ 2.2 kg/ha.
		Garden City	Keith silt loam	24 May	21 Sept.	3	2	76	9.1	none	Furadan 10G @ 1.1 kg a.i./ha.
		Hays	Harney silt loam	16 June	25 Oct.	4	2	91	9.1	44.8	Same as # 2 above (Hays).
		Minneola	Harney silt loam	7 June	20 Sept.	3	2	76	9.1	none	Furadan 10G @ 1.1 kg a.i./ha.
		St. John	Pratt loamy fine sand	23 May	27 Sept.	3	2	76	9.1	none	Furadan 10G @ 1.1 kg a.i./ha.
		Tribune	Ulysses silt loam	13 June	9 Oct.	3	2	76	9.1	none	none
5. Hybrid Yield Trial, (Burton entries)	1979	Manhattan	Muir silt loam	30 May	5 Nov.	3	2	76	7.6	67.3	Same as #4 above (Manhattan).
		Hays	Harney silt loam	16 June	25 Oct.	3	1	91	9.1	44.8	Same as #2 above (Hays).
6. Heterosis Study	1978	Manhattan	Reading silt loam	5 June	14 Sept.	4	2	76	6.1	67.3	Same as #1 above (Manhattan).
	1979	Manhattan	Muir silt loam	30 May	17 Oct.	3	2	76	9.1	67.3	Same as #4 above (Manhattan).

moisture gravimetrically. Nitrogen content was determined by the Kjeldhal procedure (49). Protein content was calculated by multiplying percent nitrogen by 6.25.

Basic plot data were converted to grain weight per hectare (adjusted to 12.5 percent moisture) one thousand seed weight, heads per hectare, yield per head, protein per hectare, and protein per 1000 seeds.

The Statistical Analysis System (SAS) Institute PROC GLM procedure was used for statistical analyses of the data. Duncan's multiple range test was used to identify significance.

In 1979, ten F_1 pearl millet hybrids and five open pollinated populations of pearl millet developed by W. D. Stegmeier, were evaluated in yield trials at six locations in Kansas: (1) Ashland Experiment Field, Manhattan; (2) Garden City Branch Experiment Station, Garden City; (3) Fort Hays Branch Experiment Station, Hays; (4) Southwest Kansas Experiment Field, Minneola; (5) Sandyland Experiment Field, St. John; and (6) Tribune Branch Experiment Station, Tribune. Dekalb sorghums C42A+, E59+, and F67 were included for comparison.

Details of the experiment are in Table 1. Planting, harvesting, and statistical procedures were the same as those described above. A vacuum pick-up planter was used at all locations except Hays and Tribune where cone planters were used. Chinch bugs were again a problem at Manhattan.

Data obtained on each entry included: grain weight, five hundred seed weight, plant height, number of heads, grain protein content, plant population (at Manhattan only) half bloom date (at Garden City, Hays, and Tribune only) and date of fifty percent heading (at Manhattan only). In addition, at Hays, plots were scored for stand establishment, visual appearance, and lodging resistance. At Garden City, dates of dark layer formation were recorded. At Minneola and Tribune, plots were also scored for seed set. Grain moisture content was determined using a Burrows digital moisture meter. Nitrogen content was determined with a Technicon Autoanalyser (62).

Basic plot data were converted to grain weight per hectare, heads per hectare, yield per head, protein per hectare, protein per 1000 seeds, and at Manhattan only, plants per hectare, heads per plant, and yield per plant. At Garden City, length of grain filling period was also calculated for one replication.

In 1979, nine hybrids developed by G. W. Burton were tested at two locations in Kansas, the Ashland Experiment Field, Manhattan, and the Fort Hays Branch Experiment Station, Hays. Dekalb sorghums C42A+ and C46+, pearl millet synthetic 'RMP-1 (S) C_1', and 'Serere 3A' (an open pollinated pearl millet cultivar from Uganda) were included for comparison.

Details of the experiment can be found in Table 1. Planting, harvesting, and statistical procedures as well as data obtained on each entry were the same as those described above.

Heterosis was studied in 1978 and 1979 among eighteen pearl millet F_1 hybrids and their inbred parents (three female, six male). These materials were developed by A. J. Casady. The Ashland Experiment Field, Manhattan, was the site of the experiment.

Table 1 contains locational and procedural data. Again cultural and statistical procedures were the same as those already described. Chinch bugs were a problem in both years.

Data obtained on each entry included: grain weight, plant height, five hundred seed weight, head numbers, average head length (of ten heads selected at random, 1978 only); and in 1979 only, grain protein content, and plant population. These basic plot data were converted to grain weight per hectare, heads per hectare, yield per head, and, in 1979 only, protein per hectare, protein per 1000 seeds, plants per hectare, heads per plant, and yield per plant.

In all experiments in both years, air temperature, precipitation data and solar radiation (where available) were recorded.

RESULTS AND DISCUSSION

HYBRID YIELD TRIAL, MANHATTAN, 1978

Yields in the hybrid yield trial at Manhattan, 1978, ranged from 5526 kg/ha (sorghum hybrid C42A+) to 1187 kg/ha (millet hybrid 4013) (Table 2). Two millet hybrids, Tift 2 and Tift 1, with yields of 4436 and 4342 kg/ha respectively, were not significantly different than sorghum hybrids C42A+ and C46+. Three additional pearl millet hybrids were not significantly different in yield than sorghum hybrid C46+. Pearl millet synthetic 'RMP-1' was one of the poorer yielders in the study producing 1885 kg/ha.

The highest yielding pearl millet hybrids exhibited tall stature. Tift 2 and Tift 1 had respective heights of 207 and 217 cm (measured to the tip of the head). However, the tallest millet hybrid in the study, Tift 7 (220 cm) was only average in yield. Millet hybrids 4013 and 4021, and sorghum hybrid C46+ were the shortest entries in the study, 126 cm each. Most millet plots demonstrated poor uniformity of plant height, reflecting a lack of homogeneity. Hybrids developed by Burton tended to be taller than those developed by Casady.

Sorghum seed weights were significantly greater than those of pearl millet. Tift 2 (the highest yielding millet) had the highest 1000 seed weight among millets (9.1 g) compared to sorghum hybrids C42A+ and C46+ with seed weights of 18.6 and 16.4 g/1000 respectively. There was no apparent relationship

Table 2. Hybrid Yield Trial, Manhattan, 1978[1/]

Entry	Yield (kg/ha)	Plant Ht (cm)	1000 Seed Wt. (g)	Heads Thous./ha	Yield/ Head (g)	Head Length (cm)
C42A+ Sorghum	5526 a[2/]	117 f	18.6 a	100 cd	54.3 a	--
C46+ Sorghum	4509 ab	126 ef	16.4 a	95 d	46.8 b	--
Tift 2	4436 ab	207 a	9.1 b	492 a	9.3 d-f	16.9 g
Tift 1	4342 ab	217 a	7.3 b-e	431 a	10.7 de	19.3 ef
Tift 6	3511 bc	191 b	6.3 c-f	209 b-d	16.8 c	20.3 de
4039	3453 b-d	144 de	5.2 d-f	280 b	12.3 cd	21.3 c-e
4035	3069 b-d	145 de	6.9 b-f	214 b-d	14.2 cd	19.9 d-f
Tift 5	3058 cd	133 d-f	8.0 b-d	243 b	12.6 cd	23.0 a-c
Tift 4	3015 cd	141 de	5.9 c-f	237 b	13.0 cd	19.4 ef
4033	2945 cd	143 de	5.5 d-f	245 b	12.2 cd	20.3 de
4041	2798 cd	135 de	5.8 c-f	227 bc	12.3 cd	19.8 ef
Tift 7	2623 c-e	220 a	8.5 bc	487 a	5.5 e-g	18.8 e-g
4023	2616 c-e	140 de	6.1 c-f	186 b-d	14.0 cd	18.7 e-g
4009	2611 c-e	145 d	6.7 b-f	196 b-d	13.3 cd	19.7 ef
4043	2591 c-e	133 d-f	6.2 c-f	197 b-d	12.7 cd	23.3 a-c
4015	2397 c-f	145 d	4.9 ef	271 b	9.0 d-f	20.3 de
4045	2235 c-f	130 d-f	5.5 d-f	202 b-d	11.1 cd	20.3 de
4021	2105 d-f	126 ef	4.8 ef	212 b-d	10.1 d-f	19.7 ef
RMP-1	1885 d-f	163 c	6.3 b-f	202 b-d	9.3 d-f	24.7 ab
4019	1882 d-f	134 d-f	4.2 ef	189 b-d	9.9 d-f	22.4 b-d
Tift 3	1297 ef	139 de	5.6 d-f	483 a	2.8 g	17.4 fg
4013	1187 f	126 ef	4.0 f	240 b	4.7 fg	25.0 a

1/ 'Tift' series hybrids developed by G. W. Burton. All other millets developed by A. J. Casady.

2/ Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

between seed weight and yield in pearl millet, however, the lowest yielding millet hybrid, 4013, also had the lowest seed weight (4.0 g/1000).

Head numbers per hectare ranged from 402,000 (millet hybrid Tift 2) to 95,000 (sorghum hybrid C46+). Among millets, there was no apparent relationship between head numbers and yield. This contradicts the findings of Singh and Ahluwalia (58) who reported that ear-bearing tiller number was the most important character in determining yields of S_0 and S_1 pearl millet populations.

Sorghum hybrids had significantly higher yields per head than millets. Yields per head varied from 54.3 g (sorghum hybrid C42A+) to 2.9 g (millet hybrid Tift 3). Among millets, Tift 6 had the highest yield per head (16.8 g). Very low yielding millets tended to have lower yields per head than medium or high yielding millets. Gupta and Nanda (26) found that head weight was an important selection criterion in all groups of pearl millet germplasm examined.

Pearl millet head lengths ranged from 25 cm (millet hybrid 4013) to 16.9 cm (Tift 2). There was no apparent relationship between head length and yield.

HYBRID YIELD TRIAL, HAYS, 1978

Yields in the hybrid study at Hays, 1978, ranged from 3650 kg/ha (sorghum hybrid C46+) to 970 kg/ha (pearl millet synthetic RMP-1) (Table 3). Millets did not yield as well as

Table 3. Hybrid Yield Trial, Hays, 1978[1/]

Entry	Yield (kg/ha)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous./ha	Yield/ Head (g)
C46+ Sorg.	3650 a[2/]	16.2 a	14.3 h	453 a	2.30 b	123 d	29.7 a
C42+ Sorg.	3257 a	17.8 a	15.4 g	437 a	2.73 a	130 cd	25.0 b
164	2328 b	7.2 b-g	16.6 f	338 ab	1.18 c-f	193 bc	12.0 c
309	1756 bc	7.3 b-g	18.0 b-d	276 bc	1.31 c-f	197 bc	8.6 c-f
143	1724 bc	8.6 bc	17.2 d-f	257 bc	1.46 c-e	153 cd	10.8 c-e
Senegal Bulk	1707 bc	8.5 b-d	16.8 ef	251 bc	1.42 c-e	195 bc	8.7 c-f
399	1642 bc	5.4 g	18.2 bc	261 bc	0.98 f	228 ab	7.2 d-f
95	1554 bc	9.1 b	17.0 ef	230 bc	1.54 c	147 cd	10.7 c-e
195	1495 bc	6.8 c-g	17.6 b-e	230 bc	1.19 c-f	141 cd	10.5 c-e
307	1426 bc	6.2 e-g	18.5 ab	230 bc	1.13 d-f	167 b-d	8.5 c-f
174	1389 bc	8.1 b-e	17.1 d-f	208 bc	1.38 c-e	130 cd	10.9 cd
182	1345 bc	7.9 b-f	19.3 a	225 bc	1.52 c	258 a	5.0 f
139	1226 c	7.5 b-g	16.8 ef	179 c	1.25 c-f	190 bc	6.5 d-f
140	1179 c	8.6 bc	17.4 c-f	178 c	1.48 cd	166 b-d	6.5 ef
196	1060 c	6.4 d-g	17.6 b-f	163 c	1.12 ef	155 cd	6.6 d-f
RMP-1	970 c	5.8 fg	17.1 d-f	144 c	0.98 f	189 b-d	5.0 f

[1/] Pearl millet hybrids developed by W. D. Stegmeier.

[2/] Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05) sorghums. The top yielding millet, hybrid 164, produced 2328 kg/ha of grain. Senegal Bulk, an open pollinated population of pearl millet, yielded 1707 kg/ha and was not significantly different in yield than millet hybrid 164.

Pearl millet seed weights were significantly lower than sorghum seed weights. Among millets, 1000 seed weights ranged from 9.1 g (hybrid 95) to 5.4 g (hybrid 399). Sorghum hybrids C46+ and C42A+ had respective seed weights of 16.2 and 17.8 g/1000. There was no apparent relationship between seed weight and yield in pearl millet.

All millets tested were significantly higher in grain protein content than sorghum hybrids. Freeman and Bocan (18) found millet higher in protein than sorghum or corn. Among millets, protein percentage varied from 19.2 percent (millet hybrid 182) to 16.6 percent (millet hybrid 164). Sorghum hybrids C46+ and C42A+ contained 14.3 and 15.4 percent protein, respectively. Protein percentage in pearl millet did not appear to be affected by yield. Research by ICRISAT (29, 32) also indicated that yield level in pearl millet had little effect on protein content.

Protein produced per hectare ranged from 453 kg/ha (sorghum hybrid C46+) to 144 kg/ha (millet synthetic RMP-1). Pearl millet hybrid 164 produced 338 kg of protein per hectare and was not significantly different in protein yield than either of the sorghum hybrids. Protein per hectare decreased as yield decreased.

Both sorghum hybrids contained significantly more protein per 1000 seeds than any of the millets evaluated. Sorghum hybrids C46+ and C42A+ contained 2.30 and 2.73 g protein per 1000 seeds respectively compared to pearl millet hybrid 95 with 1.54 g (the highest among millets). Millet hybrid 399 and millet synthetic RMP-1 had the lowest protein contents per 1000 seeds, 0.98 g each. There was no apparent relationship between protein per 1000 seeds and yield in pearl millet. Millets with higher seed weights tended to have higher protein contents per 1000 seeds. These results are similar to those of Uprety and Austin (68) who found that two millet hybrids, though of relatively low protein content, were superior to a number of hybrids in protein per 1000 seeds due to their higher seed weights.

Head numbers per hectare varied from 258,000 (millet hybrid 182) to 123,000 (sorghum hybrid C46+). Differences in head numbers produced by sorghums and millets were not significant in many cases. Pearl millet yield levels did not appear to be affected by head numbers.

Sorghum hybrids C46+ and C42A+ had respective yields per head of 29.7 and 25.0 g, significantly higher than any of the millets. Among millets, the highest yielder, hybrid 164, also had the highest yield per head (12.0 g). Millet hybrid 182 and millet synthetic RMP-1 had the lowest yields per head, 5.0 g each. Higher yielding millets tended to produce higher yields per head.

F_1 HYBRID DIALLEL STUDY, HAYS 1978

Overall yield levels were lower for the F_1 hybrid diallel study, Hays, 1978, than for the hybrid yield study at Hays even though both experiments were planted in close proximity in the same field (Table 4). Local variations in soils may have accounted for this difference. Yields ranged from 2460 kg/ha (sorghum hybrid C42A+) to 414 kg/ha (millet hybrid 1020). Seventeen pearl millet hybrids were not significantly different in yield than sorghum hybrids C42A+ and E59+, and were significantly higher than sorghum hybrid F67. The top millet hybrid, 1006, yielded 2354 kg/ha. Sorghum hybrids E59+ and F67 produced yields of 1523 and 735 kg/ha respectively. Yields of E59+ and F67, both relatively late maturing hybrids, probably were reduced due to moisture stress during grain filling. Meteorological data for Hays, 1978 (Table 20), indicates that both August and September were dry months with 2.95 and 2.19 cm of rainfall, respectively.

Sorghum seed weights were significantly higher than millet seed weights. Sorghum hybrid E59+ had the highest 1000 seed weight of 20.1 g followed by F67 and C42A+ with 16.5 and 15.0 g respectively. Among millets, 1000 seed weights ranged from 9.7 g (hybrid 1007) to 4.8 g (hybrid 1002). Seed weights did not appear to be affected by yield in pearl millet.

Grain protein content varied from 19.7 percent (millet hybrid 1002) to 14.0 percent (sorghum hybrid F67). Most millet hybrids were significantly higher in protein percentage than

Table 4. F_1 Hybrid Diallel Study, Hays, 1978[1/]

Entry	Yield (kg/ha)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous./ha	Yield Head (g)
C42A+ Sorg.	2460 a[2/]	15.0 c	16.6 kl	357 a	2.49 b	122 h-l	20.2 a
1006	2354 ab	8.3 d-g	16.4 lm	338 ab	1.36 c-f	187 a-h	12.6 b
1031	1929 a-c	7.0 e-n	17.6 f-k	296 a-c	1.23 c-n	211 a-c	8.9 b-h
1005	1905 a-d	7.5 e-j	17.3 h-l	289 a-c	1.29 c-j	208 a-e	9.1 b-h
1042	1878 a-d	7.5 e-j	17.2 h-l	281 a-c	1.28 c-k	197 a-h	8.7 b-i
1013	1831 a-d	6.0 i-q	17.2 h-l	275 a-d	1.03 i-q	235 a	7.8 b-k
1041	1803 a-e	6.3 i-q	17.5 g-k	274 a-e	1.09 f-q	200 a-g	8.7 b-i
1037	1790 a-f	8.5 d-f	17.2 h-l	270 a-f	1.46 c-e	178 a-i	10.0 b-g
1024	1741 a-g	7.0 e-n	17.6 f-k	268 a-g	1.23 c-m	142 c-k	12.0 bc
1019	1639 a-h	5.9 i-q	17.9 e-j	256 a-h	1.06 g-q	171 a-i	9.7 b-g
1025	1631 a-h	5.7 j-q	17.8 f-j	251 a-h	1.02 j-q	230 ab	6.7 d-k
1039	1609 a-h	6.0 i-q	17.6 f-k	243 a-h	1.05 i-q	229 ab	6.8 d-k
1008	1568 a-h	6.7 g-p	17.7 f-j	242 a-h	1.18 e-p	192 a-h	8.1 b-j
1035	1568 a-h	7.3 e-k	17.6 f-k	241 a-h	1.28 c-k	189 a-h	8.3 b-j
1045	1562 a-h	6.1 i-q	17.7 f-j	242 a-h	1.09 f-q	169 a-i	7.4 c-k
1023	1560 a-h	6.7 f-o	17.8 f-j	244 a-h	1.20 d-o	194 a-h	8.0 b-j
E59+ Sorg.	1523 a-i	20.1 a	15.2 n	204 a-i	3.05 a	88 j-l	17.0 a
1007	1521 a-i	9.7 d	15.6 mn	208 a-i	1.52 c	197 a-h	7.9 b-k
1004	1492 a-j	8.7 de	16.8 j-l	219 a-i	1.47 cd	148 c-j	10.2 b-e
1026	1394 b-j	5.7 j-q	18.1 c-h	218 a-i	1.03 i-q	163 a-j	8.6 b-i
1011	1377 b-j	8.1 e-h	16.9 i-l	205 a-i	1.37 c-f	212 a-c	6.6 d-k
1027	1343 b-j	7.6 e-i	17.8 f-j	207 a-i	1.35 c-g	150 c-j	8.8 b-h
1021	1323 b-j	5.1 o-q	18.4 b-f	210 a-i	.94 o-q	210 a-d	6.0 d-k
1040	1266 c-j	6.2 i-q	17.7 f-j	195 b-i	1.10 f-q	145 c-j	8.4 b-i
1001	1208 c-j	7.3 e-k	18.1 c-h	189 b-i	1.31 c-i	179 a-i	7.1 d-k
1014	1200 c-j	5.5 k-q	18.4 b-f	189 b-i	1.00 k-q	187 a-h	6.6 d-k
1036	1192 c-j	7.1 e-m	17.7 f-k	183 b-i	1.24 c-l	178 a-i	6.7 d-k
1038	1153 c-j	6.7 f-o	18.6 b-f	184 b-i	1.24 c-l	207 a-e	5.6 d-k
1015	1107 c-j	7.4 e-j	17.6 f-k	173 c-i	1.29 c-j	134 d-l	8.2 b-j
1029	1081 c-j	5.5 k-q	19.1 a-c	180 b-i	1.05 h-q	130 f-l	8.2 b-j
1017	1076 c-j	4.6 q	19.0 a-d	177 b-i	.88 q	165 a-i	6.4 d-k
1010	1049 c-j	6.3 i-q	17.9 e-i	165 c-i	1.12 f-q	179 a-e	5.8 d-k
1022	1039 c-j	5.2 n-q	18.1 c-h	164 c-i	.94 n-q	181 a-h	5.8 d-k
1009	1030 c-j	7.5 e-j	18.0 d-i	162 c-i	1.34 c-h	201 a-f	5.1 f-k
1030	1007 c-j	7.2 e-l	18.0 d-i	156 c-i	1.29 c-j	132 e-l	6.8 d-k
1002	983 c-j	4.8 q	19.7 a	169 c-i	.94 m-q	187 a-h	4.4 h-k
1033	893 c-j	6.3 h-q	18.5 b-f	144 c-i	1.17 f-p	198 a-h	4.5 h-k
1044	824 d-j	5.3 m-q	18.3 c-h	131 c-i	.96 l-q	188 a-h	4.3 h-k
1046	742 e-j	5.5 k-q	17.7 f-j	115 d-i	.98 l-q	148 c-j	5.1 f-k
F67 Sorg.	735 e-j	16.5 b	14.0 o	92 hi	2.33 b	70 kl	10.1 b-f
1012	714 f-j	5.5 k-q	17.8 f-j	110 e-i	.97 l-q	130 f-l	5.0 g-k
1032	696 g-j	7.5 e-j	18.0 d-i	109 f-i	1.35 c-f	130 f-l	5.4 e-k
1018	658 g-j	4.9 pq	18.5 b-f	105 g-i	.91 o-q	154 b-j	4.2 h-k
1003	653 h-j	5.4 l-q	18.5 b-f	106 f-i	1.00 k-q	148 c-j	4.5 h-k
1028	631 h-j	6.8 f-o	18.9 a-e	106 f-i	1.29 c-j	63 l	10.5 b-d
1043	477 ij	6.1 i-q	18.1 c-h	75 i	1.11 f-q	128 f-l	3.7 f-k
1034	417 j	6.1 i-q	19.4 ab	70 i	1.10 d-o	156 b-j	2.9 k
1016	415 j	4.9 pq	18.2 c-h	65 i	.90 pq	104 i-l	3.7 i-k
1020	414 j	5.6 k-q	17.2 h-l	61 i	.96 l-q	124 g-l	3.3 jk

[1/]Pearl millet hybrids developed by W. D. Stegmeier.

[2/]Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

sorghum hybrids. Yield had no apparent effect on protein percentage in pearl millet.

Protein per hectare ranged from 357 kg/ha (sorghum hybrid C42A+) to 61 kg/ha (millet hybrid 1002). Twenty-one pearl millet hybrids were not significantly different in protein per hectare than sorghum hybrids C42A+ and E59+ which produced 357 and 204 kg protein per hectare, respectively. Thirty-eight millet hybrids were not significantly different than sorghum hybrid F67 in protein per hectare, and eight millets were significantly higher than F67 which produced 92 kg protein per hectare. Among millets, hybrid 1006 had the highest protein yield of 338 kg/ha. Protein per hectare decreased as yields decreased.

All sorghum hybrids produced significantly more protein per 1000 seeds than any of the millets tested. Sorghum hybrid F67 had the lowest protein content per 1000 seeds among sorghums, 2.33 g, but this was still significantly higher than the best millet hybrid, 1004, which produced 1.47 g protein per 1000 seeds. Millet hybrid 1017 produced the least protein per 1000 seeds, 0.88 g. There was no clear relationship between protein per 1000 seeds and yield in pear millet.

Head numbers per hectare varied from 235,000 (millet hybrid 1013) to 63,000 (millet hybrid 1028). Most millet hybrids produced significantly more heads per hectare than sorghum hybrids. There was no apparent relationship between number of heads and yield in pearl millet.

Sorghum hybrids C42A+ and E59+ had yields per head of 20.2

and 17.0 g respectively, significantly higher than any of the millets tested. However, several millet hybrids had yields per head not significantly different than sorghum hybrid F67 which produced 10.1 g of grain her head. Among millets, yields per head ranged from 12.6 g (hybrid 1006) to 2.9 g (hybrid 1034). Higher yielding millets produced higher yields per head.

HYBRID YIELD TRAILS, 1979 (STEGMEIER ENTRIES)

Manhattan

Due to excessive chinch bug damage, the third replication of the experiment (which was adjacent to a wheat field) was not included in the data analysis.

Sorghum yields were significantly higher than millet yields at Manhattan in 1979 (Table 5). Sorghum hybrids C42A+, F67, and E59+ had respective yields of 6891, 6842, and 6642 kg/ha. Millet yields ranged from 4063 kg/ha (hybrid 2118 x 7101) to 1402 kg/ha (hybrid 1212 x 1700). Seven additional pearl millet hybrids and four pearl millet populations had yields not significantly different than the top yielding millet hybrid. The two lowest yielding entries, millet hybrids 1166 x 1700 and 1212 x 1700, were developed in 1977. All other millet hybrids were developed in 1978. Higher sorghum yields may have been favored by high rainfall at Manhattan (See Table 20). In addition, chinch bug damage was more severe in pearl millet than sorghum.

Table 5. Hybrid Yield Trial, Manhattan, 1979 (Stegmeier Entries)[1]

Entry	Yield (kg/ha)	Plant Ht. (cm)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous/ha	Plants Thous/ha	Heads/ Plant	Yield/ Head (g)	Yield/ Plant (g)	Date of 50% heading(Julian)
C42A+ Sorghum	6891 a[2]	--	22.0 b	10.3 c-e	618 a	2.25 b	134 fg	86 a-c	1.6 c	52 a	82 bc	211.0 de
F67 Sorghum	6842 a	--	26.1 a	10.1 de	603 a	2.63 a	141 e-g	60 bc	2.4 bc	49 a	116 a	217.0 bc
E59+ Sorghum	6642 a	--	26.2 a	9.1 e	529 ab	2.38 b	130 g	67 bc	2.0 bc	51 a	101 ab	219.0 ab
2118 x 7101	4063 b	139 c	10.0 cd	11.7 ab	417 bc	1.17 c-g	304 a	95 ab	3.4 b	13 c-e	45 de	207.0 e-g
HMP 559	3981 bc	280 a	8.2 ef	11.5 a-c	400 cd	.94 hi	154 d-g	88 a-c	2.1 bc	26 b	58 cd	221.5 a
2224 x 7101	3770 b-d	116 d-f	9.9 cd	10.8 a-d	356 c-f	1.06 c-e	212 b-f	84 a-c	2.6 bc	18 c-e	46 de	209.5 d-f
2090 x 7101	3751 b-d	113 d-g	10.9 c	11.9 a	396 c-d	1.31 c	189 c-g	37 c	5.3 a	20 bc	107 ab	213.5 cd
2279 x 7101	3662 b-d	121 de	10.9 c	11.6 ab	371 c-f	1.26 cd	232 a-d	82 a-c	3.0 bc	16 c-e	47 de	207.0 eg
2224 x 7024	3470 b-d	91 hi	10.1 cd	12.0 a	364 c-f	1.21 c-e	237 a-c	84 a-c	2.9 bc	15 c-e	42 de	204.0 gh
2279 x 7024	3442 b-d	108 e-g	9.9 c-e	11.0 a-d	332 c-f	1.09 d-h	222 b-d	138 a	1.7 c	16 c-e	27 de	204.5 gh
HMP 550	3351 b-d	171 b	9.8 c-e	10.2 c-e	298 c-f	1.00 f-h	233 a-d	103 ab	2.3 bc	14 c-e	33 de	205.0 f-h
HMP 557A	3345 b-d	147 c	9.3 c-e	10.4 b-d	308 c-f	.97 g-i	252 a-c	101 ab	2.5 bc	13 c-e	33 de	205.0 f-h
2090 x 7024	3266 b-d	101 f-i	10.7 c	11.0 a-d	314 c-f	1.18 c-f	243 a-c	112 ab	2.2 bc	13 c-e	29 de	204.0 gh
2118 x 7024	3245 b-d	88 i	8.9 d-f	11.4 a-c	320 c-f	1.01 f-h	224 b-d	105 ab	2.1 bc	15 c-e	31 de	206.0 f-h
HMP 1700 ('77)	2957 b-d	125 d	7.4 fg	10.8 a-d	278 d-f	.80 ij	262 a-c	138 a	1.9 bc	11 d-f	22 e	205.5 f-h
HMP 561	2876 cd	162 b	9.8 c-e	10.4 b-c	259 f	1.02 e-h	215 b-e	99 ab	2.2 bc	13 c-e	29 de	202.0 h
1166 x 1700	2777 d	100 g-i	6.4 g	11.0 a-d	267 ef	.70 j	275 a-b	101 ab	2.8 bc	10 ef	29 de	207.0 e-g
1212 x 1700	1402 e	105 f-h	5.8 g	11.4 a-c	139 g	.66 j	209 b-f	97 ab	2.2 bc	6 f	14 e	209.5 d-f

1/ Pearl millet hybrids and populations developed by W. D. Stegmeier.

2/ Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

Unlike pearl millet hybrids tested in 1978, those evaluated in 1979 were much shorter and displayed better uniformity of height within the row. Among millets, plant height ranged from 280 cm (population HMP 559) to 88 cm (hybrid 2118 x 7024). Populations tended to be taller and less uniform than hybrids. Plant height did not appear to influence yield in pearl millet.

Sorghum seed weights were significantly higher than millet seed weights. Sorghum hybrids E59+, F67, and C42A+ had 1000 seed weights of 26.2, 26.1, and 22.0 g respectively. Among millets, 1000 seed weights varied from 10.9 g (hybrids 2090 x 7101 and 2279 x 7101) to 5.8 g (hybrid 1212 x 1700). Seed weights of 1977 series hybrids (1166 x 1700 and 1212 x 1700) were significantly less than those of other millets tested. Pearl millet seed weights varied independently of yield, however, the lowest yielding millet (1212 x 1700) also had the lowest 1000 seed weight.

Overall grain protein contents were lower for millets and sorghums evaluated in 1979 than for those tested in 1978. Protein percentage varied from 12.0 percent (millet hybrid 2224 x 7024) to 9.1 percent (sorghum hybrid E59+). Four pearl millet hybrids contained a significantly higher percentage of protein than sorghum hybrid C42A+ which had the highest protein percentage among sorghums (10.3 percent). Yield had no effect on grain protein content.

Protein per hectare ranged from 618 kg/ha (sorghum hybrid C42A+) to 139 kg/ha (millet hybrid 1212 x 1700). Millet hybrid 2118 x 7101 was best among millets producing 417 kg of protein per hectare. There was no significant difference in protein per hectare between sorghum hybrid E59+ (the lowest protein yielder among sorghums) and millet hybrid 2118 x 7101. E59+ had a protein yield of 529 kg/ha. Protein per hectare decreased as yield decreased.

Sorghum hybrids were significantly higher than millet hybrids in protein per 1000 seeds. Sorghum hybrids F67, E59+, and C42A+ contained 2.63, 2.38, and 2.25 g protein per 1000 seeds respectively. Among millets, protein per 1000 seeds ranged from 1.3 g (hybrid 2090 x 7101) to 0.66 g (hybrid 1212 x 1700). 1977 series hybrids (1166 x 1700 and 1212 x 1700) were significantly lower in protein per 1000 seeds than other millets tested, with the exception of population HMP 1700. Low 1000 seed weights among these millets contributed to low protein levels per 1000 seeds. There was no apparent relationship between protein per 1000 seeds and yield.

Head numbers per hectare ranged from 304,000 (millet hybrid 2118 x 7101) to 130,000 (sorghum hybrid E59+). Millet hybrids and populations generally produced more heads per hectare than sorghum hybrids. Among millets, head numbers per hectare did not vary widely and there was no apparent relationship between head numbers and yield. However, the highest yielding millet (hybrid 2118 x 7101), also produced the most heads per hectare.

Plant numbers per hectare varied from 138,000 (millet hybrid 2279 x 7024 and millet population HMP 1700) to 37,000 (millet hybrid 2090 x 7101). There were no significant differences between millets and sorghums in most cases. Lower yielding millets tended to have slightly higher plant populations though these differences were not significant. This contradicts Harinarayana (28) who reported that unless 170,000 to 200,000 plants per hectare are maintained, the full potential of pearl millet hybrids could not be realized.

Head numbers per plant ranged from 5.3 (millet hybrid 2090 x 7101) to 1.6 (sorghum hybrid C42A+). Millet hybrid 2090 x 7101 appeared to compensate for its low plant population by tillering. There were few significant differences between sorghums and millets in head numbers per plant. Yield levels apparently were not influenced by head numbers per plant.

Sorghum hybrids produced significantly higher yields per head than millet hybrids or populations. Sorghum hybrids C42A+, E59+, and F67 had yields per head of 52, 51, and 49 g respectively. Among millets, yields per head ranged from 26 g (millet population HMP 559) to 6 g (millet hybrid 1212 x 1700). Although head lengths were not measured, it was observed that the heads of HMP 559 were much longer than those of any other millet in this trial and this would likely account for its high yield per head. Higher yielding millets tended to have higher yields per head.

Yields per plant ranged from 116 g (sorghum hybrid F67) to 14 g (millet hybrid 1212 x 1700). Millet hybrid 2090 x 7101 produced 107 g of grain per plant and was not significantly different than sorghum hybrids for this characteristic. In addition, millet population HMP 559, did not differ significantly from sorghum hybrid C42A+ in yield per plant. Higher yielding millets tended to have higher yields per plant, though few millets were significantly higher in yield per plant than others.

As a rough estimate of relative maturity, dates at which half of the plants in each plot had headed were recorded and analyzed. Millet population HMP 559 was the last entry to reach the 50 percent headed stage (day 221.5) though it was not significantly later than sorghum hybrid E59+ (day 219.0). In addition there was no significant difference between millet hybrid 2090 x 7101 (day 213.5) and sorghum hybirds F67 and C42A+ (days 217.0 and 211.0 respectively) in date of 50 percent heading. However most of the millets were significantly earlier in date of 50 percent heading than any of the sorghums, though several were not significantly different from C42A+. Yield level among millets apparently was not affected by date of 50 percent heading. More accurate estimates of maturity were obtained at Garden City, Hays, and Tribune where half bloom dates were recorded.

Garden City

At Garden City yields ranged from 4598 kg/ha (sorghum hybrid F67) to 844 kg/ha (millet population HMP 559) (Table 6). Sorghum hybrid F67 was significantly higher in yield than any of the millets. However, six millet hybrids and one millet population were not significantly different in yield than

Table 6. Hybrid Yield Trial, Garden City, 1979 (Stegmeier Entries)[1/]

Entry	Yield (kg/ha)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous./ha	Yield/ Head (g)	Date of 50% Bloom(Julian)	Date of Dark Layer Formation(Julian)[3/]	Days of Grain fill[3/]
F67 Sorghum	4598 a[2/]	21.5 b	6.9 d-f	277 ab	1.48 ab	121 ed	38 a	226.0 a	262	35
C42A+ Sorghum	3587 ab	20.9 b	6.2 f	196 a-d	1.31 b	108 ed	33 a	213.0 b-d	243	31
E59+ Sorghum	3395 bc	24.7 a	6.7 ef	199 a-d	1.64 a	101 e	34 a	223.3 a	257	33
2224 x 7024	3306 b-d	9.6 c	9.5 a-c	286 a	.92 cd	185 ab	18 b	212.0 cd	241	28
2224 x 7101	3029 b-e	9.6 c	9.9 a	268 ab	.95 cd	198 a	15 bc	214.0 b-d	241	28
2118 x 7024	2952 b-e	8.9 cd	8.4 a-e	221 a-d	.75 c-e	179 ab	16 bc	214.0 b-d	240	28
2279 x 7024	2920 b-e	9.6 c	7.7 c-f	198 a-d	.74 c-e	193 a	15 bc	213.3 b-d	241	30
2279 x 7101	2841 b-e	10.0 c	9.9 a	250 a-c	.99 c	170 a-c	16 bc	216.0 b	244	28
HMP 550	2424 b-f	9.4 cd	9.0 a-d	191 a-d	.84 c-e	191 ab	13 b-d	211.3 d	241	30
2090 x 7024	2388 b-f	10.1 c	7.8 b-f	164 a-d	.79 c-e	147 b-d	16 bc	215.3 bc	240	28
HMP 557 A	2228 c-f	8.3 d	8.6 a-d	171 a-d	.72 de	190 ab	12 b-d	213.7 b-d	242	29
2090 x 7101	2188 d-f	10.0 c	9.0 a-c	173 a-d	.90 cd	135 c-e	16 bc	212.3 cd	242	29
2118 x 7101	2159 d-f	9.4 cd	8.9 a-d	168 a-d	.83 c-e	180 ab	12 b-d	213.3 b-d	241	29
HMP 1700 ('77)	2120 d-f	7.1 e	9.8 ab	184 a-d	.70 de	204 a	10 cd	212.7 b-d	242	28
HMP 561	2032 ef	9.3 cd	8.2 a-f	145 b-d	.76 c-e	187 ab	11 cd	212.3 cd	243	30
1166 x 1700	1606 fg	6.9 e	8.9 a-d	122 cd	.60 e	183 ab	9 d	211.7 cd	237	27
1212 x 1700	1389 fg	6.6 e	9.0 a-d	108 cd	.59 e	208 a	7 d	211.3 d	239	27
HMP 559	884 g	6.9 e	10.0 a	89 d	.69 de	96 e	10 cd	225.3 a	252	29

[1/]Pearl millet hybrids and populations developed by W. D. Stegmeier.

[2/]Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

[3/]Data from one replication only.

sorghum hybrids C42A+ and E59+, which yielded 3587 and 3395 kg/ha respectively. One additional millet population was not significantly different in yield than sorghum hybrid E59+. Millet hybrid 2224 x 7024 was the best millet with a yield of 3306 kg/ha. HMP 559, a late maturing population which yielded well at Manhattan, was a poor performer at Garden City (and all other locations). A lack of pollen at the time of stigma exertion was the probable cause of this poor performance. At Manhattan, adjacent fields containing pearl millet genotypes of similarly late maturity, ensured adequate pollination of HMP 559, and thus better seed set and better yields. At Garden City, 1977 series pearl millet hybrids (1166 x 1700 and 1212 x 1700) were also poor performers.

Sorghum seed weights were significantly higher than millet seed weights. Sorghum hybrids E59+, F67, and C42A+ had 1000 seed weights of 24.7, 21.5, and 20.9 g respectively. Millet seed weights ranged from 10.1 g (hybrid 2090 x 7024) to 6.6 g (hybrid 1212 x 1700). Lower yielding millets tended to have lower seed weights.

Many millets were significantly higher in grain protein percentage than sorghums. Among millets, protein content ranged from 10.0 percent (population HMP 559) to 7.7 percent (hybrid 2279 x 7024). Sorghum hybrids F67, E59+, and C42A+ contained 6.9, 6.7, and 6.2 percent protein respectively. Yield levels in pearl millet did not affect protein percentage.

Protein per hectare ranged from 286 kg/ha (millet hybrid 2224 x 7024) to 89 kg/ha (millet population HMP 559). Most sorghum and millet entries did not differ significantly in protein per hectare. As yield decreased, protein per hectare tended to decrease, but only entries with very low and very high protein yields per hectare differed significantly.

Sorghums produced significantly higher protein yields per 1000 seeds than millets. Among sorghums, E59+ produced the most protein per 1000 seeds, 1.64 g, followed by F67 and C42A+ with 1.48 and 1.31 g respectively. Among millets, protein per 1000 seeds ranged from 0.99 g (hybrid 2279 x 7101) to 0.59 g (hybrid 1212 x 1700). Millets with very low seed weights and yields tended to produce less protein per 1000 seeds.

Head numbers per hectare ranged from 208,000 (millet hybrid 1212 x 1700) to 96,000 (millet population HMP 559). Head numbers per hectare had no apparent influence on yield in pearl millet.

Sorghum hybrids F67, E59+, and C42A+, with yields per head of 38, 34, and 33 g respectively, were significantly higher than any of the millets tested. Millet hybrid 2224 x 7024, the highest yielding millet, had the highest yield per head among millets (18 g). Millet hybrid 1212 x 1700 had the lowest yield per head among millets (7 g). Yield per head tended to decrease as yield decreased in pearl millet.

Dates at which half the plants in each plot had begun anthesis ('half bloom' dates) were recorded and analyzed to obtain some idea of the relative maturity of the entries. Half bloom dates (Julian) ranged from day 226.0 (sorghum hybrid F67) to day 211.3 (millet hybrid 1212 x 1700 and millet population

HMP 550). Millet population HMP 559 was the last millet to reach the half bloom stage (day 225). Sorghum hybrids E59+ and F67 reached half bloom on days 223.0 and 226.0 respectively. Both were significantly later than any of the millets tested except HMP 559. Most of the millets did not differ significantly from sorghum hybrid C42A+ in half bloom date. There was no apparent relationship between half bloom date and yield in pearl millet with the exception of the HMP 559 population which apparently was not adequately pollinated late in the growing season. This does not support the findings of Singh and Singh (60) who reported that days to flowering was positively correlated with grain yield.

Dates of dark layer formation (which correspond with dates of physiological maturity) were also recorded for one replication of the study in order to obtain further knowledge of the relative maturity of the entries and to determine the duration of grain fill. Sorghum hybrid F67 was the last entry to reach physiological maturity (day 262) and it had the longest grain fill period, 35 days. Sorghum hybrid E59+ reached physiological maturity on day 257, and had a grain fill period of 33 days. Millet population HMP 559 reached physiological maturity on day 252, eight days later than the next latest millet, but was similar to other millets in duration of grain fill, 29 days. Millet populations HMP 561 and HMP 550, and millet hybrid 2279 x 7024 reached physiological maturity on days 243, 241, and 241 respectively. Each of these millets had a grain fill period of 30 days (the longest among millets). Sorghum hybrid C42A+, which reached physiological maturity on day 243 and had a grain fill period of 31 days, was the only sorghum similar in maturity to the majority of pearl millets tested. The lateness of sorghum hybrids E59+ and F67 brings into question the fairness of comparing them to earlier maturing millets. In future yield comparisons, earlier maturing sorghums should be used. There was no apparent relationship between date of dark layer formation nor length of grain fill period and yield, however, additional research is needed to verify this observation.

Hays

At Hays, sorghum hybrids F67 and E59+ were significantly higher in yield than any of the millets tested (Table 7). However, three pearl millet hybrids had yields not significantly different than sorghum hybrid C42A+ (3850 kg/ha). Millet hybrid Tift 1 had the highest yield among millets (3207 kg/ha). Seven pearl millet hybrids and five pearl millet populations did not differ significantly from Tift 1. Millet population HMP 559 was the poorest yielder with 980 kg/ha.

Plant heights ranged from 240 cm (millet population HMP 559) to 83 cm (millet hybrids 2118 x 7024 and 1212 x 1700). The highest yielding millet, Tift 1, was of medium height (143 cm). Most millets and sorghums were short statured. Plant height did not appear to affect yield in pearl millet.

Sorghum seed weights were significantly higher than millet

Table 7. Hybrid Yield Trial, Hays, 1979 (Stegmeier Entries)[1/]

Entry	Yield (kg/ha)	Plant Ht. (cm)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous./ha	Yield/ Head (g)	Date of 50% Bloom(Julian)	Stand Rating[3/]	Visual Rating[4/]	Lodging Score[5/]
F 67 Sorghum	4430 a[2/]	111 c-f	25.2 b	10.7 h	409 a-c	2.70 b	94 g	48 a	238.0 a	7.3 ab	4.0 cd	0.0 c
E59+ Sorghum	4206 a	106 d-g	24.0 b	12.3 g	446 a	2.94 b	97 fg	43 b	231.3 c-e	7.5 ab	3.8 de	0.0 c
C42A+ Sorghum	3850 ab	97 e-i	28.5 a	13.0 g	437 ab	3.70 a	108 fg	35 c	225.5 hi	8.0 a	4.8 b-d	0.3 bc
Tift 1	3207 bc	143 b	8.6 d-f	15.5 b-e	424 ab	1.32 d-f	293 ab	11 d-h	226.3 g-i	6.3 ab	4.0 ed	1.0 ab
2090 x 7024	3066 b-d	86 hi	11.6 c	14.7 d-f	386 a-c	1.69 c	201 c-e	15 d	226.8 g-i	7.5 ab	2.8 e	0.3 bc
2279 x 7101	3003 b-d	99 d-i	10.2 c-e	15.8 b-d	406 a-c	1.59 cd	229 b-d	13 d-g	227.8 e-i	7.3 ab	4.5 b-d	0.3 bc
2090 x 7101	2759 c-e	106 d-g	10.8 cd	16.0 bc	378 a-c	1.70 c	192 c-e	14 de	230.0 c-g	6.8 ab	3.8 de	0.3 bc
HMP 02	2583 c-f	123 c	10.2 c-e	14.7 d-f	330 a-d	1.49 c-f	240 a-c	11 d-h	228.0 e-i	7.0 ab	4.5 b-d	1.0 ab
2118 x 7024	2572 c-f	83 i	9.6 c-f	14.3 f	317 b-e	1.36 c-f	198 c-e	13 d-f	230.8 c-f	5.5 b	4.0 cd	0.3 bc
2279 x 7024	2550 c-f	92 g-i	9.8 c-f	14.6 ef	314 b-e	1.40 c-f	197 c-e	12 d-g	226.8 g-i	8.0 a	4.3 b-d	0.0 c
2224 x 7024	2530 c-f	90 g-i	10.7 cd	14.4 ef	314 b-e	1.53 c-e	177 c-f	14 de	226.5 g-i	7.3 ab	3.8 de	0.5 a-c
HMP 550	2521 c-f	124 c	9.7 c-f	15.5 b-f	336 a-d	1.49 c-f	244 a-c	10 d-h	228.0 e-i	7.5 ab	4.5 b-d	0.5 a-c
HMP 561	2456 c-g	113 c-e	9.1 c-f	16.0 bc	342 a-d	1.45 c-f	252 a-c	10 d-h	224.3 i	7.3 ab	5.0 a-c	0.8 a-c
HMP 557A	2328 c-g	96 e-i	9.0 c-f	14.7 d-f	292 c-f	1.31 d-f	210 c-e	11 d-h	228.0 e-i	6.5 ab	4.3 b-d	0.0 c
HMP 1700 ('77)	2321 c-g	102 d-h	8.4 d-f	15.9 bc	317 b-e	1.32 d-f	310 a	8 f-h	227.3 f-i	6.8 ab	4.8 b-d	0.0 c
2224 x 7101	2271 c-g	88 hi	9.7 c-f	16.0 bc	313 b-e	1.53 c-e	176 c-f	13 d-g	232.3 cd	6.3 ab	4.5 b-d	0.0 c
2118 x 7101	2115 d-h	95 f-i	8.5 d-f	15.8 b-d	283 c-f	1.32 d-f	224 b-e	9 e-h	229.0 d-h	8.0 a	4.5 b-d	0.0 c
1166 x 1700	1761 e-h	86 hi	7.4 f	16.4 ab	249 d-f	1.20 ef	291 ab	6 h	229.8 d-g	5.5 b	6.0 a	0.3 bc
1212 x 1700	1593 f-h	83 i	7.8 ef	15.9 bc	220 d-f	1.24 d-f	197 c-e	8 gh	229.5 d-g	5.3 b	6.0 a	0.3 bc
HMP 1700 ('79)	1568 f-h	95 f-i	8.8 d-f	14.8 c-f	201 ef	1.30 d-f	143 e-g	11 d-g	233.5 bc	2.3 c	5.25 ab	0.5 ac
Senegal Bulk	1464 gh	115 cd	7.2 f	16.1 ab	201 ef	1.14 f	147 e-g	10 d-h	236.5 ab	7.5 ab	4.75 b-d	1.3 a
HMP 559	980 h	240 a	7.7 ef	17.1 a	155 f	1.28 d-f	100 fg	9 e-h	239.5 a	6.5 ab	5.25 ab	1.0 ab

[1/] All pearl millet hybrids and populations developed by W. D. Stegmeier, except millet hybrid 'Tift 1' developed by G. W. Burton.

[2/] Duncan Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

[3/] Stand Rating: 0=0 plants, 9=100% stand.

[4/] Visual Rating: 1-3=good, 4-6=fair, 7-9=poor.

[5/] Lodge Score: 0=0% lodged, 9=100% lodged.

seed weights. Sorghum hybrids C42A+, F67, and E59+ had 1000 seed weights of 28.5, 25.2, and 24.0 g respectively. Among millets, 1000 seed weights ranged from 11.6 g (hybrid 2090 x 7024) to 7.2 g (population 'Senegal Bulk'). Higher yielding millets tended to have higher seed weights.

Grain protein percentages were significantly higher in millet than sorghum. Among millets, percent protein ranged from 17.1 percent (population HMP 559) to 14.3 percent (hybrid 2118 x 7024). Sorghum hybrids C42A+, E59+, and F67 contained 13.0, 12.3, and 10.7 percent protein, respectively. Yield levels did not appear to affect percent protein in pearl millet although the lowest yielding millet, HMP 559, did have the highest protein percentage.

Protein per hectare ranged from 446 kg/ha (sorghum hybrid E59+) to 155 kg/ha (millet population HMP 559). A number of millets did not differ significantly from sorghum hybrids in protein per hectare. Among millets, hybrid Tift 1 produced the most protein per hectare (424 kg/ha). Protein per hectare decreased as yield decreased in pearl millet.

Sorghum hybrids C42A+, E59+, and F67 produced 3.70, 2.94, and 2.70 g of protein per 1000 seeds respectively, and were significantly higher for this character than any of the millets tested. Among millets, protein per 1000 seeds ranged from 1.70 g (hybrid 2090 x 7101) to 1.14 g (population Senegal Bulk). Millets with low 1000 seed weights, tended to have lower protein contents per 1000 seeds. There was no clear relationship between protein per 1000 seeds and yield in pearl millet.

Head numbers per hectare ranged from 310,000 (population HMP 1700, '77) to 94,000 (sorghum hybrid C42A+). Most millets produced significantly more heads per hectare than sorghum hybrids. Very low yielding millets tended to produce fewer heads per hectare than medium to high yielding millets.

Yields per head were significantly higher among sorghums than millets. Sorghum hybrids F67, E59+, and C42A+ produced 48, 43, and 35 grams per head respectively. Among millets, yields per head varied from 15 g (hybrid 2090 x 7024) to 6 g (hybrid 1166 x 1700). Lower yielding millets tended to have lower yields per head.

Average half bloom dates (Julian) ranged from day 239.5 (millet population HMP 559) to day 224.3 (millet population HMP 561). Sorghum hybrids F67, E59+, and C42A+ reached half bloom on days 238.0, 231.3, and 225.5 respectively. Sorghum hybrid F67 was significantly later than any of the millets tested except HMP 559. However, half bloom dates of sorghum hybrids E59+ and C42A+ were similar to those of several millets. Pearl millets with later half bloom dates tended to have lower yields.

Plant stands in each plot were rated on a scale of 0 to 9 where 0 indicated no plants and 9 indicated a 100 percent stand. Very few stands were without skips within the row, particularly among millets. Stand establishment was a problem at most locations. Low seed vigor in pearl millet is thought to be the cause of poor stand establishment. Selective harvesting of the best portion of each plot was practiced to reduce yield differences among entries due to differences in stand establishment.

Each entry was also rated for visual appearance on a scale of 0 to 9. A rating of 1 to 3 indicated good appearance (ie. uniformity of height, good head exertion, good set seed, etc.). A rating of 4 to 6 indicated fair appearance, and a rating of 7 to 9 indicated poor appearance. Most millet and sorghum entries fell into the 'fair' range, however one millet hybrid, 2090 x 7024, was in the 'good' range with an average visual rating of 2.8. 1977 series millet hybrids (1166 x 1700 and 1212 x 1700) had visual ratings of 6.0 each, the lowest in the study. Lower yielding millets tended to have lower visual ratings.

Lodging scores were also assigned to each entry on a scale of 0 to 9 where 0 indicated no lodging and 9 indicated complete lodging. Lodging was not excessive in any of the entries and several entries did not lodge at all. Millet population Senegal Bulk had the highest lodging score of 1.3. At these low levels, lodging had no apparent effect on yield.

Minneola

Sorghum hybrids C42A+ and E59+ were the top performers at Minneola with respective yields of 3862 and 3620 kg/ha (Table 8). However, two millet hybrids, 2224 x 7024 and 2090 x 7024, with yields of 3394 and 3026 kg/ha, respectively, were not significantly different in yield than C42A+ and E59+.

Table 8. Hybrid Yield Trial, Minneola, 1979 (Stegmeier Entries)[1/]

Entry	Yield (kg/ha)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous./ha	Yield/ Head (g)	Seed Set Rating[3/]
C42A+ Sorghum	3862 a[2/]	20.0 a	8.9 d	301 ab	1.78 a	132 d-g	29 a	-
E59+ Sorghum	3620 ab	22.1 a	9.0 cd	283 a-c	1.99 a	131 e-g	28 a	-
2224 x 7024	3394 a-c	9.8 a-c	10.9 a-d	325 a	1.07 bc	163 b-e	21 b	1
2090 x 7024	3026 a-d	9.7 c	9.9 b-d	262 a-d	.96 b-d	163 b-e	19 b-d	1
F67 Sorghum	2921 b-e	13.9 b	9.2 cd	235 a-d	1.24 b	104 fg	29 a	-
2118 x 7024	2858 b-f	8.4 c-e	10.5 a-d	268 a-d	.89 b-d	142 c-f	20 bc	1
2279 x 7024	2836 b-f	9.5 cd	9.9 b-d	249 a-d	.94 b-d	165 b-e	17 b-e	1
2224 x 7101	2834 b-f	8.6 c-e	11.4 ab	285 a-c	.99 b-d	194 a-c	15 c-f	3
HMP 561	2634 c-f	8.8 c-f	10.2 a-d	244 a-d	.89 b-d	218 a	12 ef	1
1166 x 1700	2539 c-f	6.9 c-e	11.3 a-c	252 a-d	.78 c-e	214 ab	12 ef	2
2090 x 7101	2438 c-f	9.7 cd	10.9 a-d	233 a-e	1.06 cd	149 c-f	17 b-f	3
2279 x 7101	2430 d-f	9.6 cd	12.4 a	263 a-d	1.20 b	179 a-e	14 c-f	2
2118 x 7101	2421 d-f	8.9 cd	10.9 a-d	230 a-e	.96 b-d	193 a-c	12 ef	3
HMP 550	2346 d-f	8.6 c-e	10.9 a-d	227 a-e	.94 b-d	166 b-e	14 d-f	2
HMP 557A	2042 ef	8.3 c-e	9.7 b-d	172 c-e	.81 c-e	171 a-e	12 ef	2
HMP 1700 ('77)	1985 f	6.5 de	10.8 a-d	185 b-e	.70 de	188 a-c	11 f	2
1212 x 1700	1974 f	5.9 e	9.3 b-d	158 de	.55 e	184 a-d	11 f	2
HMP 559	1062 g	5.9 e	11.3 a-c	105 e	.67 de	90 g	12 ef	late[4/]

[1/] Pearl millet hybrids and populations developed by W. D. Stegmeier.

[2/] Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

[3/] Seed Set Rating: 1=good, 2=fair, 3=poor. Based on one replication only.

[4/] HMP 559 had not set seed at the time this data was recorded.

Three additional millet hybrids did not differ significantly in yield from sorghum hybrid E59+. In addition, nine millet hybrids and three millet populations did not differ significantly in yield from sorghum hybrid F67, which yielded 2921 kg/ha. It should be noted, however, that F67 was harvested before it had reached physiological maturity. It was felt that it was not fair to compare a sorghum of late maturity to millets of earlier maturity. Millet population HMP 561 did not differ significantly in yield from the best yielding millet hybrid (2224 x 7024). Millet population HMP 559 was the poorest yielder in the study, producing 1062 kg grain/ha.

Sorghum seed weights were significantly higher than millet seed weights. Sorghum hybrid E59+ had the highest 1000 seed weight of 22.1 g followed by sorghum hybrids C42A+ and F67 with 20.0 and 13.9 g respectively. Millet hybrid 2224 x 7024, which was the highest yielding millet, also had the highest seed weight among millets, 9.8 g. Eleven millet hybrids and populations had 1000 seed weights not significantly different than that of 2224 x 7024. Millet hybrid 1212 x 1700 and millet population HMP 559 had the lowest 1000 seed weights among all entries, 5.9 g each. Seed weights tended to decrease as yield decreased in pearl millet.

Millet hybrids 2279 x 7101 and 2224 x 7101 contained 12.4 and 11.4 percent protein respectively and were significantly higher than any of the sorghum checks. Sorghum hybrid F67 contained the highest percentage of protein among sorghums, 9.2 percent. Ten millet hybrids and populations did not differ significantly in percent protein from the top millet hybrid (2279 x 7101). Sorghum hybrid C42A+ had the lowest protein percentage of all entries (8.9 percent). Yield level did not appear to affect protein percentage.

Protein per hectare varied from 325 kg/ha (millet hybrid 2224 x 7024) to 105 kg/ha (millet population HMP 559). Differences among most millet and sorghum entries were not significant. Protein per hectare decreased as yield decreased.

Protein per 1000 seeds ranged from 1.99 g (sorghum hybrid E59+) to 0.55 g (millet hybrid 1212 x 1700). Sorghum hybrids E59+ and C42A+ were significantly higher in protein per 1000 seeds than other entries. Millet hybrid 2279 x 7101, which had the highest protein percentage of any entry, had the highest protein content per 1000 seeds among millets (1.20 g). Entries with low 1000 seed weights had lower protein contents per 1000 seeds. As yield decreased, protein per 1000 seeds also tended to decrease.

Head numbers per hectare ranged from 218,000 (millet population HMP 561) to 90,000 (millet population HMP 559). Sorghums tended to produce fewer heads than millets though a number of millets did not differ significantly from sorghums in this character. There was no clear relationship between head numbers per hectare and yield in pearl millet.

Sorghums produced significantly higher yields per head than millets. Sorghum hybrids F67, C42A+, and E59+ had yields per head of 29, 29, and 28 g, respectively. Millet hybrid 2224 x 7024 (which was the highest yielding millet) had the highest yield per head among millets (21 g). Millet population HMP 1700 and millet hybrid 1212 x 1700 both had yields per head of 11 g, the lowest of all entries. Yields per head tended to decrease as yields decreased.

Millets in one replication of the study were scored for seed set. Good seed set was characteristic of higher yielding millets. Poor seed set may have been a cause of reduced yields in some entries.

St. John

Overall yield levels were lower at St. John than at other locations in 1979 (Table 9). Very sandy soils, low nitrogen levels and low rainfall in late summer (see Table 26) may have caused yield reductions. Pearl millet hybrid 2224 x 7024 was the top entry with a yield of 2574 kg/ha. However, five additional millet hybrids, two millet populations, and three sorghum hybrids had yields not significantly different than that of millet hybrid 2224 x 7024. Among sorghum hybrids, F67 had the highest yield of 2426 kg/ha. Millet hybrid 1166 x 1700 was the lowest yielding entry, producing 1089 kg/ha.

Sorghum hybrids E59+, C42A+, and F67 had 1000 seed weights of 26.3, 25.9, and 23.7 g respectively, significantly higher than any of the millets tested. Among millets, 1000 seed weights ranged from 11.1 g (hybrid 2090 x 7024) to 7.1 g (population HMP 1700 and hybrid 1212 x 1700). Higher yielding millets tended to have higher seed weights.

Type 9. Hybrid Yield Trial, St. John, 1979 (Stegmeier Entries)[1/]

Entry	Yield (kg/ha)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous./ha	Yield/ Head (g)
2224 x 7024	2574 a[2/]	10.2 cd	8.2 a-d	187 a	.84 c-e	272 ab	10 d-f
2279 x 7024	2477 a	9.6 de	7.5 c-f	162 a-c	.72 e-h	294 a	8 e-g
F67 Sorghum	2426 a	23.7 b	5.8 h	122 a-d	1.37 b	116 f	21 a
C42A+ Sorghum	2280 ab	25.9 a	6.1 gh	122 a-d	1.59 a	135 d-f	17 b
2118 x 7101	2208 ab	9.7 de	9.2 a	179 ab	.89 c	256 a-c	9 e-g
2090 x 7024	2199 ab	11.1 c	7.3 c-f	142 a-d	.81 c-f	186 b-f	12 c-e
HMP 550	2034 a-c	9.2 e	8.0 b-d	144 a-d	.74 c-h	216 a-e	9 e-g
HMP 561	1941 a-d	9.1 e	8.0 cd	137 a-d	.72 d-h	247 a-c	8 f-h
2118 x 7024	1860 a-e	9.1 e	7.6 c-e	130 a-d	.70 e-h	195 b-f	10 d-f
E59+ Sorghum	1816 a-e	26.3 a	6.5 f-h	103 cd	1.71 a	127 ef	14 bc
2224 x 7101	1791 a-e	9.1 e	8.2 a-d	135 a-d	.76 c-g	229 a-c	8 f-h
HMP 557A	1607 b-e	8.2 f	7.2 d-f	102 cd	.59 hi	187 b-f	9 e-g
2090 x 7101	1535 b-e	10.5 cd	8.4 a-c	114 b-d	.88 cd	134 d-f	11 c-f
HMP 559	1505 b-e	6.8 g	6.8 e-g	89 d	.46 i	114 f	13 cd
2279 x 7101	1502 b-e	9.7 de	9.0 ab	119 a-d	.88 cd	169 c-f	9 e-g
HMP 1700 ('77)	1286 c-e	7.1 g	9.1 ab	103 cd	.65 gh	222 a-d	6 gh
1212 x 1700	1209 de	7.1 g	9.1 ab	99 cd	.65 gh	261 ab	5 h
1166 x 1700	1089 e	7.3 g	9.1 ab	86 d	.66 f-h	225 a-c	5 h

[1/]Pearl millet hybrids and populations developed by W. D. Stegmeier.

[2/]Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

Millets generally were higher in percent protein than sorghums, though in some cases, the differences were not significant. Millet hybrid 2118 x 7101 contained the highest percentage of protein, 9.2 percent. Among millets, population HMP 559, had the lowest protein content, 6.8 percent. Sorghum hybrids E59+, C42A+, and F67 contained 6.5, 6.1, and 5.8 percent protein respectively. Lower yielding millets tended to contain higher percentages of protein.

Protein per hectare ranged from 187 kg/ha (millet hybrid 2224 x 7024) to 86 kg/ha (millet hybrid 1166 x 1700). Four millet hybrids, two millet populations, and two sorghum hybrids (F67 and C42A+) did not differ significantly from millet hybrid 2224 x 7024 in protein per hectare. Protein per hectare tended to decrease as yield decreased.

Sorghums contained significantly more protein per 1000 seeds than millets. Sorghum hybrids E59+, C42A+, and F67 contained 1.71, 1.59, and 1.37 g of protein per 1000 seeds, respectively. Among millets, protein per 1000 seeds varied from 0.89 g (hybrid 2118 x 7101) to 0.46 g (population HMP 559). Low yielding millets and millets with low 1000 seed weights tended to have lower protein contents per 1000 seeds.

Millet hybrid 2279 x 7024 produced the largest number of heads per hectare, 294,000. Millet population HMP 559 produced the fewest heads per hectare, 114,000. Many millets did not differ significantly from the sorghums in head numbers produced. There was no apparent relationship between head numbers and yield in pearl millet.

Sorghum hybrids F67 and C42A+ had yields per head of 21 and 17 g respectively, significantly higher than other entries for this trait. However, two millet hybrids and one millet population did not differ significantly in yield per head from sorghum hybrid E59+ (17 g per head). Among millets, HMP 559 had the highest yield per head of 13 g. Millet hybrids 1212 x 1700 and 1166 x 1700 both produced 5 g of grain per head, the least of all entries. There was no clear relationship between yield per head and yield level in pearl millet although the two lowest yielding entries also had the lowest yield per head.

Tribune

Overall yield levels were higher at Tribune than at other locations in 1979 (Table 10). It is speculated that lower night temperatures (see Table 27) may have reduced respiration at Tribune, leaving more photosynthate for grain production. Sorghum hybrid C42A+ was the top performer with a yield of 5666 kg/ha. However, five millet hybrids as well as sorghum hybrids E59+ and F67 were not significantly different in yield than sorghum hybrid C42A+. Four additional millet hybrids and three millet populations did not differ significantly from sorghum hybrid F67 in yield. Millet hybrid 2224 x 7024 was the highest yielder among millets, producing 4598 kg/ha of grain. Millet population HMP 559 was the lowest yielding entry, producing 1444 kg/ha of grain.

Table 10. Hybrid Yield Trial, Tribune, 1979 (Stegmeier Entries)[1/]

Entry	Yield (kg/ha)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous./ha	Yield/ Head (g)	Date of 50% Bloom(Julian)	Seed Set Rating[4/]
C42A+ Sorghum	5666 a[2/]	21.7 b	11.3 ef	549 a	2.42 a	148 e	39 a	222.0 bc	1.0 d
E59+ Sorghum	5442 a	25.6 a	10.3 f	478a-c	2.59 a	179 de	32 a	232.0 a	1.0 d
2224 x 7024	4598 ab	10.7 c	12.5 de	497 a-c	1.34 d-g	298 a-c	15 b	219.7 d	2.0 bc
F67 Sorghum	4576 ab	20.9 b	10.5 f	409 a-c	2.18 b	139 e	32 a	late[3/]	1.0 d
2279 x 7024	4319 ab	10.3 c	13.4 b-d	501 a-c	1.37 c-g	337 a-c	13 b	219.7 d	2.0 bc
2090 x 7024	4286 a-c	11.0 c	12.8 cd	471 a-c	1.40 c-g	368 ab	12 b	219.7 d	2.0 bc
2118 x 7101	4202 a-d	10.3 c	14.3 a-c	526 ab	1.47 c-f	398 a	11 b	220.3 cd	3.0 a
2224 x 7101	3953 a-d	10.4 c	14.1 a-c	488 a-c	1.46 c-f	309 a-c	13 b	222.7 b	3.0 a
2090 x 7101	3521 b-d	10.9 c	14.9 ab	448 a-c	1.62 c	234 c-e	14 b	223.0 b	2.3 a-c
HMP 1700 ('77)	3334 b-d	8.5 c	14.3 a-c	419 a-c	1.22 f-g	340 a-c	10 b	219.7 d	2.0 bc
HMP 561	3316 b-d	9.9 c	14.0 a-c	400 a-c	1.37 c-g	352 ab	10 b	220.3 cd	2.3 a-c
2279 x 7101	3309 b-d	10.7 c	14.6 ab	410 a-c	1.55 c-e	261 b-d	12 b	222.0 bc	3.0 a
HMP 557A	3165 b-e	10.1 c	12.7 cd	348 b-d	1.28 fg	338 a-c	10 b	220.3 cd	2.0 bc
2118 x 7024	3151 b-e	11.3 c	14.1 a-c	387 a-c	1.59 cd	357 ab	10 b	219.7 d	2.7 ab
1212 x 1700	2894 b-e	8.6 c	13.6 b-d	342 b-d	1.17 g	293 a-c	10 b	221.0 b-d	2.0 bc
HMP 550	2497 c-e	10.5 c	14.7 ab	321 cd	1.55 c-e	269 b-d	10 b	223.0 cd	2.0 bc
1166 x 1700	2470 de	9.0 c	14.5 ab	313 cd	1.30 e-g	282 b-d	9 b	220.3 cd	2.0 bc
HMP 559	1444 e	9.0 c	15.4 a	192 d	1.39 c-g	153 e	9 b	231.0 a	1.7 cd

1/ Pearl millet hybrids and populations developed by W. D. Stegmeier.

2/ Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

3/ Sorghum hybrid F67 did not flower during the period in which these observations were recorded.

4/ Seed Set Rating: 1=good; 2=fair; 3=poor.

Sorghum hybrids E59+, C42A+, and F67 had 1000 seed weights of 25.6, 21.7, and 20.9 g respectively, all significantly higher than any of the millets tested. Among millets, hybrid 2118 x 7024 had the highest 1000 seed weight of 11.3 g. Millet population HMP 1700 had the lowest 1000 seed weight of all entries, 8.5 g. Differences in 1000 seed weights among millets were not significant. Yield levels in pearl millet did not affect 1000 seed weights.

All millets except one were significantly higher than sorghums in protein content. Protein percentage ranged from 15.4 percent (millet population HMP 559) to 10.3 percent (sorhgum hybrid E59+). Percent protein tended to increase as yield decreased.

Protein per hectare ranged from 549 kg/ha (sorghum hybrid C42A+) to 192 kg/ha (millet hybrid HMP 559). Eleven entries including sorghum hybrids, millet hybrids, and millet populations did not differ significantly from sorghum hybrid C42A+ in protein per hectare. Protein per hectare generally decreased as yield decreased.

Sorghums were significantly higher in protein per 1000 seeds than millets. Sorghum hybrids E59+, C42A+, and F67 produced 2.59, 2.42, and 2.18 g protein per 1000 seeds respectively. Millet hybrid 2090 x 7101 contained 1.62 g of protein per 1000 seeds, the highest among the millets. Millet hybrid 1212 x 1700 had the lowest protein content per 1000 seeds (1.17 g). There was no apparent relationship between protein per 1000 seeds and yield in pearl millet.

Head numbers per hectare ranged from 398,000 (millet hybrid 2118 x 7101) to 139,000 (sorghum hybrid F67). Most millets produced significantly more heads per hectare than sorghums. There was no apparent relationship between head numbers and yield in pearl millet.

Yields per head were significantly higher for sorghums than for millets. Sorghum hybrids C42A+, E59+, and F67 produced yields per head of 39, 32, and 32 g respectively. Among millets, yields per head varied from 15 g (hybrid 2224 x 7024) to 9 g (hybrid 1166 x 1700 and population HMP 559). There were no significant differences among millets in yield per head. Yield level apparently did not affect yield per head in pearl millet.

Half bloom dates were recorded as an indicator of maturity. Sorghum hybrid F67 was the last entry to reach half bloom though the actual date was not recorded. Sorghum hybrid E59+ and millet population HMP 559, which achieved half bloom on Julian days 231.0 and 232.0 respectively, were not significantly different. Sorghum hybrid C42A+, which reached half bloom on day 222.0, was not significantly different than several millets for this character. Half bloom date did not appear to affect yield in pearl millet.

Each entry was rated for seed set. All sorghums had good seed set, however most millets displayed fair or poor seed set. Higher head numbers and higher seed weights at this location may have offset the effect of poor seed set.

Analysis Across Locations

To determine the validity of analyzing entries across locations, Bartletts test of homogeneity of variance was used (62). When yield data from all six locations were included in the test, a Chi-square value of 30.59 with five degrees of freedom was obtained. The probability of a greater Chi-square was less than 0.5 percent, indicating significant differences among variances at different locations. When the Tribune yield data was excluded, a Chi-square value of 7.81 with 4 degrees of freedom was obtained. The probability of a greater Chi-square value was slightly less than 10 percent. This was acceptable, and so an analysis of variance was run using yield data from Manhattan, Garden City, Hays, Minneola, and St. John.

The analysis of variance (Table 42), shows that sites, replications within sites, hybrids, and site by hybrid interaction were highly significant.

Table 11 shows yields of each entry at five locations. Sorghum hybrid C42A+ was the top yielder at Manhattan and Minneola, while sorghum hybrid F67 was the highest yielder at Garden City and Hays and was the best performer among sorghums at St. John. Among millets, hybrid 2224 x 7024 was the top yielder at three locations; Garden City, Minneola, and St. John. At Manhattan, hybrid 2118 x 7024 was the highest yielding millet and at Hays hybrid 2090 x 7024 was the best. Except at Manhattan, millet population HMP 559 was a consistently low yielder. 1977 series hybrids 1166 x 1700 and 1212 x 1700 were also consistently poor performers.

Table 11. Yields at Five Locations, 1979 (Stegmeier Entries)

Entry	Yield (kg/ha)				
	Manhattan	Garden City	Hays	Minneola	St. John
F67 Sorghum	6842	4598	4430	2921	2426
C42A+ Sorghum	6891	3587	3850	3862	2280
E59+ Sorghum	6642	3395	4206	3620	1816
2224 x 7024	3470	3306	2530	3394	2574
2279 x 7024	3442	2920	2550	2836	2477
2090 x 7024	3266	2388	3066	3026	2199
2118 x 7024	3245	2952	2572	2858	1860
2279 x 7101	3662	2841	3003	2430	1502
2224 x 7101	3770	3029	2271	2834	1791
HMP 550	3351	2424	2521	2346	2034
2090 x 7101	3751	2188	2759	2438	1535
2118 x 7101	4063	2159	2115	2421	2208
HMP 561	2876	2032	2456	2643	1941
HMP 557A	3345	2228	2328	2042	1607
HMP 1700 ('77)	2947	2120	2321	1985	1286
1166 x 1700	2777	1606	1761	2539	1089
HMP 559	3981	844	980	1062	1505
1212 x 1700	1402	1389	1593	1974	1209

HYBRID YIELD TRIALS, 1979, (BURTON ENTRIES)

Manhattan

In the hybrid yield trial at Manhattan, 1979, sorghum hybrid C42A+ was the top performer with a yield of 4153 kg/ha (Table 12). However seven millet hybrids, two millet populations, and sorghum hybrid C46+ had yields not significantly different than that of sorghum hybrid C42A+. Hybrid Tift 2 had the highest yield among millets, 3938 kg/ha. Millet hybrid Tift 11 had the lowest yield of all entries, 1960 kg/ha.

Most of the millets tested were quite tall. Plant height among millets ranged from 245 cm (Serere 3A) to 129 cm (Tift 3). Sorghums were not measured. Plant height had no apparent effect on yield in pearl millet.

Sorghum seed weights were significantly higher than those of pearl millet. Sorghum hybrids C42A+ and C46+ had 1000 seed weights of 22.7 and 20.6 g respectively. Among millets, population Serere 3A had the highest 1000 seed weight of 11.6 g and hybrid Tift 11 had the lowest, 4.9 g/1000. There was no apparent relationship between seed weight and yield in pearl millet.

Grain protein content varied from 12.8 percent (millet hybrid Tift 3) to 9.6 percent (sorghum hybrid C46+). Most millets were significantly higher in protein percentage than sorghums. Yield levels in pearl millet did not appear to affect protein percentage.

Table 12. Hybrid Yield Trial, Manhattan 1979 (Burton Entries)[1/]

Entry	Yield (kg/ha)	Plant Ht. (cm)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous./ha	Plants Thous./ha	Heads/ Plant	Yield Head (g)	Yield/ Plant (g)	Date of 50% heading(Julian)
C42A+ Sorghum	4153 a[2/]	-	22.7 a	9.8 fg	354 a	2.21 a	127 e	51 b	2.8 c-e	33 b	89 a	210.6 cd
Tift 2	3938 ab	216 b	9.7 d	11.0 b-e	382 a	1.07 de	429 a	95 a	4.6 b	9 de	42 b	200.3 e
C46+ Sorghum	3800 ab	-	20.6 b	9.6 g	320 ab	1.98 b	100 e	42 b	2.5 c-e	38 a	95 a	212.0 c
Tift 15	3625 ab	183 c	7.1 f-h	10.8 c-e	345 a	.76 gh	355 ab	129 a	2.7 c-e	10 de	28 b	206.7 d
Tift 1	3536 ab	239 a	8.6 e	10.6 d-f	328 ab	.91 f	388 a	141 a	2.8 c-e	9 de	26 b	199.7 e
Tift 9	3498 a-c	242 a	7.7 f	11.3 b-d	347 a	.88 fg	420 a	34 b	12.2 a	8 de	101 a	220.3 b
Tift 8	3426 a-c	192 c	6.2 h	11.5 bc	347 a	.72 h	180 de	113 a	1.6 de	19 c	31 b	242.3 a
RMP-1	3412 a-c	184 c	6.7 gh	10.5 d-f	318 ab	.71 h	280 bc	125 a	2.5 c-e	12 d	30 b	212.0 c
Tift 12	2805 a-c	213 b	7.7 f	11.7 bc	284 ab	.89 f	414 a	111 a	4.1 bc	7 e	26 b	197.3 e
Serere 3A	2697 a-c	245 a	11.6 c	11.1 b-e	266 ab	1.29 c	136 de	105 a	1.4 e	20 c	27 b	210.7 cd
Tift 7	2595 a-c	240 a	9.8 d	11.8 b	269 ab	1.16 d	408 a	99 a	4.1 bc	6 e	26 b	212.3 c
Tift 3	2541 bc	129 e	7.5 fg	12.8 a	284 ab	.96 ef	420 a	136 a	3.1 b-d	6 e	20 b	197.7 e
Tift 11	1960 c	149 d	4.9 i	10.3 e-g	174 b	.51 f	223 cd	99 a	2.3 de	8 de	20 b	218.0 b

1/Pearl millet hybrids developed by G. W. Burton.

2/Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

Most entries did not differ significantly in protein per hectare. Tift 2 produced 382 kg of protein per hectare, the most of any entry. Millet hybrid Tift 11, which was the lowest yielding millet, also was the lowest protein yielder, producing 174 kg of protein per hectare. Protein per hectare decreased as yield decreased.

Sorghums were significantly higher in protein per 1000 seeds than millets. Sorghum hybrids C42A+ and C46+ contained 2.21 and 1.98 g of protein per 1000 seeds respectively. Among millets, protein per 1000 seeds ranged from 1.29 g (population Serere 3A) to 0.51 g (hybrid Tift 11). Millets with higher seed weights tended to contain more protein per 1000 seeds. There was no apparent relationship between protein per 1000 seeds and yield in pearl millet.

Most millets produced significantly more heads per hectare than sorghums. Millet hybrid Tift 2, the highest yielding millet, also produced the most heads per hectare (429,000). Millet population Serere 3A produced the fewest heads per hectare among millets (136,000). Sorghum hybrids C42A+ and C46+ produced 127,000 and 100,000 heads per hectare respectively. Head numbers did not appear to affect yield in pearl millet.

Most millets had significantly higher plant populations than sorghums. Sorghum hybrids C42A+ and C46+ had plant populations of 51,000 and 42,000 plants per hectare respectively. Among millets, plant populations ranged from 141,000 plants per hectare (hybrid Tift 1) to 34,000 plants per hectare (hybrid Tift 9). With the exception of Tift 9, millets did not differ significantly in plant population.

Millet hybrid Tift 9, which had the lowest plant population of any entry, produced significantly more heads per plant than other entries (12.2 heads per plant). Apparently this hybrid was able to compensate for its low plant population by tillering. The highest yielding millet, hybrid Tift 2, produced the second largest number of heads per plant (4.6 heads per plant) however, this was not significantly different than several other millets. Sorghum hybrids C42A+ and C46+ were intermediate in head numbers per plant with 2.8 and 2.5 heads per plant respectively. There was no apparent relationship between heads per plant and yield.

Sorghum hybrids C46+ and C42A+ produced yields per head of 38 and 33 g respectively, and were significantly higher in this character than any of the millets tested. Yields per head among millets ranged from 20 g (population Serere 3A) to 6 g (hybrid Tift 3). There was no apparent relationship between yield per head and yield in pearl millet.

Millet hybrid Tift 1 and sorghum hybrids C46+ and C42A+ were significantly higher in yield per plant than other entries. Tift 1 had the highest yield per plant of 101 g followed by C46+ and C42A+ with 95 and 89 g per plant, respectively. Millet hybrids Tift 3 and Tift 11 both had yields per plant of 20 g, the lowest of all entries, though not significantly different than other millets with the exception of Tift 9.

Dates of 50 percent heading ranged from Julian day 242.3 (millet hybrid Tift 8) to day 197.3 (millet hybrid Tift 12).

Sorghum hybrids C46+ and C42A+ were 50 percent headed on days 212.0 and 210.6 respectively. Date of 50 percent heading did not appear to influence yield in pearl millet.

Hays

In the hybrid yield trial at Hays, 1979, sorghums yielded significantly higher than millets (Table 13). Sorghum hybrids C42A+ and C46+ had yields of 4988 and 4966 kg/ha respectively. Millet yields ranged from 3266 kg/ha (hybrid Tift 2) to 272 kg/ha (hybrid Tift 8). Six millet hybrids and two millet populations did not differ significantly in yield from Tift 2.

Millets were not as tall at Hays as at Manhattan. Low rainfall at Hays may have been responsible. A number of millets were significantly taller than the sorghum hybrid checks. Millet hybrid Tift 1 was the tallest entry at 188 cm. Millet hybrid Tift 3 was the shortest entry at 100 cm. Sorghum hybrids C46+ and C42A+ were 121 and 110 cm tall respectively. Plant height did not seem to affect yield in pearl millet.

Sorghum seed weights were substantially higher than those of millet. Sorghum hybrids C42A+ and C46+ had 1000 seed weights of 30.9 and 25.4 g respectively. Millet seed weights varied from 12.4 g (population Serere 3A) to 5.1 g (hybrids Tift 11 and Tift 8). There was no apparent relationship between seed weight and yield in pearl millet.

Millets were significantly higher in protein content than sorghums. Millet hybrid Tift 8, the lowest yielding millet,

Table 13. Hybrid Yield Trial, Hays, 1979 (Burton Entries)[1/]

Entry	Yield (kg/ha)	Plant Ht. (cm)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous./ha	Yield/ Head (g)	Date of 50% Bloom(Julian)	Stand Rating[3/]	Visual Rating[4/]	Lodging Score[5/]
C42A+ Sorghum	4988 a[2/]	110 de	30.9 a	11.8 d	516 ab	3.66 a	162 e	33 b	223.3 d	9.0 a	2.7 g	0.6 b
C46+ Sorghum	4966 a	121 d	25.4 b	14.2 cd	619 a	3.61 a	109 e	47 a	227.0 c	8.7 a	3.0 fg	0.0 b
Tift 2	3266 b	165 b	9.8 d	15.8 bc	452 b	1.55 bc	367 b-d	9 cd	223.3 d	7.7 ab	4.3 c-e	0.3 b
Tift 12	3240 b	163 b	8.5 de	16.3 bc	462 b	1.38 bc	417 b	8 cd	221.3 d	8.0 ab	5.3 a-c	2.3 a
Tift 9	3049 b	139 c	6.8 ef	17.3 b	463 b	1.17 c	483 b	6 cd	238.0 a	4.7 c	6.3 a	0.7 b
Tift 1	3011 b	188 a	8.7 de	15.9 bc	419 b	1.39 bc	354 b-d	9 cd	223.0 d	8.3 ab	4.7 b-d	1.0 b
Tift 3	2983 b	100 e	6.7 ef	15.1 bc	394 b	1.01 c	384 bc	8 cd	222.7 d	7.3 ab	4.3 c-e	0.0 b
Tift 7	2941 b	175 ab	10.5cd	17.6 b	451 b	1.86 b	702 a	4 cd	232.7 b	7.7 ab	6.0 a	0.3 b
Tift 15	2911 b	118 d	8.2 de	16.0 bc	406 b	1.31 bc	248 c-e	12 c	226.3 c	7.0 ab	3.3 e-g	0.0 b
RMP-1	2801 b	114 de	8.7 de	15.4 bc	381 b	1.33 bc	247 c-e	11 c	228.7 c	7.3 ab	3.7 d-g	1.0 b
Serere 3A	2676 b	185 a	12.4 c	15.6 bc	363 b	1.93 b	228 de	12 c	228.3 c	8.7 a	4.0 d-f	1.0 b
Tift 11	964 c	113 de	5.1 f	15.9 bc	151 c	.90 c	221 de	5 cd	233.0 b	6.7 a-c	5.7 ab	0.0 b
Tift 8	272 c	127 cd	5.1 f	21.2 a	50 c	1.07 c	178 e	2 d	late	6.0 bc	6.0 a	0.0 b

1/ Pearl millet hybrids developed by G. W. Burton.

2/ Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

3/ Stand Rating: 0=0 plants; 9=100% stand.

4/ Visual Rating: 1-3=good; 4-6=fair; 7-9=poor.

5/ Lodging Score: 0=0% lodged; 9=100% lodged.

contained the highest percentage of protein, 21.2 percent. Millet hybrid Tift 3 contained the lowest percentage of protein among millets, 15.1 percent. Sorghum hybrids C46+ and C42A+ contained 14.2 and 11.8 percent protein respectively. Yield levels in pearl millet did not appear to affect protein content except in the case of hybrid Tift 8.

Sorghum hybrid C46+ produced significantly more protein per hectare than any of the millets tested (619 kg protein per hectare). However seven millet hybrids and two millet populations did not differ significantly from sorghum hybrid C42A+ in protein per hectare. Millet hybrid Tift 9 had the highest protein yield among millets, 463 kg/ha. Millet hybrid Tift 8 had the lowest protein yield of 50 kg/ha. Protein per hectare generally decreased as yield decreased.

Sorghums contained more protein per 1000 seeds than millets. Sorghum hybrids C42A+ and C46+ contained 3.66 and 3.61 g protein per 1000 seeds respectively. Among millets, protein per 1000 seeds ranged from 1.93 g (population Serere 3A) to 0.90 g (hybrid Tift 11). There was no apparent relationship between protein per 1000 seeds and yield in pearl millet.

Most millets produced significantly higher head numbers per hectare than sorghums. Millet hybrid Tift 7 produced the most heads of any entry, 702,000 per hectare. Tift 8 produced the fewest heads per hectare among millets, 178,000. Sorghum hybrids C42A+ and C46+ produced 162,000 and 109,000 heads per hectare respectively. Higher yielding millets tended to produce higher head numbers per hectare.

Sorghum hybrids C46+ and C42A+ produced yields per head of 47 and 33 g respectively, both significantly higher than any of the millets tested. Millet hybrid Tift 15 and millet population Serere 3A both produced 12 g of grain per head, the highest among millets.

Millet hybrid Tift 8 was the last entry to reach half bloom though the actual date was not recorded. Millet hybrid Tift 9 was the next latest entry, reaching half bloom on Julian day 238.0. Tift 12 was the first entry to reach half bloom (day 221.3). Sorghum hybrids C42A+ and C46+ were similar to several millets in date of half bloom. There was no apparent relationship between half bloom date and yield, though the latest entry, Tift 8, had the lowest yield. This was probably due to low moisture availability during grain fill.

Each entry was rated for stand establishment. Most plants contained skips within the row but only one entry, Tift 9, had an excessively poor stand. Selective harvesting reduced the influence of stand variations on yield.

Entries were also rated for visual appearance. Sorghum hybrids C42A+ and C46+ had good visual ratings while most millets received fair ratings for appearance. Entries with better visual ratings tended to yield better.

Lodging scores were also assigned to each entry. Lodging was generally very slight. Tift 12, one of the higher yielding millets, had the highest degree of lodging. Lodging did not appear to affect yield.

Analysis Across Locations

Manhattan and Hays yield data were tested for equality of variance by the F test procedure described by Snedecor and Cochran (62). An F-value of 2.48 with 24 degrees of freedom for both numerator and denominator was obtained. This was not significant at the 1 percent level, and so it was decided to proceed with an analysis of variance across locations.

The analysis of variance (Table 43) shows that hybrids and site by hybrid interaction were highly significant. Sites and replications within sites were not significant at the 5 percent level.

Table 14 shows yields of each entry at Manhattan and Hays. Sorghum hybrids C42A+ and C46+ were the first and second highest yielders at both locations. Among millets, Tift 2 was the top performer at both locations. Tift 8, a relatively late maturing millet hybrid, yielded well at Manhattan but was the poorest yielder at Hays. Millet hybrid Tift 11 was a poor performer at both locations.

Heterosis Study

1978

In 1978, heterosis was clearly demonstrated in most hybrids (Table 15). None of the hybrids yielded lower than their female parent and only one hybrid (4017) yielded lower than its male parent, however, this difference was not significant. Thirteen

Table 14. Yields at Two Locations, 1979 (Burton Entries)

Entry	Yield	
	Manhattan	Hays
C42A+ Sorghum	4153	4988
C46+ Sorghum	3800	4966
Tift 2	3938	3266
Tift 1	3536	3011
Tift 9	3498	3049
Tift 15	3625	2911
RMP-1	3412	2801
Tift 12	2805	3240
Tift 7	2595	2941
Tift 3	2541	2983
Serere 3A	2697	2676
Tift 8	3426	272
Tift 11	1960	964

Table 15. Heterosis Study, Manhattan, 1978

Entry	Yield (kg/ha)	Percent Yield Increase Over Better Parent	Plant Ht. (cm)	1000 Seed Wt. (g)	Heads Thous./ha	Head Length (cm)	Yield/ Head (g)
4051 x 4057	3070a[1/]	71	136 a-c	6.6 a	249 b-e	20.5 c-g	12.5 a
4050 x 4055	2905 ab	151	121 g-j	5.4 a-f	259 a-e	20.0 d-h	11.2 ab
4050 x 4058	2903 ab	113	139 ab	5.7 a-e	276 a-d	20.8 b-f	10.5 a-d
4049 x 4057	2842 ab	58	145 a	6.5 a	248 b-e	21.4 a-f	11.7 a
4050 x 4057	2774 ab	54	133 b-d	6.1 a-c	267 a-e	19.3 e-i	10.5 a-d
4051 x 4055	2629 a-c	127	135 a-d	6.6 a	229 b-e	17.4 i-k	12.2 a
4050 x 4053	2426 a-d	83	133 b-e	5.7 a-e	218 b-e	19.6 e-i	11.2 a-c
4049 x 4055	2403 a-d	108	131 b-g	5.7 a-e	204 c-e	23.0 ab	11.8 a
4051 x 4058	2387 a-d	74	132 b-f	5.9 a-d	228 b-e	20.3 d-g	10.5 a-d
4049 x 4059	2334 a-d	67	121 f-j	6.6 a	212 c-e	22.7 a-c	11.0 a-c
4051 x 4053	2329 a-d	76	129 b-g	6.3 ab	193 c-e	17.7 h-j	12.2 a
4051 x 4059	2328 a-d	66	124 d-i	6.2 ab	241 b-e	20.3 d-g	9.8 a-e
4050 x 4059	2061 b-e	47	113 i-l	5.5 a-f	235 b-e	22.3 a-d	8.9 a-f
4050 x 4054	1903 c-f	119	145 a	5.6 a-e	232 b-e	20.3 d-g	8.2 b-f
4057 (♂)	1799 d-f	-	116 h-k	5.2 b-f	321 ab	16.5 jk	5.6 f-h
4049 x 4058	1499 e-g	9	132 b-g	4.9 c-f	181 de	23.3 a	7.8 c-f
4059 (♂)	1399 e-h	-	117 h-k	6.1 a-c	212 c-e	19.3 e-i	6.9 e-g
4058 (♂)	1366 e-h	-	107 k-m	4.7 ef	218 b-e	16.1 j-l	6.8 e-g
4049 x 4053	1359 e-h	3	121 e-j	4.9 c-f	194 c-e	20.6 c-g	6.7 e-g
4053 (♂)	1325 e-h	-	113 i-l	4.9 c-f	165 e	19.9 d-h	7.5 d-f
4055 (♂)	1158 g-i	-	102 l-m	3.2 h	299 a-c	14.3 lm	4.0 g-i
4050 (♀)	869 g-i	-	70 n	4.3 fg	296 a-c	15.3 k-m	3.1 hi
4049 x 4054	840 g-i	20	130 b-g	4.9 c-f	204 c-e	21.4 a-f	4.1 g-i
4054 (♂)	700 h-i	-	111 j-m	3.5 gh	271 a-e	19.0 f-i	2.4 hi
4051 x 4054	648 h-i	(-7)	126 c-h	4.9 c-f	210 c-e	21.6 a-e	3.1 hi
4051 (♀)	531 i	-	73 n	4.7 d-f	358 a	13.8 m	1.7 i
4049 (♀)	470 i	-	100 m	4.4 e-g	154 e	18.1 g-j	3.4 g-i

[1/] Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

hybrids had yields significantly higher than their better parent. Percent yield increase over better parent ranged from 151 percent (4050 x 4055) to minus 7 percent (4051 x 4054). Average yield increase over better parent for all hybrids was 69 percent. Many other researchers also have reported heterosis for yield in pearl millet (1, 10, 13, 47, 52, 61).

In Table 16, average results for all parents and hybrids are shown. Increases in plant height, seed weight, head length, and yield per head were observed in addition to an overall increase in yield. Head numbers per hectare showed a slight decrease. Heterosis for plant height also has been observed by other researchers (10, 13, 45, 61), as has heterosis for head length (10, 13, 51, 65). However, Lal and Singh (45) did not observe heterosis for head length nor seed weight. Singh and Lal (59) reported heterosis for number of spike bearing branches.

1979

In 1979, heterosis was again clearly exhibited in each of the hybrids (Table 17). All hybrids outyielded both their male and female parents, and sixteen hybrids had yields higher than the combined yields of their parents. Ten hybrids had yields significantly higher than their better parent. Percent yield increase over better parent ranged from 309 percent (4051 x 4056) to 43 percent (4049 x 4057). Average yield increase over better parent was 165 percent.

In Table 18, average results for all parents and hybrids

Table 16. Results for all parents and hybrids, 1978.

	Yield (kg/ha)	Plant Ht. (cm)	1000 Seed Wt. (g)	Heads Thous./ha	Head Length (cm)	Yield Head (g)
Female parents	623	81	4.5	269	15.7	3.07
Male parents	1292	111	4.6	248	17.5	5.53
Hybrids	2202	130	5.8	227	20.7	9.66

Table 17. Heterosis Study, Manhattan, 1979

Entry	Yield (kg/ha)	% Yield Increase Over Better Parent	Plant Ht. (cm)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous./ha	Plants Thous./ha	Heads/ Plant	Yield Head (g)	Yield Plant (g)
4050 x 4054	5708 a[1/]	154	177 a	7.9 a-c	11.5 c-e	581 a	.92 ab	348 a	132 a-c	3.8 b	17 b-d	60 a-c
4051 x 4055	5491 ab	188	167 a-c	8.3 ab	11.0 c-f	529 ab	.91 ab	273 ab	78 b-g	3.6 b	20 ab	73 a
4049 x 4055	4511 a-c	137	158 a-d	6.9 a-f	10.4 e-g	412 a-d	.72 ef	203 bc	85 b-f	2.6 b	22 ab	55 a-c
4050 x 4053	4502 a-c	85	165 a-d	7.9 a-c	11.6 c-e	465 a-c	.92 a	259 ab	108 a-e	2.4 b	17 bc	41 a-d
4050 x 4055	4415 a-d	132	156 a-d	6.5 b-f	11.3 c-f	431 a-d	.73 d-f	220 a-c	72 c-f	3.4 b	22 ab	65 ab
4051 x 4054	4374 a-d	95	159 a-d	7.9 a-c	10.5 e-g	403 a-e	.84 a-e	167 bc	80 b-f	2.0 b	26 a	53 a-d
4049 x 4059	4256 a-d	172	152 b-d	7.7 a-c	10.0 fg	371 a-f	.77 b-f	245 a-c	88 b-f	3.2 b	17 bc	54 a-d
4050 x 4059	4223 a-d	170	147 b-e	7.7 a-c	10.9 c-f	402 a-e	.83 a-e	230 a-c	112 a-e	2.2 b	19 ab	41 a-d
4051 x 4059	4151 a-d	165	142 d-f	8.6 a	10.2 fg	373 a-f	.88 a-d	270 ab	88 b-f	3.1 b	15 b-e	46 a-d
4051 x 4053	4024 a-e	66	165 a-d	8.3 ab	10.9 c-f	384 a-f	.90 ab	198 bc	122 a-d	1.8 b	20 ab	36 a-d
4051 x 4057	3626 a-f	309	157 a-d	8.4 ab	11.1 c-f	351 b-f	.93 a	231 a-c	141 ab	1.7 b	16 b-e	27 b-d
4049 x 4058	3620 a-f	186	151 b-d	6.8 a-f	10.8 d-f	342 b-f	.73 c-f	201 bc	131 a-c	1.8 b	18 bc	30 a-d
4051 x 4058	3563 a-f	290	157 a-d	7.8 a-c	11.2 c-f	351 b-f	.88 a-d	226 a-c	86 b-f	2.7 b	15 b-e	43 a-d
4049 x 4053	3482 a-f	43	142 c-f	7.7 a-c	12.0 b-d	360 a-f	.92 ab	185 bc	69 c-f	2.7 b	19 ab	51 a-d
4050 x 4058	3470 b-f	280	153 b-d	7.3 a-e	11.1 c-f	337 b-f	.81 a-e	241 bc	129 a-c	1.9 b	15 b-e	27 b-d
4050 x 4057	3434 b-f	287	159 a-d	7.2 a-e	11.3 c-f	338 b-f	.81 a-e	233 a-c	88 b-f	2.7 b	15 b-e	40 a-d
4049 x 4057	3414 b-f	170	167 ab	7.5 a-d	9.4 g	281 c-g	.71 ef	182 bc	105 a-e	1.7 b	19 ab	33 a-d
4049 x 4054	3246 b-f	44	144 b-f	7.5 a-d	10.9 c-f	309 b-g	.82 a-e	166 bc	73 c-f	2.4 b	19 ab	47 a-d
4053 (♂)	2430 c-g	-	124 f-h	6.5 b-f	13.2 b	276 c-g	.85 a-e	187 bc	57 d-f	4.3 b	15 b-e	58 a-d
4054 (♂)	2248 d-g	-	123 f-h	6.1 c-g	12.9 b	255 c-g	.79 a-f	243 a-c	75 c-f	4.5 b	9 d-f	42 a-d
4055 (♂)	1907 e-g	-	115 gh	4.3 g	12.9 b	212 d-g	.56 g	191 bc	92 b-f	3.7 b	10 c-f	32 a-d
4059 (♂)	1565 e-g	-	128 d-g	7.0 a-f	11.2 c-f	152 e-g	.78 a-f	185 bc	89 b-f	2.2 b	8 ef	19 b-d
4049 (♀)	1266 fg	-	106 gh	5.9 c-g	13.2 b	149 fg	.78 a-f	202 bc	161 a	1.2 b	6 f	7 d
4058 (♂)	913 g	-	113 gh	5.6 d-g	14.7 a	115 g	.81 a-e	195 bc	57 d-f	4.3 b	5 f	18 cd
4057 (♂)	887 g	-	114 gh	6.7 a-f	13.0 b	94 g	.88 a-d	143 bc	79 b-f	1.8 b	6 f	10 d
4051 (♀)	861 g	-	103 h	5.0 fg	12.0 b-d	83 g	.90 a-c	124 c	47 ef	2.6 b	7 f	19 cd
4050 (♀)	706 g	-	75 i	5.2 e-g	12.3 bc	75 g	.64 fg	209 a-c	36 f	8.6 a	3 f	33 a-d

[1/] Duncans Multiple Range Test. Values with the same letter are not significantly different (alpha = .05).

Table 18. Results for all Parents and Hybrids, 1979.

	Yield (kg/ha)	Plant Ht. (cm)	1000 Seed Wt. (g)	Percent Protein	Protein/ha (kg/ha)	Protein/1000 Seeds (g)	Heads Thous./ha
Female Parents	944	95	5.4	12.50	102	.77	178
Male Parents	1658	120	6.0	12.98	184	.79	191
Hybrids	4084	157	7.7	10.89	390	.84	227

	Plants Thous./ha	Heads/ Plant	Yield/ Head (g)	Yield/ Plant (g)
Female Parents	81	4.13	5	20
Male Parents	75	3.47	9	30
Hybrids	99	2.54	18	46

are shown. Increases in plant height, seed weight, protein per hectare, protein per 1000 seeds, heads per hectare, yield per head, yield per plant, and plant population (indicating better seedling emergence in hybrids) were observed in addition to substantial yield increases. Protein percentage decreased in hybrids, as did heads per plant. Phul et al (52) also found that F_1 hybrids contained less protein than their parents.

A test of the equality of variance was calculated for yield data in 1978 and 1979. A F-value of 5.58 was obtained with 49 degrees of freedom for the denominator. This was significant at the 1 percent level, and so an analysis of variance across years would not be legitimate.

CONCLUSIONS

Pearl millet hybrids and populations yielded as well as grain sorghum hybrids at several locations, particularly in areas of low rainfall. Pearl millet hybrids usually outyielded pearl millet populations. When analyzed for yield across five locations in 1979, millets developed by W. D. Stegmeier showed significant genotype by environment interaction. The same was true of millets developed by G. W. Burton when analyzed for yield across two locations in 1979.

In 1978 the highest yielding millets exhibited tall stature and lacked uniformity of height. However in 1979, both short and tall millets demonstrated good yielding ability. Uniformity of millet hybrids was also greatly improved. Short stature in pearl millet appeared to reduce lodging.

Sorghum seed weights were significantly higher than those of pearl millet. Seed weights generally were higher in millets tested in 1979 than in those tested in 1978. This apparent increase may have been the result of better growing conditions in 1979 than in 1978, but some genetic gain may have been made in the selection for larger seeded types. Low yielding millets tended to have low seed weights.

The majority of millets tested were significantly higher in percent protein than sorghum hybrids. Overall protein levels were higher in 1978 than in 1979. Yield levels generally had no effect on protein content in pearl millet.

Sorghums tended to produce more protein per hectare than millets, though in some studies, a number of millets did not differ from sorghums in protein yield. Protein per hectare decreased as yields decreased.

Sorghums usually contained more protein per 1000 seeds than millets. Low yielding millets, and millets with low seed weights, generally had low protein contents per 1000 seeds.

Millets tended to produce more heads per hectare than sorghums. Quite often there was no relationship between head numbers and yield in pearl millet, though in a few instances higher yielding millets produced higher head numbers per hectare.

Differences in plant population generally did not affect yield in pearl millet. Low plant populations tended to be offset by increased tillering. However high head numbers per plant did not necessarily result in high yields.

Sorghums usually had significantly higher yields per head than millets. Higher yielding millets tended to produce higher yields per head.

Yields per plant were generally higher in sorghums than in millets. Higher yielding millets developed by W. D. Stegmeier tended to produce higher yields per plant, however this was not true of hybrids developed by G. W. Burton.

Head length, measured only for millets grown at Manhattan in 1978, did not appear to affect yield.

Stand establishment was a problem at most locations. Selective harvesting of the best portion of each plot minimized the effect of poor stand establishment on yield.

Heterosis was conclusively demonstrated in pearl millet hybrids tested in 1978 and 1979. Significant yield increases over better parent were noted for many hybrids. Increases in plant height, seed weight, heads per hectare, head length, protein per hectare, protein per 1000 seeds, yield per head, yield per plant, and plant population were also observed. However, protein percentage in hybrids decreased as did heads per plant.

ACKNOWLEDGMENTS

The author wishes to convey his utmost gratitude to his major professor, Dr. Richard L. Vanderlip, for his guidance and continued support throughout the program of study. His contributions to the design of the experiments, the analysis of data, and the preparation of the manuscript were invaluable.

Appreciation is also extended to the advisory committee, Drs. F. L. Barnett and G. M. Paulsen, for their contributions to the completion of this research and their suggestions for the improvement of the text.

The author is also obliged to W. D. Stegmeier, Merle Witt, James Ball, Marvin Lundquist, Pat Gallagher, and Roy Gwin for tending the research plots at remote locations. In addition, the provision of seed for these studies by W. D. Stegmeier, G. W. Burton, and A. J. Casady was much appreciated.

A special thanks is offered to Dr. H. A. Praeger, Jr., for his aid in the design of the studies, his encouragement, and his valuable advice.

The author is further indebted to his colleagues John Gardner, Jim Schaffer, Joe Bunck, Julius Okonkwo, Mithlesh Kumar, Hartmut Stützel, Gallus Mwageni, and Sam Jaiyesimi for their assistance in the execution of this research.

He is also grateful to students Barb Schmidt, Alan Hobson, Doug Sharp, Greg Walker, Ann Bunck, John Stone, Jeff Randall, Warren Schepmann, Lynn Parsons, Andrina Boys, and Tom Bettenhausen for their help with the field work and data collection.

Thanks are also extended to the Department of Agronomy, Kansas State University for making this research possible.

Personal thanks are given to Donna Sorden for her moral support and understanding.

Lastly the author wishes to express his most sincere gratitude to his mother and father for their perpetual encouragement, support, and generosity.

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APPENDIX

Table 19. Meteorological Data, Manhattan, 1978

Month	Avg. Air Temp., °C High	Avg. Air Temp., °C Low	Rainfall (cm)	Avg. Daily Solar Radiation (Langleys)
May	23.6	11.6	13.00	484.1
June	30.6	17.9	12.17	624.9
July	33.8	20.8	8.00	582.0
Aug.	33.4	19.7	3.12	562.0
Sept.	30.7	16.4	11.58	431.6
Oct.	21.7	6.1	0.61	350.1

Table 20. Meteorological Data, Hays, 1978

Month	Avg. Air Temp., °C High	Avg. Air Temp., °C Low	Rainfall (cm)
May	22.1	10.2	9.91
June	30.7	16.3	5.18
July	34.9	19.1	7.21
Aug.	34.1	16.4	2.95
Sept.	30.4	13.6	2.16
Oct.	23.2	3.2	0.18

Table 21. Meteorological Data, St. John, 1978

Month	Avg. Air Temp., °C High	Avg. Air Temp., °C Low	Rainfall (cm)	Avg. Daily Solar Radiation (Langleys)
15 May to 31 May	25.2	16.3	5.44	539.5
June	30.0	17.7	10.08	629.9
July	36.0	20.6	2.11	617.8
Aug.	33.3	18.2	1.02	544.6
1 Sept. to 10 Sept.	35.4	18.1	0.00	520.3

Table 22. Meteorological Data, Manhattan, 1979

Month	Avg. Air Temp., °C High	Avg. Air Temp., °C Low	Rainfall (cm)	Avg. Daily Solar Radiation (Langleys)
May	24.2	10.9	6.96	532.0
June	29.7	16.6	7.85	553.9
July	30.5	20.4	14.10	463.0
Aug.	31.4	19.6	7.42	503.3
Sept.	29.2	13.8	3.20	466.0
Oct.	22.9	8.1	15.11	315.9

Table 23. Meteorological Data, Garden City, 1979

Month	Avg. Air Temp., °C High	Low	Rainfall (cm)
May	22.3	8.1	6.48
June	30.1	14.1	3.84
July	32.6	17.8	11.30
Aug.	30.1	14.9	12.67
Sept.	29.7	11.8	0.38
Oct.	25.5	3.9	4.47

Table 24. Meteorological Data, Hays, 1979

Month	Avg. Air Temp., °C High	Low	Rainfall (cm)
May	22.8	8.6	2.59
June	30.6	14.7	3.38
July	32.9	19.1	9.78
Aug.	31.1	16.1	5.36
Sept.	30.1	12.1	1.07
Oct.	24.4	5.3	7.70

Table 25. Meteorological Data, Dodge City (air temperature and solar radiation) and Minneola (rainfall) 1979.

Month	Avg. Air Temp., °C High	Avg. Air Temp., °C Low	Rainfall (cm)	Avg. Daily Solar Radiation (Langleys)
May	22.4	9.2	12.50	527.3
June	30.6	15.7	2.39	636.7
July	32.4	18.6	9.63	549.4
Aug.	30.9	15.8	2.77	536.0
Sept.	29.0	14.0	0.38	486.4
Oct.	22.9	6.4	9.88	373.1

Table 26. Meteorological Data, St. John, 1979.

Month	Avg. Air Temp., °C High	Avg. Air Temp., °C Low	Rainfall (cm)	Avg. Daily Solar Radiation (Langleys)
May	23.1	9.8	6.65	505.0
June	30.3	16.3	5.31	579.0
July	33.0	19.9	10.39	524.0
Aug.	31.1	17.6	5.82	534.0
Sept.	30.8	13.4	0.18	492.0
Oct.	24.8	6.6	10.01	359.0

Table 27. Meteorological Data, Tribune, 1979.

Month	Avg. Air Temp., °C High	Avg. Air Temp., °C Low	Rainfall (cm)
May	23.1	5.3	4.93
June	30.2	11.1	3.56
July	33.4	16.1	8.89
Aug.	32.1	13.3	2.95
Sept.	30.1	10.2	1.19
Oct.	23.7	3.5	3.00

Table 28. Analysis of Variance, Hybrid Yield Trial, Manhattan, 1978.

Source of Variation	Degrees of Freedom	Mean Squares			
		Yield	1000 Seed Wt.	Heads/ha	Plant Ht.
Replications	2	476694	.81	328737243	97
Hybrids	21	3297324**	37.92**	38351778885**	2709**
Error	38	490121	2.08	4436755739	73

Source of Variation	Degrees of Freedom	Mean Squares	
		Head Length	Yield/head
Replications	2	1.10	.00002000
Hybrids	21	119.26**	.00044417**
Error	38	1.37	.00000858

** Significant at 1% level.

Table 29. Analysis of Variance, Hybrid Yield Trial, Hays, 1978.

Source of Variation	Degrees of Freedom	Mean Squares			
		Yield	1000 Seed Wt.	Percent Protein	Protein/ha
Replications	3	972418	5.28*	.00007483	18176
Hybrids	15	2243669**	48.13**	.00055375**	31233**
Error	45	368346	1.72	.00004039	7686

Source of Variation	Degrees of Freedom	Mean Squares		
		Protein/1000 Seeds	Heads/ha	Yield/Head
Replications	3	.13021112	1402550696	.00001295
Hybrids	15	.86124505**	5589068006**	.00018914
Error	45	.04694949	1586846548	.00000690

** Significant at 1% level.

* Significant at 5% level.

Table 30. Analysis of Variance, F_1 Hybrid Diallel Study, Hays, 1979.

Source of Variation	Degrees of Freedom	Mean Squares			
		Yield	1000 Seed Wt.	Percent Protein	Protein/ha
Replications	2	3577583**	5.03**	.00048424**	75153**
Hybrids	48	736828**	24.69**	.00029040**	15607**
Error	96	281261	.79	.00002862	6657

Source of Variation	Degrees of Freedom	Mean Squares		
		Protein/1000 Seeds	Heads/ha	Yield/Head
Replications	2	.07138574	2770649695	.00007381**
Hybrids	48	.47732748	4735111080**	.00003135**
Error	96	.02061017	1417314431	.00000608

** Significant at 1% level.
* Significant at 5% level.

Table 31. Analysis of Variance, Hybrid Trial, Manhattan, 1979 (Stegmeier Entries).

Source of Variation	Degrees of Freedom	Mean Squares			
		Yield	1000 Seed Wt.	% Protein	Protein/ha
Replications	1	1,500,102	0.40	.00020211*	5,768
Hybrids	17	4,294,919**	1304.42**	.00011489**	28,860**
Error	17	225,700	0.53	.00002950	2,947

Source of Variation	Degrees of Freedom	Mean Squares			
		Protein/1000 Seeds	Heads/ha	Plants/ha	Heads/Plant
Replications	1	.00379702	358,881,451	1,339,413,604	1.4406
Hybrids	17	.64324060**	4,779,975,811**	1,190,569,900**	1.3727**
Error	17	.00713347	1,089,286,472	578,227,796	.3932

Source of Variation	Freedom	Mean Squares			
		Yield/Head	Yield/Plant	Date of 50% Heading	Plant Ht.
Replications	1	.00002105	.00144064	11.11	94
Hybrids	17	.00041203**	.00191641**	62.19**	4602 (14)1/
Error	17	.00000843	.00019042	4.11	41 (14)

** Significant at 1% level.
* Significant at 5% level.

1/ Degrees of freedom for these mean squares only.

Table 32. Analysis of Variance, Hybrid Yield Trial, Garden City, 1979 (Stegmeier Entries).

Source of Variation	Mean Squares			
	Yield	1000 Seed Wt.	Percent Protein	Protein/ha
Replications	257892 (2)[1/]	.19 (2)	.00007761 (2)	555 (2)
Hybrids	2272357** (17)	78.32** (17)	.00034159** (17)	8260 (17)
Error	374288 (32)	.42 (30)	.00009625 (30)	4892 (30)

Source of Variation	Protein/1000 Seeds	Heads/ha	Half Bloom Date
Replications	.00461505 (2)	340763907514 (2)	.67 (2)
Hybrids	.23505040** (17)	3588535616** (17)	66.75 (17)
Error	.01740575 (30)	469914352 (31)	3.54 (34)

** Significant at 1% level.

1/ Degrees of Freedom shown in Parentheses

Table 33. Analysis of Variance, Hybrid Yield Trial, Hays, 1979 (Stegmeier Entries) Complete[1/]

Source of Variation	Degrees of Freedom	Mean Squares: Half Bloom Date	Plant Ht.	1000 Seed Wt.	Stand Rating
Replications	3	14.64*	1153**	21.57**	6.98**
Hybrids	21	65.05**	4417**	145.34**	6.52**
Error	63	5.01	106	2.46	1.75

Source of Variation	Degrees of Freedom	Mean Squares: Visual Rating	Lodging Score	Percent Protein	Protein/1000 Seeds
Replications	3	14.83**	2.3144**	.00414759**	.04005988
Hybrids	21	2.23**	.6131*	.00084580**	1.63504860**
Error	63	.42	.3303	.00004881	.04834340

Degrees of Freedom	Mean Squares: Heads/ha	Yield	Protein/ha	Yield/Head
3	19436099991**	10768628**	115397**	.00007094**
21	14745850781**	2575085**	22212**	.00050944**
61	2466451937	360322	5696	.00001008

** Significant @ 1% level.
* Significant @ 5% level.

1/ Includes Tift 1, HMP 1700('79), HMP 02, and Senegal Bulk.

Table 34. Analysis of Variance, Hybrid Yield Trial, Hays, 1979 (Stegmeier Entries) Balanced[1/]

Source of Variation	Degrees of Freedom	Mean Squares			
		Half Bloom Date	Plant Ht.	1000 Seed Wt.	Stand Rating
Replications	3	25.05**	628	19.80**	3.17
Hybrids	17	62.43**	5038**	169.63**	2.97
Error	51	4.31	100	2.91	1.67

Source of Variation	Degrees of Freedom	Mean Squares			
		Visual Rating	Lodging Score	Percent Protein	Protein/1000 Seeds
Replications	3	13.27**	1.2037**	.00316601	.0742
Hybrids	17	2.54**	.3235	.00100747	1.8853**
Error	51	.45	.2037	.00003840	.0542

Degrees of Freedom	Mean Squares			
	Heads/ha	Yield	Protein/ha	Yield/Head
3	17436859306**	10276441**	120751**	.00006514**
17	14321607382**	2492512**	17262**	.00060450**
49	2157744264	339646	5171	.00001167

** Significant at 1% level.
* Significant at 5% level.

1/ Does not include Tift 1, HMP 1700 ('79), HMP 02, and Senegal Bulk.

Table 35. Analysis of Variance, Hybrid Yield Trial, Minneola, 1979 (Stegmeier Entries).

Source of Variation	Degrees of Freedom	Mean Squares			
		Yield	Percent Protein	Protein/ha	Protein/1000 Seeds
Replications	2	101060	.00123132**	12488*	.18689766**
Hybrid	17	128746**	.00028228*	8762*	.38984845**
Error	33	222785	.00013424	3740	.03294948

Source of Variation	Degrees of Freedom	Mean Squares		
		1000 Seed Wt.	Yield/Head	Heads/ha
Replications	2	.2459	.00000446	1231117313
Hybrid	17	58.1679**	.00117270**	3566130069**
Error	33	2.2798	.00000866	717438480 (34)1/

** Significant @ 1% level.
* Significant @ 5% level.

1/ Degrees of Freedom for this mean square only.

Table 36. Analysis of Variance, Hybrid Yield Trial, St. John, 1979 (Stegmeier Entries).

Source of Variation	Degrees of Freedom	Mean Squares			
		Heads/ha	Yield	1000 Seed Wt.	Percent Protein
Replications	2	12229674864**	481275	.1089	.00034159**
Hybrids	17	9740030260**	606626**	122.9286**	.00034396**
Error	34	2195526344	167642	.2532	.00002983

Source of Variation	Degrees of Freedom	Mean Squares		
		Protein/ha	Protein/1000 Seeds	Yield/Head
Replications	2	7187**	.04064189**	.00000400
Hybrids	17	2481*	.34414360**	.00005346**
Error	34	1253	.00689163	.00000382

** Significant @ 1% level.
* Significant @ 5% level.

Table 37. Analysis of Variance, Hybrid Trial, Tribune, 1979 (Stegmeier Entries).

Source of Variation	Degrees of Freedom	Mean Squares Heads/ha	Yield	1000 Seed Wt.	Percent Protein
Replications	2	36325560026**	6276587**	15.72**	.00220503**
Hybrids	17	19460757101**	3398677**	75.04**	.00065626**
Error	34	3373727030	848863	2.11	.00006612

Source of Variation	Degrees of Freedom	Mean Squares Protein/ha	Protein/1000 Seeds	Yield/Head
Replications	2	30256	.1204**	.00010970*
Hybrids	17	24265*	.4947**	.00024961**
Error	34	9981	.0175	.00002525

Source of Variation	Degrees of Freedom	Mean Squares Seed Set Rating	Half Bloom Date
Replications	2	.22	6.02
Hybrids	17	1.19**	26.69** (16) 1/
Error	34	.18	1.35 (30)

** Significant at 1% level.
* Significant at 5% level.

1/ Degrees of Freedom for these mean squares only.

Table 38. Analysis of Variance, Hybrid Yield Trial, Manhattan, 1979 (Burton Entries)

Source of Variation	Degrees of Freedom	Mean Squares			
		Plants/ha	Date of 50% Heading	Heads/ha	Yield
Replications	2	342711121	10.23	2634384974	67161
Hybrids	12	3698920039**	436.69**	49558604266**	1256026
Error	24	641906117	5.59	2681108803	633878

Source of Variation	Degrees of Freedom	Mean Squares			
		Yield/Plant	Percent Protein	1000 Seed Wt.	Protein/ha
Replications	2	.00003934	.00031607**	.14	3541
Hybrids	12	.00271202**	.00023106**	88.45**	8733
Error	24	.00028347	.00002353	.25	6471

Source of Variation	Degrees of Freedom	Mean Squares			
		Protein/1000 Seeds	Heads/Plant	Yield/Head	Plant Ht.
Replications	2	.01311252	.30	.00000518	25
Hybrids	12	.73667483**	22.87**	.00032057**	4651 (10)1/
Error	24	.00483515	.73	.00000694	110 (20)

** Significant @ 1% level.

1/ Degrees of Freedom for these mean squares only.

Table 39. Analysis of Variance, Hybrid Yield Trial, Hays, 1979 (Burton Entries).

Source of Variation	Degrees of Freedom	Mean Squares			
		Plant Ht.	Heads/ha	Yield	Stand Rating
Replications	2	533	7140920920921	40081	4.00
Hybrids	12	2908**	76857301569**	4905451**	4.31*
Error	24	84	6321739558	255974	1.50

Source of Variation	Degrees of Freedom	Mean Squares			
		Visual Rating	Lodging Score	Percent Protein	Protein/ha
Replications	2	1.87*	.0256	.00001508	2171
Hybrids	12	4.47**	1.4231*	.00139755**	65155**
Error	24	.34	.2756	.00021408	7237

Source of Variation	Degrees of Freedom	Mean Squares			
		Protein/1000 Seeds	1000 Seed Wt.	Yield/Head	Half Bloom Date
Replications	2	.0376	1.05	.00003042	26.39
Hybrids	12	2.4660**	183.87**	.00049039**	74.12 (11)1/
Error	24	.1156	1.56	.00001972	1.84 (21)

** Significant @ 1% level.
* Significant @ 5% level.

1/ Degrees of Freedom for these mean squares only.

Table 40. Analysis of Variance, Heterosis Study, 1978.

Source of Variation	Degrees of Freedom	Mean Squares			
		Plant Ht.	Yield	Heads/ha	Head Length
Replications	3	140.59	659551	16610995206**	5.16
Hybrids	26	1339.42**	2658773**	8823635794**	25.57**
Error	76	47.32	228897	4013506680	2.03

Source of Variation	Degrees of Freedom	Mean Squares	
		Yield/Head	1000 Seed Wt.
Replications	3	.00001575*	.9065
Hybrids	26	.00004768**	3.2761**
Error	76	.00000416	.5329 (75) 1/

** Significant @ 1% level.
* Significant @ 5% level.

1/ Degrees of Freedom for this mean square only.

Table 41. Analysis of Variance, Heterosis Study, 1979.

Source of Variation	Mean Squares			
	Plants/ha	Plant Ht.	Heads/ha	Yield
Replications	465059912 (2)[1/]	113 (2)	9848070424 (2)	1772465 (2)
Hybrids	2662807662** (26)	1819** (26)	6011059437 (26)	5564882** (26)
Error	1057567449 (52)	141 (52)	4353692068 (49)	1277234 (49)

Source of Variation	Mean Squares			
	1000 Seed Wt.	Percent Protein	Protein/ha	Protein/1000 Seeds
Replications	.8961 (2)	.00002507 (2)	17030 (2)	.00542579 (2)
Hybrids	3.4704** (26)	.00040059** (26)	45947** (26)	.02354966** (26)
Error	1.0261 (49)	.00004308 (48)	12989 (48)	.00597641 (48)

Source of Variation	Mean Squares		
	Heads/Plant	Yield/Head	Yield/Plant
Replications	2.3153 (2)	.00000616 (2)	.00004496 (2)
Hybrids	4.9463 (26)	.00009629** (26)	.00077160 (26)
Error	4.1878 (49)	.00001553 (49)	.00047693 (49)

** Significant @ 1% level.

1/ Degrees of Freedom indicated in parentheses.

Table 42. Combined Analysis of Variance Over Five Locations (Manhattan, Garden City, Hays, Minneola and St. John) (Stegmeier Entries) 1979.

Source of Variation	Degrees of Freedom	Mean Squares Yield
Site	4	22,179,578**
Rep (Site)	10	3,400,988**
Hybrid	17	7,713,046**
Site x Hybrid	68	900,485**
Error	165	275,809

** Significant at 1% level.

Table 43. Combined Analysis of Variance over Two Locations (Manhattan and Hays) (Burton Entries) 1979.

Source of Variation	Degrees of Freedom	Mean Squares Yield
Site	1	1,773,312
Rep (Site)	4	53,621
Hybrid	12	4,395,277**
Site x Hybrid	12	1,766,199**
Error	48	444,926

** Significant at 1% level.

Table 44. Cross identities of pearl millet hybrids furnished by G. W. Burton.

Entry	Cross Identification
Tift 1	T 23 DAE x 769
Tift 2	T 23 DAE x 781
Tift 3	T 23 DAE x 756
Tift 4	T 23 DAE x 756 D
Tift 5	T 23 DAE x 780 D
Tift 6	T 23 DAE x 799 S
Tift 7	T 23 DAES x 799 S
Tift 8	T 23 DA x 18 DB
Tift 9	T 23 DAES x 764 S
Tift 11	T 23 DAE x 28 DE
Tift 12	T 23 DAE x 294
Tift 15	T 23 DAE x 786

Table 45. Pedigrees of pearl millet entries furnished by W. D. Stegmeier for the hybrid yield trial at Hays, 1978.

Entry	Pedigree
95	PI 185642 D_2A_1/2/Tift 239 D_2A_2/4*Serere 3A
399	PI 185642 D_2A_1/3/PI 286839/T 239 D_2B_1/2*Serere 17
139	PI 185642 D_2A_1/3/PI 1856452/T 23 D_2B_1/2/ PI 295126/T 23 DB_1
140	PI 185642 D_2A_1/4/PI 185642/2/T 239 D_2A_2/2* Serere 3A/3/PI 295156/T 23 DB_1
143	PI 185642 D_2A_1/4/PI 185642/2/T 239 D_2A_2/2* Serere 3A/3/PI 295156/T 23 DB_1
164	PI 185642 D_2A_1/3/PI 300088/T 239 D_2B_2/2/ PI 185642
174	PI 185642 D_2A_1/3/PI 287001/PI 185642/2/ PI 287001/T 239 D_2B_2
195	PI 186542 D_2A_1/3/PI 287001/PI 185642/2/ PI 287001/T 239 D_2B_2
196	PI 185642 D_2A_1/3/PI 287001/PI 185642/2/ PI 287001/T 239 D_2B_2
182	PI 185642 D_2A_1/3/PI 286900/2/T 239 D_2/2* Serere 17
307	PI 185642 D A /3/PI 185642/2/PI 295127/T 239 DB_1
309	PI 185642 D_2A_1/3/PI 185642/2/PI 295127/T 23 DB_1
Senegal population[1/]	
RMP-1 (S) C_1[2/]	

[1/] Senegal population obtained from Senegal Bambey Experiment Station. The population is derived from crosses between African lines and varieties and Tift 23 D_2B_1.

[2/] See Crop Science 16:745, 1976 for parentage of RMP-1 (S) C_1

Table 46. Pedigrees of pearl millet hybrids furnished by W. D. Stegmeier for the F_1 hybrid diallel study at Hays, 1978.

Entry	Pedigree
1001	$71\text{-}1^2$ DA_1 x $MS3A^4$
1002	"
1003	"
1004	"
1005	"
1006	"
1007	"
1008	$71\text{-}1^2$ DA_1 x (3A x 71-2)($MS3A^2$)
1009	"
1010	"
1011	"
1012	$71\text{-}1^2$ DA_1 x (71-2 DB_1)($MS3A^2$)
1013	"
1014	"
1015	"
1016	$71\text{-}1^2$ DA_1 x (72-96 DB_1)(71-1 ADB_4)
1017	"
1018	"
1019	"
1020	$71\text{-}1^2$ DA_1 x (71-ADB_1)(72-96 DB_1)
1021	"
1022	"
1023	"
1024	$71\text{-}1^2$ DA_1 x (72-107)($MS3a^3$)
1025	"
1026	"
1027	"
1028	"
1029	"
1030	"
1031	"
1032	$71\text{-}1^2$ DA_1 x Senegal S_2
1033	"
1034	"
1035	"
1036	"

Table 46. (continued)

Entry	Pedigree
1037	$71\text{-}1^2$ DA_1 x 71-104 DB_2E
1038	"
1039	"
1040	"
1041	"
1042	"
1043	$71\text{-}1^2$ DA_1 x 71-53 DB_1E
1044	"
1045	"
1046	"

Table 47. Pedigrees of pearl millet entries furnished by W. D. Stegmeier for hybrid yield trials at six locations, 1979.

Entry	Pedigree
<u>1978 Series Hybrids</u>	
2279 x 7101	PI 185642 DA_1/3/Tift 239 DB_2/3*Serere 3A/2/PI 185642
2224 x 7101	"
2118 x 7101	"
2090 x 7101	"
2279 x 7024	PI 185642 DA_1/2/Tift 239 DB_2/4*Serere 3A
2224 x 7024	"
2118 x 7024	"
2090 x 7024	"
<u>1977 Series Hybrids</u>	
1166 x 1700	PI 185642/3/PI 263540/Tift 23 DB_1/2/Tift 239 DB_2/2*Serere 3A
1212 x 1700	"
<u>Bulks and Populations</u>	
HMP 1700 C_1S_0	PI 263540/Tift 23 DB_1/2/Tift 239 DB_2/2*Serere 3A
HMP 550 C_2S_0	Tift 23 DB_1/2*PI 185642
HMP 557A C_2S_0	Bulk population of Tift 239 DB_2/3*Serere 3A and Tift 239 DB_2/4*Serere 3A
HMP 559	Bulk population of 22 open pollinated plant introductions
HMP 561 C_1S_0	Tift 23 DB_1/PI 307697/ / Tift 239 DB_2/2*Serere 3A

Table 48. Pedigrees of pearl millet materials furnished by A. J. Casady for heterosis studies in 1978 and 1979, and for the hybrid yield trial at Manhattan, 1978[1/]

Entry	Pedigree or Parent Identification
Female Inbreds	Pedigree
4049	Tift 239 (B-line) x Serere 3A
4050	"
4051	"
Male Inbreds	
4053	Tift 239 (B-line) x Serere 3A
4054	"
4055	Tift 239 (B-line) x Serere 17
4057	"
4058	"
4059	"
F_1 Hybrids	Parents
4007	4049 x 4053
4009*	4050 x 4053
4011	4051 x 4053
4013*	4049 x 4054
4015*	4050 x 4054
4017	4051 x 4054
4019*	4049 x 4055
4021*	4050 x 4055
4023*	4051 x 4055
4031*	4049 x 4057

[1/]Hybrids marked by asterisks were planted in the hybrid yield trial at Manhattan, 1978.

Table 48. (continued)

Entry	Pedigree or Parent Identification
$\underline{F_1}$ Hybrids	Parents
4033*	4050 x 4057
4035*	4051 x 4057
4037	4049 x 4058
4039*	4050 x 4058
4041*	4051 x 4058
4043*	4049 x 4059
4045*	4050 x 4059
4047	4051 x 4059

YIELD COMPARISONS OF PEARL MILLET (*PENNISETUM AMERICANUM* (L.) LEEKE) AND GRAIN SORGHUM (*SORGHUM BICOLOR* (L.) MOENCH)

by

JOHN CRAIG PALMER

B. S., University of California, Davis, 1978

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

Pearl millet (*Pennisetum americanum* (L.) Leeke) has traditionally been characterized by low yields, excessive height, small seed size, and other undesirable agronomic characteristics. To aid plant breeders working with pearl millet, yield trials involving promising pearl millet hybrids were conducted in 1978 and 1979. In addition, heterosis was studied among pearl millet inbreds and their F_1 hybrid offspring.

In 1978, three locations were selected in Kansas for the planting of hybrid yield trials, (1) Ashland Experiment Field, Manhattan; (2) Fort Hays Branch Experiment Station, Hays; and (3) Sandyland Experiment Field, St. John.

At Manhattan, eight pearl millet hybrids developed at the Coastal Plains Station, Tifton, Georgia, and twelve pearl millet hybrids developed at Kansas State University, Manhattan, were planted. Two commercial sorghum hybrids and an open pollinated population of pearl millet were included for comparison.

At Hays and St. John, twelve pearl millet hybrids developed at the Fort Hays Branch Experiment Station, Hays, Kansas were planted. Two commercial sorghum hybrids and two pearl millet populations were included for comparison. The study at St. John was replanted due to poor stand establishment, however, stand establishment was again unacceptable and this site was abandoned.

An F_1 diallel hybrid study also was grown at Hays. In this study, forty-six pearl millet hybrids were compared to three commercial sorghum hybrids.

In these studies attention was focused on yield, plant height, 1000 seed weight, head number per unit area, head lengths, and percent protein.

In 1979, ten pearl millet hybrids developed at the Fort Hays Branch Experiment Station, Hays, Kansas, were tested at six locations in Kansas, (1) Ashland Experiment Field, Manhattan; (2) Garden City Branch Experiment Station, Garden City; (3) Fort Hays Branch Experiment Station, Hays; (4) Southwest Kansas Experiment Field, Minneola; (5) Sandyland Experiment Field, St. John; and (6) Tribune Branch Experiment Station, Tribune. Five pearl millet populations and three commercial sorghum hybrids were included for comparison.

In a separate study, nine pearl millet hybrids developed at the Coastal Plains Station, Tifton, Georgia, were planted at two locations in Kansas, the Ashland Experiment Field, Manhattan, and the Fort Hays Branch Experiment Station, Hays. Two commercial sorghum hybrids and two pearl millet populations were included for comparison.

Notes were taken on yield, plant height, seed weight, percent protein, heads per unit area, plant population, half bloom date (or date of 50 percent heading), date of dark layer formation, degree of lodging, and seed set.

Pearl millet hybrids and populations yielded as well as grain sorghum hybrids at several locations, particularly in areas of low rainfall. In 1979 there was significant genotype by environment interaction for yield.

Sorghum seed weights were significantly higher than those of pearl millet. Low yielding millets tended to have low seed weights.

Protein content was significantly higher in millet than in sorghum. Yield levels generally did not affect protein content in pearl millet.

Sorghums tended to produce more protein per hectare than millets. Protein per hectare decreased as yields decreased.

Sorghums usually contained more protein per 1000 seeds than millets. Low yielding millets, and millets with low seed weights, generally had low protein contents per 1000 seeds.

Millets tended to produce more heads per hectare than sorghums. At some locations, higher yielding millets produced higher head numbers per hectare.

Differences in plant population generally did not affect yield in pearl millet. Low plant populations tended to be offset by increased production of heads, however high head numbers did not necessarily result in high yields.

Sorghums usually had significantly higher yields per head than millets. Higher yielding millets tended to produce higher yields per head.

Sorghums generally had higher yields per plant than millets. Some higher yielding millets tended to produce higher yields per plant.

Head length did not appear to affect yield.

Heterosis studies were conducted in 1978 and 1979 at the Ashland Experiment Field, Manhattan, Kansas. Twenty-seven pearl millet hybrids and their inbred parents were studied.

Significant yield increases over better parents were noted for many hybrids. Increases in plant height, seed weight, heads per hectare, head length, protein per hectare, protein per 1000 seeds, yield per head, yield per plant, and plant populations were also observed. However, percent protein decreased in hybrids as did heads per plant.