PN-ABE-442
64952

J. Agronomy & Crop Science 160, 191—197 (1988)
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ISSN 0931-2250

Contribution 85-151-J, Agron. Dept., Kansas Agric. Exp. Stn., Manhattan KS 66506. Cooperative project between contract AID/DSAN-G-D149, Agency for International Development, Title XII, INTSORMIL, and Kansas State University

Grain Yield of Intercropped Sorghum and Pearl Millet as Influenced by Sorghum Genotype and Cropping Pattern

H. Stützel and R. L. Vanderlip

Authors' addresses: Dr. H. Stützel, Institut für Pflanzenbau (340); Universität Hohenheim, D-7000 Stuttgart 70 (Germany) and Prof. Dr. R. L. Vanderlip, Department of Agronomy, Throckmorton Hall, Kansas State University, Manhattan, KS 66506 (U.S.A.).

With one figure and 10 tables

Received July 7, 1987; accepted October 12, 1987

Abstract

Intercropping of sorghum and pearl millet with different growth cycles is used widely in third-world countries to ensure and increase yields. However, it is questionable whether yield increases because of intercropping can be maintained under more developed systems, since temporal differences are necessary to allow mechanized planting and harvesting.

Three sorghum hybrids with expected growth cycles from 90 to 110 days were planted in sole stands and in alternate rows and mixed within the rows with a pearl millet hybrid having a growth cycle similar to that of the early sorghum. Sole stands of millet also were included. The plots were planted at three locations in Kansas, two dryland and one including dryland and irrigated. Results show that yields were consistently highest in sole stands of sorghum, owing to the higher yield level of sorghum. No yield increase could be found on a land equivalent ratio basis, indicating no intercropping advantages. However, under good moisture conditions, a tendency toward yield increase was observed with the later maturing sorghums, which had 1—2 weeks of grain filling after the millet was mature. When moisture supply was insufficient, millet showed higher competitiveness for water than sorghum, and sorghum was adversely affected more than pearl millet was favored. It was concluded that moisture conditions have to be good and that temporal differences between sorghum and millet have to be greater than those used in this experiment to achieve intercropping yield advantages.

Key words: Sorghum, millet, intercropping, competition, LER

Introduction

Intercropping sorghum, *Sorghum bicolor* (L.) Moench and pearl millet, *Pennisetum americanum* (L.) Leeke, is a traditional and widely used practice in third-world countries to ensure and increase yields. This traditional cropping system takes advantage of great differences in development between the crops.

The sorghum/millet intercropping literature shows experiments with great temporal differences between crops. Andrews (1972) intercropped a very early maturing millet with a much later maturing sorghum and found yield increases, depending on the spatial arrangement, of up to 50 %. Kassam and Stockinger (1973) planted sorghum and millet on 15 May, and harvested millet on 18 August and sorghum on 14 November. Yield increases of 19 % were observed compared to sole sorghum yields. Baker and Norman (1975),

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working in Nigeria, developed a quadratic equation, which indicated that intercrop yields were higher than sole crop yields if the maturity difference between crops was at least five weeks. In 16 combinations with four millet and four sorghum lines in India, WILLEY and RAO (1977) found the highest yield increase of 32 % on a land equivalent ratio (LER) basis in a combination with greatest temporal difference between crops, although there was no correlation between temporal difference and yield over the experiment as a whole.

Yield increases because of intercropping can be explained by reduced competition between plants, since maximum demands by the two crops for growth factors occur at different times. However, large temporal differences in development allow only limited mechanization (ANDREWS 1972). When working with higher levels of mechanization, only small differences in maturity can be used, since both crops have to be planted and harvested at the same times.

Since both sorghum and millet are excellent feedgrains and could be harvested together, the purposes of this study were to find out:

(1) if relatively small differences in development of sorghum and pearl millet would result in yield increases, and

(2) how different moisture supplies and different planting patterns would influence competition and, as a result, grains yields.

Materials and Methods

Three sorghum hybrids, early (ACCO 1014), medium (Pioneer 8324), and late (DeKalb F67) were planted in sole stands and intercropped as within-row mixtures and in alternate rows with pearl millet hybrid 2159 × 7024 developed by W. D. Stegmeier, Fort Hays Branch Experiment Station, Hays, Kansas. These sorghum hybrids were high yielding and differed not more than 10 cm in height from pearl millet. The millet hybrid was about the same maturity as ACCO 1014, flowered about 1 week before

Table 1. Sorghum hybrid and intercropping system effects on sorghum and millet grain yields, Manhattan, irrigated, 1980

Cropping system	Sorghum hybrid		
	Early	Medium	Late
Sorghum, kg/0.5 ha			
sole stand	3022	3212	2785
alternate rows	2244	3419	3266
within-row mixtures	2011	3487	3065
LSD (.05)		340	
Sorghum, LER			
sole stand	.500	0.500	.500
alternate rows	.396	0.536	.620
within-row mixtures	.334	0.545	.603
LSD (0.5)		0.096	
Sorghum, g/head			
sole stand	35.5	38.8	35.6
alternate rows	32.0	49.0	47.6
within-row mixtures	27.5	45.5	43.9
LSD (.05)		7.7	
Millet, kg/0.5 ha			
alternate rows	2014	1802	1863
within-row mixtures	2272	1666	1503
LSD (.05)		112	

Pioneer 8324 and about 2 weeks before DeKalb F67. The study contained the following treatments replicated four times:

Sorghum	Pearl millet	Cropping system
1. Early	—	sole stand
2. Medium	—	sole stand
3. Late	—	sole stand
4. Early	2159 × 7024	alternate rows
5. Medium	2159 × 7024	alternate rows
6. Late	2159 × 7024	alternate rows
7. Early	2159 × 7024	within-row mixture
8. Medium	2159 × 7024	within-row mixture
9. Late	2159 × 7024	within-row mixture
10. —	2159 × 7024	sole stand

Hybrids were planted on 28 May, 1980 on the Ashland experiment field near Manhattan, Kansas, on a Eudora silt loam (Fluventic Hapludoll, Coarse-Silty, Mixed, Mesic); on 29 May, 1980 at the Sandyland Experiment Field at St. John, Kansas on a Pratt loamy fine sand (Psammentic Haplustalf, Sandy, Mixed, Thermic); and on 3 June, 1980 at the Garden City Branch Experiment Station on a Keith silt loam (Aridic Argiustoll, Fine-Silty Mixed, Mesic). At Manhattan, a dryland and an irrigated study were planted. Furrow irrigation was applied to the latter weekly from the second week of July to maturity. A row width of 76 cm was used for all plantings. Each plot consisted of eight rows, 13 m long at Manhattan and of six rows, 8 m long, at St. John and Garden City. Plant populations were 130,000 plants/ha at Manhattan and 75,000 plants/ha at St. John and Garden City. The ratio between sorghum and millet plants in intercrops was 1 : 1.

Weeds were controlled at Manhattan by pre-emergence application of 2.2 kg propazine/ha; at St. John mechanically, and at Garden City mechanically and with 2,4-D ca. 6 weeks after the crop had emerged. Harvested row length was 3 m of each of the four center rows at Manhattan and 4.5 m of each of the two center rows at St. John and Garden City. Basic plot data were converted separately for each crop into kg/0.5 ha or kg/ha and adjusted to 12.5 % moisture. Grain yields were calculated further on the basis of Land Equivalent Ratio (LER) with the formula

$$LER = \sum \frac{y_i}{y_u}$$

where y_i is the yield of the component in the intercrop on one unit area and y_u is the yield of the same crop on the same area in a sole stand.

Yield components, heads/ha, head weight, seeds/head, and seed weight were determined. All computations were carried out with the statistical package SAS (BARR et al. 1979).

Results

Grain yields and yield components of sorghum grown at Manhattan under irrigation are shown in Tables 1 and 2. Grain yields, averaged over cropping systems, were highest from the medium hybrid as a result of highest seed number/head. Low seed numbers/head for the early and late maturing hybrids were partially compensated for by higher seed weight (Table 2). On an LER basis, the medium and late maturity hybrids did not differ significantly. The early hybrid had significantly higher yields in sole stands than in both intercropping treatments, yields of the late hybrid were higher in alternate rows than in sole stands, and the medium hybrid yielded equally in both intercropping treatments.

Millet intercropped with the early sorghum hybrid yielded significantly more than when intercropped with either the medium or late

Table 2. Sorghum hybrid effects on millet yield (LER) and millet and sorghum yield components, Manhattan, irrigated, 1980

Yield component	Sorghum hybrid		
	Early	Medium	Late
Millet yield (LER)	.571 a	.464 b	.449 b
Millet head no. (th/.5 ha)	148.9 a	126.9 b	123.1 b
Millet seed wt. (g/1000)	12.1 a	11.6 b	11.3 b
Sorghum seed/head	1389 c	2211 a	1848 b
Sorghum seed wt. (g/1000)	20.0 a	17.7 b	20.3 a

Means followed by the same letter in a row are not significantly different (P = 0.05)

Table 3. Total grain yields (sorghum + millet), Manhattan, irrigated, 1980

Hybrid	Yield, kg/ha	Cropping system	Yield, kg/ha
Early	4862 b	sole stand-sorghum	6012 a
Medium	5599 a	alternate rows	4869 b
Late	5089 b	within-row mixtures	4668 b
Millet	3753	sole stand-millet	3753

Means followed by the same letter in a column are not significantly different (P = 0.05)

hybrid (Table 2). This was due to significantly higher head numbers and 1000-seed weights. Millet grain yields were higher in within-row mixtures than in alternate rows when intercropped with the early sorghum hybrid, and higher in alternate rows when intercropped with either the medium or late hybrids (Table 1).

Total grain yields of treatments (kg/ha) at Manhattan under irrigation (Table 3) showed the much higher yield level of pure sorghum as compared to millet, and yields of the intercropping treatments close to the arithmetic mean of the two species.

Moisture conditions on the study without irrigation at Manhattan were influenced mainly by mid-summer drought, beginning 1 week before flowering of the early sorghum hybrid and millet and continuing for 3 to 4 weeks thereafter (Fig. 1).

Sorghum grain yields (LER and absolute) and most of the yield components were consistently higher in sole stands of sorghums with all three hybrids (Table 4). However, 1000-seed weights of the late hybrid increased in intercropping treatments. Millet yields and yield components were not significantly influenced by cropping systems or sorghums used for intercropping.

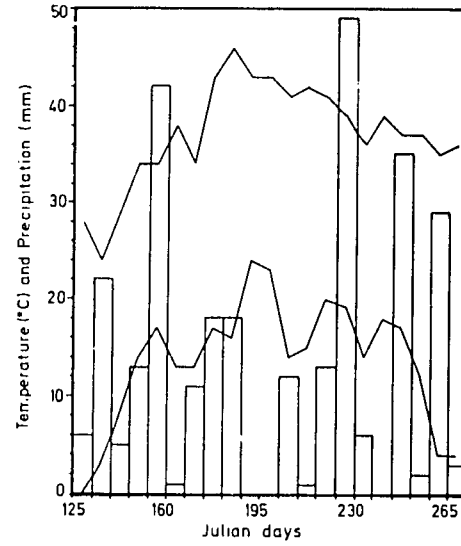

Fig. 1. Manhattan precipitation (bar graph), minimum and maximum temperature

Table 4. Sorghum yield and yield components affected by intercropping system, Manhattan, dryland, 1980

Yield component	Cropping system: Sole crop	Alternate row	Within row mixture
Sorghum yield (kg/.5 ha)	1846 a	1017 b	933 b
Sorghum yield (LER)	.50 a	.28 b	.27 b
Sorghum yield (g/head)	25.9 a	19.5 b	17.2 b
Sorghum, head no. (th/.5 ha)	71.8 a	49.5 b	54.3 b
Sorghum, seed/head	1303 a	897 b	847 b
Early	17.8 bc	17.9 bc	14.0 d
Medium	16.5 c	18.8 a	19.3 ab
Late	17.6 bc	20.4 a	20.8 a

Means followed by the same letter in a row are not significantly different (P = 0.05)

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Total grain yields of sole sorghum at Manhattan without irrigation were about twice as high than those of mixtures (Table 5). Sole stands of millet did not differ significantly from mixtures.

Table 5. Total grain yields (kg/ha), Manhattan, dryland, 1980

Cropping system	Yield, kg/ha
Sole stand-sorghum	3691 a
Alternate rows	1838 b
Within-row mixtures	1824 b
Sole stand-millet	1464

Means followed by the same letter are not significantly different (P = 0.05)

At St. John, sorghum grain yields (kg/.5 ha) were significantly higher in sole stands (Table 6), followed by within-row mixtures and alternate rows. The same order was observed for head numbers and 1000-seed weights. Treatments with the medium and late sorghums produced significantly higher grain yields than the early, mainly as a result of highest seed numbers/head. The early sorghum, in contrast, developed significantly more heads than either of the other sorghums. Millet grain yields at St. John did not differ significantly between cropping systems nor between sorghum hybrids with which they were intercropped, as was the case at Manhattan on dryland. Total grain yields of treatments showed the same trend as sorghum yields (Table 7).

At Garden City, sorghum grain yields and yield components did not depend on cropping systems. Early and medium sorghums had significantly higher grain yields than the late hybrid, mainly because of higher head numbers and better seed set (Table 8). Grain yields on an LER basis were significantly higher from the early than from either medium or late sorghums, as a result of poor seed set especially in alternate rows with the latter ones. Millet, on the other hand, developed significantly more heads in alternate rows than in within-row mixtures, however, this did not

Table 6. Sorghum grain yields (kg/.5 ha) and yield components, St. John, 1980

Hybrid and planting pattern	Grain yield/.5 ha (kg)	(LER)	Head no. (.5 ha)	Grain yield/head (g)	Seeds/head	Seed weight g/1000
Hybrid						
ACCO 1014	443 b	0.38	58,712 a	7.8 b	291 b	24.1
Pioneer 8324	801 a	0.43	38,598 b	20.5 a	767 a	23.4
DeKalb F67	950 a	0.39	39,250 b	24.1 a	864 a	24.0
Pattern						
Sole stand	917 a	0.50	47,948 a	21.1	701	26.2 a
Alternate rows	556 b	0.32	42,621 b	13.8	528	22.5 b
Within-row mixture	744 ab	0.39	45,991 ab	18.3	729	22.8 b

Means followed by the same letter in a column are not significantly different (P = 0.05)

Table 7. Total grain yields, St. John, 1980

Hybrid	Yield, kg/ha	Planting pattern	Yield, kg/ha
ACCO 1014	1214 b	sole stand-sorghum	1815 a
Pioneer 8324	1628 a	alternate rows	1317 b
DeKalb F67	1852 a	within row mixtures	1572 ab
		sole stand-millet	1756

Means followed by the same letter in a column are not significantly different (P = 0.05)

Table 8. Sorghum grain yields (kg/.5 ha) and yield components, Garden City, 1980

Sorghum hybrid	Grain yield/.5 ha (kg)	(LER)	Head no. (.5 ha)	Grain yield/ head (g)	Seeds/ head
ACCO 1014	1022.0 a	0.63 a	30,364 a	33.66 a	1409 a
Pioneer 8324	929.6 a	0.36 b	31,787 a	31.51 a	1169 a
DeKalb F67	199.5 b	0.33 b	16,526 b	11.34 b	517 b

Means followed by the same letter in a column are not significantly different (P = 0.05)

Table 9. Total grain yields, Garden City

Planting pattern and hybrid	Yield, kg/ha	LER
Sole stand-sorghum	1466 a	
Alternate rows	852 b	
Within-row mixtures	903 b	
Sole stand-millet	518	
Early sorghum	1504 a	1.05 a
Medium sorghum	1551 a	0.87 ab
Late sorghum	480 b	0.69 b

Means followed by the same letter in a column are not significantly different (P = 0.05)

influence grain yield of millet, which showed no dependence on cropping systems nor on sorghum hybrid intercropped.

Total grain yields were highest in sole stands of sorghum. Intercrop yields did not differ significantly from sole millet yields (Table 9).

Discussion

Looking at the results of the irrigated study in Manhattan, where soil moisture was unlikely to be limiting at any time during growth, a consistent picture develops of what has taken place in terms of competition. When pearl millet was intercropped with the early sorghum, which had about the same life cycle, millet appeared to show higher competitiveness. It produced more tillers than when intercropped with the other sorghums, reducing tillering of sorghum and occupying more space. After tillering, the early sorghum presumably was not able to produce or maintain as many floral primordia in intercrops as in sole stands, resulting in fewer seeds/head. Reduced head bearing tillers and reduced seed set resulted in lower sorghum yields. Millet, however, was able to increase yield because of better tillering.

In mixtures with the medium and late sorghums, millet could not produce as many heads as with the early sorghum, presumably owing to the longer vegetative phase of sorghum. Seed set of the medium and late sorghums was not reduced by competition with millet. The late sorghum had a longer period during grain filling free from millet competition, resulting in higher sorghum seed weights. Consequently, yield increases of the late sorghum in competition with millet were highest, supporting the hypothesis that yield increases

Table 10. Climatic data, St. John and Garden City, 1980

	St. John				Garden City			
	Temperature Celsius			Precip. mm	Temperature Celsius			Precip. mm
Month	Min.	Max.	Avg.		Min.	Max.	Avg.	
May	10.8	25.3	18.1	50.3	7.8	21.3	14.6	145.0
June	18.5	34.9	26.7	12.7	15.8	31.9	24.2	39.9
July	22.3	39.8	31.1	40.4	19.3	37.5	28.4	12.7
August	20.6	30.1	28.3	119.9	17.5	33.0	25.3	71.1
September	15.3	31.3	23.3	40.0	12.2	28.5	20.4	0.1
October	6.6	23.7	15.2	24.9	2.2	23.2	12.7	3.8

relative to sole stands are a function of temporal differences between intercropped components.

On dryland at Manhattan and St. John, intercropping with pearl millet always reduced sorghum grain yields. Owing to insufficient moisture (Fig. 1, Table 10), competition increased and millet obviously was more competitive. However, sorghum was more adversely affected that millet was favored, bringing intercrops to the same yield level as millet alone. Only the late sorghum was able to compensate somewhat for millet competition during grain filling, when millet was already mature.

Whereas under irrigation, different competition mechanisms associated with light interception (e.g., greater tillering of millet, and longer vegetative phase of medium and late sorghums resulting in increased seed set and head numbers) play a role, competition for water and the higher competitiveness of pearl millet dominated under dryland conditions.

In terms of absolute grain yields, sole sorghum stands were generally more productive than millet or intercrops. But even on an LER basis, no evidence for superiority of mixed stands could be found when soil moisture was limiting. Under virtually non-limiting soil moisture conditions, there was some indication that increasing temporal differences between the two crops can produce grain yields greater than 1 on an LER basis. However, since even approximately 10 days difference resulted in relatively small yield increases, the advantages of sorghum pearl millet intercrops appear to be limited when mechanized harvest is to be ensured.

Zusammenfassung

Sorghum und Perlhirse mit unterschiedlicher Entwicklungsdauer werden in Ländern der Dritten Welt häufig zur Ertragssicherung und -steigerung gemischt angebaut. Es ist jedoch ungeklärt, ob Mischanbau auch in weiter entwickelten Produktionssystemen zu Ertragssteigerungen führen kann, da hier Entwicklungsunterschiede aufgrund der mechanisierten Durchführung von Saat und Ernte nur begrenzt nutzbar sind.

Drei Sorghumhybriden, die zwischen 90 (frühe Hybride) und 110 Tagen (späte Hybride) zur Kornreife benötigten, wurden in Reinbeständen sowie vollständig und in alternierenden Reihen gemischt mit einer Perlhirsehybride angebaut. Die Entwicklungsdauer der Perlhirse, die ebenfalls rein angebaut wurde, war mit derjenigen der frühen Sorghumhybride vergleichbar. Die Versuche wurden in Kansas/USA an zwei Standorten ohne, an einem weiteren Ort ohne und mit Bewässerung angelegt. Aufgrund des höheren Ertragsniveaus der Sorghumhybriden waren die Absoluterträge der reinen Sorghumbestände durchgängig am höchsten. Auch relativ („land equivalent ratio") konnten keine Ertragssteigerungen durch Mischanbau nachgewiesen werden. Bei guter Bodenfeuchte (Bewässerung) tendierten jedoch die Mischvarianten mit der späten Sorghumhybride, deren Korntüllungsphase sich 1—2 Wochen über die der Perlhirse erstreckte, zu relativen Mehrerträgen. Bei knappem Wasserangebot war die Perlhirse konkurrenzkräftiger als die Sorghumhybriden, deren Ertragseinbußen allerdings die Ertragsvorteile der Perlhirse übertraten. Aus den Ergebnissen kann geschlossen werden, daß Sorghum-Perlhirse-Mischungen nur bei ausreichender Bodenfeuchte und bei Nutzung größerer Entwicklungsunterschiede, als dies in den vorliegenden Versuchen geschah, Ertragsvorteile aufweisen können.

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