Plant Yields and Fodder Quality Related Characteristics of Millet–Stylo Intercropping Systems in the Sahel

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ABSTRACT

The integration of forage legumes into the low-input, cereal-based farming system of the Sahel may be the key to sustaining soil, crop, and livestock production. The objectives of this study were to evaluate the effects of intercropping the forage legumes *Stylosanthes fruticosa* (Retz.) Alston or *S. hamata* (L.) Taub. with millet [*Pennisetum glaucum* (L.) R. Br.] on grain yield, fodder yield, and crude protein (CP) yield and concentration. Four field trials were conducted on a Psammentic Paleustalf (siliceous, isohyperthermic) soil from 1988 to 1990 at Sadoré, Niger. Each *Stylosanthes* species was grown in alternate single and triple row patterns with millet for 1 and 2 yr, with stylo regrowing from stubble during the second year. Control treatments were sole crops of millet and stylo. Intercropping either *Stylosanthes* species with millet for 1 yr in alternate single rows did not affect millet grain yield, because of low stylo competition. Total dry matter (DM) harvested of intercrop was similar to that of sole millet, while CP concentration of total DM increased moderately from 43 g kg^{-1} in sole millet crop to 75 g kg^{-1} in intercrop. During the second year of association, stylo was very competitive, depressing intercropped millet grain by an average of 67% in 1989 and 48% in 1990 compared with sole millet grain yield. Total DM and CP yields, and CP concentration of the harvested fodder were, respectively, 1.4, 3.0, and 2.3 times greater in intercrop than sole millet. Millet-stylo intercrops, with each species planted at half its sole crop density, appear to have an advantage in fodder yield and CP over sole millet cropping but not in total grain yield.

INTERCROPPING annual cereal crops and grain legumes is a widespread practice in farming systems of sub-Saharan Africa. The technique maximizes returns to labor and minimizes risks in a climatically-uncertain environment. Unlike food crops, intercropping forage legumes with cereals is not common in the region (Okigbo and Greenland, 1976), probably because forages do not contribute directly to food security of farmers (Mohamed-Saleem, 1985). In the Sahel, however, forage legume–cereal intercropping may be the key to sustaining the productivity of crops and livestock. Although millet is primarily used for human consumption, the stover constitutes the main feed source for livestock during the long dry season. Furthermore, increasing population pressure in recent years has caused an expansion of cultivated areas at the expense of grazing lands with a subsequent reduction of fallow period. This has resulted in a decline of both crop and animal productivity (Spencer, 1985). There is, therefore, a need for a land-use system that limits the degradation of the natural resource base while sustaining food and feed production.

Forage legume–cereal intercropping has been shown to increase the quantity and feeding value of biomass yields compared to cereal monocropping (Waghmare and Singh, 1984; Mandal et al., 1990). The presence of a legume increased the nutritive value of harvested products due to increased protein yield. Conversely, yield depressions of the main crop have often been reported (Shelton and Humphreys, 1975; Mohamed-Saleem, 1985).

Other beneficial effects of forage legume–cereal intercropping included improvement of soil physical and chemical properties (Badaruddin and Meyer, 1989),

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Abbreviations: CP, crude protein; DM, dry matter; LER, land equivalent ratio; MSf1R, alternate single row millet-Sf intercrop; MSf3R, alternate triple rows millet-Sf intercrop; MSh1R, alternate single row millet-Sh intercrop; MSh3R, alternate triple rows millet-Sh intercrop; PM, pure millet; Sf, *Stylosanthes fruticosa*; Sh, *S. hamata*.

control of soil erosion (Fussell et al., 1987), and increased performance of animals fed crop residues as a basal diet (Mosi and Butterworth, 1985; Kouamé et al., 1992). There is little information on forage legume–cereal intercropping in the Sahel although *S. Fruticosa* and *S. hamata* have been shown to be potentially valuable crops (ICRISAT, 1987). This study was designed to determine the influence of stylo intercropping on millet yields and fodder quality-related characteristics.

MATERIALS AND METHODS

Four field experiments were conducted from 1988 to 1990 at the Sahelian Center of the International Crop Research Institute for the Semi-Arid Tropics. The center is located at Sadoré (13° 15′ N, 2° 18′ E) in the Republic of Niger. The well-drained, sandy soil of the station is acidic (pH = 5.6 in 1:1 soil:water mixture) and low in native fertility (West et al., 1984). Long-term yearly rainfall averages 560 mm. Rainfall was 623 mm in 1989 and 400 mm in 1990.

Seven cropping patterns were evaluated in all combinations, with two planting strategies designated as 1-yr intercrop and 2-yr intercrop. Specific cultural practices of each planting strategy are listed in Table 1. For the 1-yr intercrop (Exp. 1a and 2a), *S. fruticosa* (Sf) and *S. hamata* (Sh) were interseeded with millet on newly cleared land. Millet was sown 2 to 3 wk before stylo. In the 2-yr intercrop (Exp. 1b and 2b), millet was replated on land previously used for the 1-yr intercrop on which stylo would regrow from the previous crop stubble. The seven cropping patterns included: (i) pure millet (PM), (ii) pure Sf, (iii) intercrop millet-Sf in alternate single rows (MSf1R), (iv) intercrop millet-Sf in alternate triple rows (MSf3R, (v) pure Sh, (vi) intercrop millet-Sh in alternate single rows (MSh1R), and (vii) intercrop millet-Sh in alternate triple rows (MSh3R). Cropping patterns were randomly assigned to 9- by 12-m plots. An annual application of 13 kg P ha^{-1} as single superphosphate was broadcast preplant and incorporated into 40- to 50-cm tall ridges with an oxen-drawn plough after the first rains. All treatments were replicated four times.

Legumes for the trials were selected for their performance in previous screening evaluations. A local accession of Sf (ILCA 13860), a perennial highly-persistent forage legume which is tolerant to drought, and 'Verano' Sh, an Australian selection from South American material with an excellent herbage yield potential which behaves as a biannual in Niger (ICRISAT, 1987) were used. A composite millet cultivar 'Composite Inter-Varietal de Tarna', recommended for the area, was used.

Millet was sown in pockets at 1.2-m spacing on ridges 0.75 m apart on 16 June 1988, 30 June 1989, and 30 May 1990. Planting consisted of dropping 10 to 20 seeds into a 3- to 5-cm deep hole made with a hoe and stepping on it to cover the seed. Millet plants were thinned 3 wk later to three per individual planting site. Those three plants were referred to as a pocket. Millet planting densities were 11 000 and 5500 pockets ha^{-1} (33 000 and 16 500 plants ha^{-1}) in sole and intercrop treatments, respectively. At approximately 30 d post-emergence, millet was top-dressed with 15 kg N ha^{-1} as calcium ammonium nitrate in a single application. Plots were hand-weeded twice during each growing season. Millet was harvested on 23 Sept. 1988, 3 Oct. 1989, and 7 Sept. 1990.

The stylo lines were sown in continuous rows on firm ridges, 0.75 m apart. Seed was inoculated with a mixture of *Rhizobium* strains (cowpea, stylo, and *Macroptiloma* types). For the 1-yr intercrop, stylo plantings occurred on 9 July 1988 and 12 July 1989, and the herbage was harvested only once, at the end of the cropping season. In the 2-yr intercrop, stylo regrew from the stubble of the previous year's crop, and the herbage was harvested twice, approximately 60 and 120 d after millet emergence. All stylo plants were cut at 15-cm stubble height with a hand-sickle.

Yields were measured by hand-harvesting and weighing the biomass from the innermost 3 by 6 m of each plot. Millet plants were divided into panicles, leaf (blade plus sheath), and stem. Subsamples of millet plant parts were sundried to constant weight for DM yield determination. Panicles were threshed to determine grain yield. Subsamples of stylo herbage were oven dried (75 °C, 48 h) for DM determination. Plant samples were milled to pass through a 1-mm screen and acid-digested by a micro-Kjeldahl procedure with N concentration determined, after distillation, by titration (Nelson and Sommers, 1980). Crude protein yield was calculated by multiplying N yield by 6.25. The relative DM yields of intercrop millet (RYM) and stylo (RYS) were calculated as (DM yield in intercrop) / (DM yield in pure crop) for each component crop in an intercrop. Land equivalent ratio (LER) was calculated as per Willey (1979) were for each intercrop, LER = RYM + RYS.

Data were analyzed by ANOVA using the general linear model procedures (SAS Institute, 1982). Year was included in the model as the main plot in a split-split plot arrangement of the completely randomized design. The planting strategy was assigned to subplot and the cropping patterns to sub-sub plot. When there was a significant overall treatment effect ($P < 0.10$), single-degree-of-freedom orthogonal contrast was used to compare (i) PM to the mean of intercrop, (ii) millet-Sf to millet-Sh intercrops, and (iii) alternate single row to alternate triple rows intercrops.

RESULTS AND DISCUSSION

Grain Yield

Sole millet crop produced higher ($P < 0.01$) grain yield than the average of intercropped millet in both 1- and 2-yr intercrops (Tables 2 and 3). Low intercrop millet grain yield was partly due to the reduced millet plant population in the intercrop treatments compared to PM. This is consistent with the substitutive theory proposed by Willey (1979). Cereal yield reductions due to intercropping with grain or fodder legumes have been frequently reported (Shelton and Humphreys, 1975; Izaurralde et al., 1990; Mandal et al., 1990). Yield decline varied with planting strategy and planting pattern. For the 1-yr intercrop, a non-orthogonal contrast indicated no difference ($P < 0.05$) between PM and either MSf1R or MSh1R (not shown). Grain yields tended to be lower in the alternate triple-row planting patterns than in the alternate single-row planting patterns than in the

Table 1. Cultural practices and dates of individual experiments.

Experiment no.	Evaluation year	Site	Cropping† sequence	Millet Sowing	Millet Harvest	Stylo establishement
1a	1988	1	F-<u>MS</u>	16 June	22 Oct.	seeded 9 July
1b	1989	1	F-MS-<u>MS</u>	30 June	3 Oct.	regrowth
2a	1989	2	F-<u>MS</u>	30 June	3 Oct.	seeded 12 July
2b	1990	2	F-MS-<u>MS</u>	30 May	7 Sep.	regrowth

† Cropping sequency preceding the experiment: *F* = Fallow, MS = millet-stylo intercrop, the underlined system represents the year of evaluation.

Table 2. Grain, total dry matter (DM), and crude protein (CP) yields and concentrations of millet and stylo in 1-yr intercrop.

	1988				1989			
Cropping pattern†	Grain	DM	CP		Grain	DM	CP	
	kg ha^{-1}							
Pure millet	910	2220	98	(45)‡	1080	2700	117	(43)
Intercrop MSf1R	760	2110	103	(50)	800	2420	140	(58)
Intercrop MSf3R	440	1450	76	(53)	610	2720	172	(63)
Intercrop MSh1R	630	2350	174	(75)	1020	2450	129	(53)
Intercrop MSh3R	580	2230	160	(72)	440	1630	98	(60)
CV, %	29	31	28	12	30	35	41	16
Contrast§								
Millet vs intercrop	0.01	0.61	0.14	0.01	0.01	0.27	0.49	0.03
Intercrop 1R vs 3R	0.09	0.25	0.26	0.94	0.15	0.43	0.98	0.39
Intercrop MSf vs MSh	0.96	0.14	0.01	0.01	0.28	0.11	0.06	0.71

† Cropping pattern abbreviations: M = millet, Sf = *Stylosanthes fruticosa*, Sh = *S. hamata*, 1R = alternate single-row planting arrangement, and 3R = alternate triple-row planting arrangement.
‡ Number in parentheses is crude protein concentration of dry matter (g kg^{-1}).
§ Probability levels (*F*-test) for single-degree-of-freedom orthogonal contrast.

Table 3. Grain, total dry matter (DM), and crude protein (CP) yields and concentrations of millet and stylo in 2-yr intercrop.

	1989				1990			
Cropping pattern†	Grain	DM	CP		Grain	DM	CP	
	kg ha^{-1}							
Pure millet	640	2660	158	(60)‡	830	3200	94	(29)
Intercrop MSf1R	310	3240	296	(94)	430	3750	273	(73)
Intercrop MSf3R	110	3120	349	(111)	610	3000	188	(64)
Intercrop MSh1R	270	5700	616	(107)	220	4350	413	(95)
Intercrop MSh3R	140	4940	555	(113)	440	3580	304	(85)
CV, %	39	17	19	10	14	12	11	10
Contrast§								
Millet vs intercrop	0.01	0.01	0.01	0.01	0.01	0.07	0.01	0.01
Intercrop 1R vs 3R	0.02	0.27	0.91	0.22	0.01	0.01	0.01	0.04
Intercrop MSf vs MSh	0.44	0.01	0.01	0.09	0.01	0.01	0.01	0.01

† Cropping pattern abbreviations: M = millet, Sf = *Stylosanthes fruticosa*, Sh = *S. hamata*, 1R = alternate single-row planting arrangement, and 3R = alternate triple-row planting arrangement.
‡ Number in parentheses is crude protein concentration of dry matter (g kg^{-1}).
§ Probability levels (*F*-test) for single-degree-of-freedom orthogonal contrast.

alternate single-row planting ($P = 0.09$ in 1988 and $P = 0.15$ in 1989) possibly due to the wide spacing between rows of millet plants in the latter arrangement. This effect of planting pattern was similar to that described by Azam-Ali et al. (1984). When planting millet at different row spacings, they observed that millet exhibited little self-shading and was more productive in the wide- than the narrow-row spacings.

In the 2-yr intercrop, the mean grain yield of intercropped millet was 26 to 83% lower ($P < 0.01$) than that of PM (Table 3). The intercropped stylo effect on millet grain yield seemed dependent on environmental conditions. Cropping patterns involving Sh reduced millet grain yield ($P < 0.01$) more than those involving Sf in 1990 but not in 1989. Alternate triple-row planting of millet with either stylo species yielded, on average, 43% as much grain as alternate single-row planting in 1989 ($P = 0.02$), whereas the former planting system outyielded the latter by 62% in 1990 ($P < 0.01$). The contrasting trends in millet grain yields may be related to the different rainfall patterns which are known to affect millet grain yield in the Sahel (Fussell et al., 1987; Sivakumar, 1988). May to October rainfall was 11% higher in 1989 and 29% lower in 1990 than the long term annual mean of 560 mm. During 1989, more than 40% of the precipitation fell during the month of August (Table 4) and occurrences of drought were frequent during the period of crop establishment. Drought conditions in the 1990 growing season developed during the stem elongation period and caused a moisture stress to the millet plants. Moisture stress was more severe in alternate single- than alternate triple-row planting patterns and more in millet-Sh than in millet-Sf treatments (visual observations). Although millet growth rate was not monitored in these studies, millet plant height at 60 d after planting were compared in 1990 and ranked as PM > MSf1R > MSf3R > MSh1R > MSh3R ($P < 0.05$). Similar ranking was obtained for the number of harvested panicles per sampling area. Intercropped stylo presumably competed directly with millet for the limited soil resources resulting in reduced millet growth and grain yields.

Stylo Herbage Yield

During the seeding year (Exp. 1a and 2a), stylo herbage yields were higher ($P < 0.01$) in pure stands than those of intercrop, except in 1989 when pure Sf plots established poorly (Table 5). In contrast to millet yield, stylo herbage yield was about 40% greater in alternate triple-row than that obtained in alternate single-row treatments. A similar negative correlation between peanut (*Arachis hypogaea* L.) and millet was attributed to shading which decreased the photosynthetic activity of the legume (Nambiar et al., 1983). Although no light measurements were taken in this research, alternate single-row planting is likely to shade stylo seedings more than

Table 4. Growing season rainfall recorded at the experimental station, Sadoré, Niger.

Month	Year		
	1988	1989	1990
	mm		
May	1.0	34.6	77.1
June	90.5	36.0	50.5
July	173.1	92.0	104.0
August	238.8	234.0	98.5
September	186.9	198.4	69.4
October	0.0	27.9	0.0

alternate triple-row planting thereby causing the most herbage yield decline.

Greatest herbage yield was produced in the 2-yr intercrop, possibly due to a more fully developed stylo root system. Edye et al. (1991) evaluated 15 accessions of *S. hamata* in association with volunteer native grass species and reported a lower initial seedling establishment in poor than in favorable environmental conditions, but the difference disappeared during the second year after the stylo plants had developed well established root systems. When averaged over cropping patterns, the two stylo species differed ($P = 0.09$) in their DM production abilities, with Sh producing two times more herbage than Sf. The MSh1R treatments produced more herbage than the MSh3R in 1990 ($P < 0.01$) but not in 1989, whereas no difference was found in MSf1R and MSf3R herbage yield in either year. Yearly herbage yield difference among Sh planting patterns could be due to different rainfall conditions which may have affected the competitive ability of the intercrop components.

Total Dry Matter Yield

The combined DM yields of intercrop millet and stylo varied with planting strategies and cropping patterns. In the 1-yr intercrop, no difference was found between the average DM yield of the intercrop treatments and that of PM (Table 2). Dry matter yield tended to be greater ($P = 0.14$ in 1988 and $P = 0.11$ in 1989) with MSf than MSh intercrop. Low stylo herbage yields during the seeding year contributed little to intercrop total DM, leading to no yield advantage of intercropping over millet monoculture. Relative DM yields showed that millet was the dominant crop (RYM > RYS). Land equivalent ratio of intercrop treatments ranged from 0.79 to 1.12 in 1988 (Table 6) and from 0.94 to 1.07 in 1989 (not shown), indicating little or no land use advantage of intercropping in 1-yr intercrop. These LER values are within the ranges of those reported by N'Nadi and Haque (1988) with maize– and sorghum–lablab intercrops.

In the 2-yr intercrop, the combined DM yield of millet and stylo was greater ($P < 0.01$ in 1989 and $P = 0.07$ in 1990) in the intercrop treatments than that of PM (Table 3). Dry matter yield was higher ($P < 0.01$) in alternate single-row than alternate triple-row intercrop in 1990 and tended in the same direction in 1989. Land equivalent ratio indicated a 16 to 22% land use advantage for DM production in alternate single row intercrops (Table 6). The high Sh herbage yield resulted in a greater ($P < 0.01$) harvested DM yield in millet-Sh than millet-Sf intercrops. The increased DM production per unit of land area achieved through intercropping stylo with millet may alleviate the frequent feed shortage constraint during the long dry season in the Sahel. Increased DM productivity through intercropping has been reported elsewhere (Waghmare and Singh, 1984; Mandal et al., 1990; Izaurralde et al. 1990).

Crude Protein Concentration and Yield

Interseeding stylo with millet increased the CP concentration and yield of the harvested DM. In the 1-yr intercrop, CP concentration of intercrop DM was greater ($P < 0.03$) than that of PM (Table 2). Nonetheless, CP concentration of all harvested DM was generally at or below 70 g kg^{-1}. This moderate feed quality was likely due to the small contribution of protein-rich stylo in the total DM yield. In the 2-yr intercrop, however, CP concentration of the harvested fodder was generally above 70 g kg^{-1} with the exception of MSf3R in 1990. Yields and concentration of CP were higher ($P < 0.01$) in intercrop than PM and higher in millet-Sh than millet-Sf intercrops (Table 3). Increased CP yields of intercropped treatments were attributable to an increased percentage of stylo in total DM yield. That led to a greater ($P < 0.01$) CP concentration in intercrop than PM in either year. Similarly, the high Sh herbage yield resulted in greater CP yield and concentration in millet-Sh than in millet-Sf intercrops. Kamara and Haque (1991) recently intercropped maize and fodder cowpea in the highland of Ethiopia and obtained 60 to 100 g kg^{-1} DM higher CP concentration in intercrop than in pure maize residue. The current study indicated that interplanting stylo with millet raised the total herbage CP concentration of the 2-yr intercrop from 60 g kg^{-1} DM in PM to over 100 g

Table 5. Herbage yields of *Stylosanthes fruticosa* (Sf) and *S. hamata* (Sh) as affected by cropping pattern and planting strategy.

Cropping pattern†	1-yr intercrop				2-yr intercrop			
	1988		1989		1989		1990	
	Sf	Sh	Sf	Sh	Sf	Sh	Sf	Sh
	kg ha^{-1}							
Pure stylo	860	1830	210	550	3070	1260	2890	3940
Intercrop 1R	180	770	20	20	2030	4700	1520	3060
Intercrop 3R	200	830	330	330	3510	4120	1150	2270
CV, %	44	20	37	30	15	20	13	7
Contrast‡								
Stylo vs intercrop	0.01	0.01	0.35	0.01	0.02	0.01	0.01	0.01
Intercrop 1R vs 3R	0.92	0.80	0.01	0.01	0.28	0.30	0.28	0.01

†Cropping pattern abbreviations: 1R = alternate single-row planting arrangement, and 3R = alternate triple-row planting arrangement.
‡ Probability levels (*F*-test) for single-degree-of-freedom orthogonal contrast.

Table 6. Relative dry matter yields of millet (RYM) and stylo (RYS), and land equivalent ratio (LER) as affected by cropping pattern in the 1-yr (1988) and 2-yr (1990) intercrop.

	1-yr intercrop			2-yr intercrop		
Cropping pattern†	RYM	RYS	LER	RYM	RYS	LER
Pure millet	1.00	0	1.00	1.00	0	1.00
Intercrop MSf1R	0.86	0.21	1.07	0.70	0.52	1.22
Intercrop MSf3R	0.56	0.23	0.79	0.57	0.40	0.97
Intercrop MSh1R	0.70	0.42	1.12	0.38	0.78	1.16
Intercrop MSh3R	0.63	0.45	1.08	0.41	0.58	0.98

† Cropping pattern abbreviations: M = millet, Sf = *Stylosanthes fruticosa*, Sh = *S. hamata*, 1R = alternate single-row planting arrangement, 3R = alternate triple-row planting arrangement.

kg^{-1} DM in 1989 (Exp. 1b). Crude protein concentrations in 1990 (Exp. 2b) were also raised from 30 in PM to 95 g kg^{-1} in the intercrop. This increase in the CP concentration of harvested crop residues by 69 to 125% through intercropping may provide enough protein supplement to sheep diets (Kouamé et al., 1992) in a short-term feeding system, e.g., the 2 to 3 mo before major religious holidays.

CONCLUSION

The study showed that interseeding Sh of Sf in alternate single row patterns with millet did not affect millet grain yield or total DM output. Sowing millet into year old established stylo, however, resulted in millet grain yield reduction while total DM and CP yields and CP concentration increased substantially. There is an indication that millet grain yield reduction was due in part to increased competition for water. Although a large grain yield reduction was observed in the 2-yr intercrop systems, major benefits may derive from the increase in total DM output and feeding value. The high DM production per unit of land area and the subsequent increase in CP yield in intercrops could provide enough N to supplement sheep diets in a short-term feeding system. With the increasing importance of the pastoral system to the economy of the Sahel, millet-stylo intercropping systems offer an alternative to support food and feed production without exhausting the production resource base.

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