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ON-FARM EXPERIMENTS WITH MAIZE-MUCUNA SYSTEMS IN THE LOS TUXTLAS REGION OF VERACRUZ, SOUTHERN MEXICO. II. MUCUNA VARIETY EVALUATION AND SUBSEQUENT MAIZE GRAIN YIELD

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SUMMARY

Despite interest in mucuna (*Mucuna pruriens*) as a green manure/cover crop, biomass production of its accessions has been poorly quantified, including in the Los Tuxtlas region of Veracruz, Mexico where smallholders have used maize (*Zea mays*)-mucuna systems increasingly since 1991. This on-farm research compared the biomass production of three mucuna varieties (white-, mottled-, and black seeded) in a rotational maize-mucuna system. Mucuna was sole-cropped during the first season (on eleven and five fields in 1996 and 1997 respectively), and its impact on the second-season maize yield was measured (on seven fields in 1996). White and mottled varieties produced equal biomass (7.92 and 6.74 $\mathrm{t\,ha^{-1}}$ in 1996 and 1997 respectively), and more than the black variety (6.85 and 4.90 $\mathrm{t\,ha^{-1}}$ in 1996 and 1997 respectively). Mucuna increased 1996/97 second-season maize grain yields by 50 % (from 0.97 to 1.46 $\mathrm{t\,ha^{-1}}$). Plots previously cropped with white and mottled varieties produced greater maize yield (1.55 $\mathrm{t\,ha^{-1}}$) than did black-variety plots (1.29 $\mathrm{t\,ha^{-1}}$). The research confirmed the higher productivity of the white and mottled varieties and the potential of the rotational system. Allocating the more desirable first-season growth period to mucuna and the riskier second season to maize is problematic, but the system may have potential in the region as a short-term fallow that permits second-season maize production.

INTRODUCTION

In the past decade, *Mucuna pruriens* has been the most promoted and researched green manure/cover crop. In spite of this, the biomass production of different mucuna accessions has been poorly quantified. Lack of systematic trials in contrasting environments, and the uncertain taxonomy of mucuna (Duke, 1981) have contributed to this situation. Evaluation of mucuna accessions is imperative, however, because of the role biomass production plays in determining benefits (soil and yield improvement, as well as weed suppression) derived from the incorporation of mucuna in the farming system (Carsky *et al*., 1998).

The taxonomy of the genus *Mucuna* is confused (Duke, 1981; Carsky *et al*., 1998). The genus is at times referred to as *Stizolobium*, and there has been disagreement over the correct categorization of accessions within the genus. In recent decades,

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both Kay (1979) and Wilmot-Dear (1984) have suggested that a number of accessions that were previously treated as species within the genus *Mucuna*, such as *M. deeringiana*, *M. utilis*, *M. cochinchinensis*, *M. aterrima*, *M. nivea*, and *M. hassjoo*, be considered as varieties of *Mucuna pruriens*. In later literature, however, mucuna types frequently are referred to by their place of origin and/or by seed colour (Carsky *et al*., 1998; Lorenzetti *et al*., 1998). Recent evidence on the variability of L-dopa concentration in mucuna seeds of white, black, speckled (i.e. mottled) and stippled colour suggests that genetic variation does exist between types differentiated by seed colour (Lorenzetti *et al*., 1998). Additional evidence of genetic variation is provided by research conducted at the International Institute of Tropical Agriculture (IITA) in Nigeria, where response to fertilization varied among seed colour types (Sanginga *et al*., 1996; Tian and Kang, 1998; Tian *et al*., 1998).

In the Los Tuxtlas region of southeastern Veracruz, Mexico, farmers most typically use either white or mottled mucuna seed and, often, plant a mixture of the two. Some mucuna with black seeds is also available. In Veracruz, the white and mottled mucuna types are otherwise indistinguishable: they share white flowers, relatively broad leaves, and similar seed weight. The Veracruz black type differs slightly, having purple inflorescences, more slender leaves, and seemingly slower initial development and lower seed weight. All types have silky and adpressed pubescence on the pods, causing no stinging or itching.

During an on-farm study that involved assessment of the farmer-practised maize-mucuna systems (Eilittä, 1998; Eilittä *et al*., 2003), farmers reported contradictory impressions of the performance of these three mucuna types. No quantification of biomass production has been conducted in the area, nor are data available characterizing mucuna varieties.

Maize yields in the Los Tuxtlas area are low due to poor soil fertility, pests and diseases, and management factors. The second-season maize yield is particularly low, reported to average only 0.50 t ha^{-1} (Buckles and Erenstein, 1996). Low and erratic rainfall and high winds typically limit second-season production. Observational data (Triomphe, 1996) and farmer adoption of mucuna throughout Mesoamerica, including Atlantic Honduras (Buckles, 1995), support the potential of higher main-crop yield in a rotational system where mucuna is grown during the first rainy season, is slashed, and the second-season maize crop is planted immediately. Such a system was spontaneously adopted by a small number of farmers in a few communities of the Los Tuxtlas region. However, mucuna promotion since 1992 in the region had focused on relay-cropping systems. Such systems provided seemingly minimal productivity impacts on first-season maize during their first years of use (Eilittä, 1998; Eilittä *et al*., 2003).

Because of the absence of data on possible impact of mucuna variety on biomass production, a field experiment was designed to compare the biomass production of white-, mottled-, and black-seeded types. An additional objective was to further examine the potential of a rotational system in which mucuna is sole-cropped in the main rainy season and slashed just prior to second-season maize planting.

MATERIALS AND METHODS

A general description of the study area, its climate, cropping practices, the principles behind trial design (i.e. mimicking farmer management), and data analysis can be found in Eilittä *et al*. (2003). The trial compared the biomass production of the three mucuna types available in the region (identified by seed colour – white, mottled and black) when sole-cropped during the first growing season, and their subsequent impact on second-season maize crop yield. The trial design was a randomized complete blocks, with two blocks per field. Plot size was 5 × 5 m.

The trial was conducted in the first season of 1996 in 11 fields located in five communities: Santa Rosa Cintepec (three fields), La Candelaria (three fields), Salto de Eyipantla (two fields), Soteapan (one field), and San Fernando (two fields); and in the first season of 1997 in five fields: in La Candelaria (three fields) and Santa Rosa Cintepec (two fields). In 1996, fields were chosen both to represent a diversity of farming conditions in the region and farmer interest. In these fields, soil phosphorus (P) (Mehlich I) varied between 1.8 and 9.8 mg kg^{-1} (average 3.8 mg kg^{-1}) and potassium (K) between 28.5 and 177 mg kg^{-1}(average 96 mg kg^{-1}) at 0–150 mm. Farmer cooperation was extremely good and no sites were lost in 1996. Because the researcher was absent most of the first season of 1997, the experiment was continued only in two easily accessible communities with closest farmer cooperation. That year, one of the six fields was lost due to extreme weed infestation.

In early June 1996, dried plant residues were slashed with a machete and removed from the plots. The three mucuna types were planted at a spacing of 800 × 500 mm with two seeds per hill (50 000 seed ha^{-1}). As there is little mucuna sole-cropping in the region Eilittä *et al*. (2003), this planting pattern was modelled on the local bean planting pattern. Maize was planted at traditional density in a fourth plot of each replicate. Mucuna was weeded one month after planting, and seedling density counted. At two months after planting, percentage ground cover was estimated and mucuna plant height measured (in 1996 only). Immediately before second-season maize planting, mucuna and weed biomass were measured from a representative 1 × 1-m quadrat according to the method described in Eilittä *et al*. (2003). This trial was researcher-managed in the first season of 1996 and the 1996/97 second season, and farmer managed according to researcher's instructions in the first season of 1997; in other respects, the trial management did not differ in execution.

The second-season maize trial took place during 1996/97 only. It was conducted in seven of the 11 mucuna variety trial fields in the communities of Santa Rosa, La Candelaria, and Soteapan. Mucuna and maize plots were slashed late October-early November. Plant residues (mucuna, weeds and mulch) originating from each plot were kept within the plot. Mucuna that had grown outside the experimental area was removed. A traditional maize variety was planted at farmer planting pattern and density (30 000 seeds ha^{-1}, three seeds per hill). Maize was weeded manually as needed. Ear leaves of all maize plants in four to five hills were cut at tasseling, oven dried at 60–70 °C, and analysed for nitrogen (N) and P. To ensure yield estimates in the case of theft, maize ears were harvested from border rows (16 m^2) as green maize. Green maize cobs were counted and total weight taken. Grain was harvested from the interior nine hills (9 m^2) of each plot following the procedure described in Eilittä *et al.* (2003), which also describe the laboratory and data analyses conducted.

RESULTS

Mucuna variety trial

Sole-cropped mucuna grew quickly. By two months after planting, mucuna had reached almost 100 % ground cover in the fastest-growing fields, and had begun shedding lower leaves, presumably due to shading by the upper leaves. Such shedding intensified greatly with the advancing season, forming a uniform mulch layer in most fields by slashing time. As much of the crop residues had been cleared prior to mucuna planting, typically 80–90 % of the mulch layer was of mucuna origin. During 1996, in the fields with highest biomass, mucuna produced up to almost 5 t ha^{-1} live dry matter, and 11 t ha^{-1} total dry matter during its four-month growing period. Only the average pod weights remained very low (0.04–0.11 t ha^{-1} dry immature pods), as the mucuna was slashed typically at an early flowering stage. In many plots, no pods were produced.

There were no differences in mucuna biomass between white and mottled types for any of the biomass fractions or for total mucuna biomass (above-ground including mulch), which totalled 7.90 t ha^{-1} for the white, and 7.94 t ha^{-1} for the mottled variety. In contrast, total mucuna biomass was 1.07 t ha^{-1} lower for the black variety than for the white and mottled varieties (Table 1). Variability in pod weight was extremely high. Weeds averaged a mere 10 % of the total biomass; in five fields, live weeds constituted less than 5 % of the total biomass. Weed weight did not differ by mucuna variety, but high variability characterized this fraction.

Field effects were significant for all fractions measured, but there was no field × treatment interaction for any fraction. In low-yielding fields, the poor growth of first-season maize in areas adjacent to the experimental plots (estimated maize yields 0.50 to 0.80 t ha^{-1}) suggested poor soil fertility conditions. Total mucuna biomass production was almost 5 t ha^{-1} across these low-yielding fields, about half that obtained in fields with higher fertility. Live mucuna biomass (leaf, stem and pod) ranged between 1.84 and 4.89 t ha^{-1} in the 11 fields. A large part of the mucuna biomass consisted of

Table 1. Biomass (t ha^{-1}) of three mucuna varieties. Data are means across 11 fields in 1996.

Variety	Leaf	Stem	Mulch	Pod	Weed	Total mucuna biomass†
White	1.08	2.43	4.28	0.11	0.59	7.90
Mottled	1.00	2.25	4.63	0.07	0.75	7.94
Black	0.89	1.95	3.97	0.04	0.90	6.85
s.e.	0.044	0.116	0.294	0.018	0.097	0.355

†Above-ground mucuna biomass including mulch.

Table 2. Nitrogen and phosphorus content ($\mathrm{kg\,ha^{-1}}$) in weed and mucuna biomass from plots of three mucuna varieties. Data are means across 11 fields in 1996.

	Nitrogen		Phosphorus	
Variety	Weed	Leaf + stem + mulch	Weed	Leaf + stem + mulch
White	12	172	1.0	6.6
Mottled	16	169	1.4	6.2
Black	18	148	1.6	5.5
s.e.	2.2	8.1	0.20	0.27

Table 3. Biomass ($\mathrm{t\,ha^{-1}}$) of different fractions for three mucuna varieties. Data are means across five fields in 1997.

Variety	Leaf + stem	Mulch	Pod	Weed	Total mucuna biomass†
White	2.33	4.10	0.24	0.66	6.67
Mottled	2.57	4.00	0.26	0.55	6.80
Black	2.06	2.80	0.02	1.07	4.90
s.e.	0.208	0.261	0.024	0.143	0.361

†Above-ground mucuna biomass including mulch.

mulch, with field averages ranging from 3.97 to 4.28 $\mathrm{t\,ha^{-1}}$. Total mucuna biomass production in flat fields significantly exceeded that in sloping fields, attesting to the fact that environments favouring maize production favour mucuna as well. As a consequence, field-level correlation was high ($r^2 = 0.85, p = 0.032$) between first-season total mucuna biomass and second-season maize yield in the control plots where no mucuna had been grown.

Total mucuna biomass contained an average of 172 $\mathrm{kg\,ha^{-1}}$ N for the white and mottled mucuna types (Table 2). The N content of the black mucuna type was 24 kg $\mathrm{ha^{-1}}$ less. Mucuna contained approximately 6 $\mathrm{kg\,ha^{-1}}$ P; the P content of black mucuna was slightly less than that of white and mottled types (Table 2). The N content (kg $\mathrm{ha^{-1}}$) of the weed fraction tended to be greatest for the black type (Table 2) because of a trend to higher weed yield.

In 1997, the trial was conducted only in five fields in two communities. The average total biomass production was about 1 $\mathrm{t\,ha^{-1}}$ lower than in 1996. Such a difference occurred largely because planting in 1997 was delayed until early July due to late rains. Moreover, some of the higher-yielding fields of 1996 were not included and there may have been greater weed competition in some fields. Total biomass averaged 6.67, 6.80, and 4.90 $\mathrm{t\,ha^{-1}}$ for the white, mottled, and black varieties respectively; this total was significantly lower for the black variety than for the others (Table 3). As in 1996, no differences were found in any individual fraction between the white and mottled mucuna types, while the black variety produced less mulch and pod. There were no differences among varieties in the combined leaf and stem fraction, while weed biomass was greater in plots with the black mucuna type, presumably due to the poorer mucuna growth.

Table 4. Second-season maize yield ($t\,ha^{-1}$) and ear leaf nutrient concentration (%) after three sole-cropped mucuna varieties. Data are means across seven fields in 1996–97.

Variety	Maize yield	N	P
White	1.63	2.2	0.19
Mottled	1.46	2.3	0.20
Black	1.29	2.2	0.19
Control	0.97	2.1	0.21
s.e.	0.070	0.05	0.005

Second-season maize trial

Second-season maize was planted only after the 1996 variety trial, i.e. during the second season of 1996/97. Second-season maize yields were higher after first-season mucuna (1.46 $t\ ha^{-1}$) than after a first-season maize crop (0.97 $t\ ha^{-1}$) (Table 4). Throughout the growing season, mucuna and no-mucuna plots could be differentiated by maize leaf colour and plant height. Yields were unusually high for second-season maize in the study communities in 1996, attesting to the year's favourable second-season growing conditions and the generally high production levels in some fields. The average 50 % yield increase due to mucuna occurred despite a long, 10-d lag time between mucuna slashing and second-season maize planting, as dry weather forced postponement of the maize planting.

Maize yield averaged 1.63 $t\ ha^{-1}$ when second-season maize was planted after white-seeded mucuna, while yields after the mottled type were 1.46 $t\ ha^{-1}$, and after the black type were 1.29 $t\ ha^{-1}$. No difference in maize yield was detected between white and mottled mucuna types. Maize yield after white and mottled mucuna exceeded that after black mucuna by an average of 0.26 $t\ ha^{-1}$.

Maize production differed significantly among fields and there was a trend toward field-by-treatment interaction. The highest-yielding field averaged 2.56 $t\ ha^{-1}$ of maize grain, while the lowest-yielding field produced 0.67 $t\ ha^{-1}$. At the field level, the percentage increase in yield as a result of added mucuna ranged from 32 to 86 %. In two of the experimental fields, however, no difference was detected between the treatments with prior mucuna and prior maize. In one of these fields, the experimental area was highly variable while the other was greatly affected by winds, and the resulting lodging may have obscured the treatment response.

Ear-leaf N concentration was slightly higher in the mucuna treatments than in the no-mucuna control, but P tended to be higher in the control (Table 4). No differences in ear-leaf N and P concentrations were detected among mucuna varieties. These average figures are very low, however, at 2.2 and 0.20 % for N and P respectively, and well below the critical values of 3 % and 0.25 % suggested by Jones *et al.* (1990).

Green maize, harvested from the border rows, gave relatively good estimates of final grain yield when a correction factor was used ($r^2 = 0.81$) (Fig. 1). In areas where crop theft is common or grazing cattle endanger final crop harvests, this technique can be used to minimize risk of loss of data.

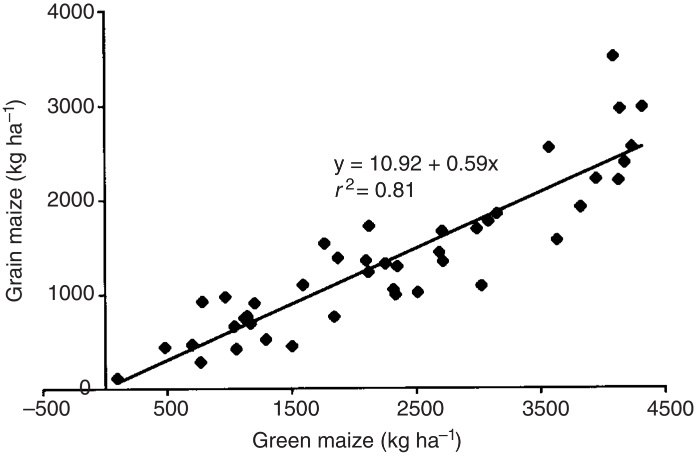

Fig. 1. Relationship between green and grain maize yield (kg ha^{-1}) in the experimental plots.

DISCUSSION

All three mucuna varieties generated large biomass yields when sole cropped during the first season. In the highest-producing fields, biomass production (at 11 t ha^{-1} including mulch) was comparable to average mucuna biomass in Atlantic Honduras, where mucuna has been cultivated for decades (Triomphe, 1996). This biomass is also comparable to those obtained under experimental conditions (Carsky *et al.*, 1998). The large variability in biomass production among fields confirms earlier findings that production is clearly higher in more fertile soil (Tian and Kang, 1998; Tian *et al.*, 1998). Mucuna competed effectively with weeds in most fields with a single weeding performed one month after mucuna planting. Similarly, weed biomass measured in Atlantic Honduras was very small (Triomphe, 1996).

In 1997, average biomass production was approximately 1 t ha^{-1} lower than in 1996 for the white and mottled types, and about 2 t ha^{-1} lower for the black types. Yield responses during both study years indicated that production potential of the black type is somewhat less than of white and mottled types. Though the black seeds germinated less well under field conditions (approximately 62 % as compared with 84 % for the others) and regression between plant density at one month and percent canopy ground cover at eight weeks after planting was significant ($p = 0.001, r^2 = 0.279$), by slashing time plant density was not important in explaining total mucuna biomass. In contrast, field observations suggest that the black variety grew more poorly and its morphology, thinner stems and seemingly smaller leaves, may have accounted for some of the difference. The black mucuna type also exhibited a slower initial development. The lower pod weight of the black type at the biomass measurement stage may suggest slower development still at slashing time, but no firm conclusions can be made. Poorer performance of the black variety has been observed by farmers in Oaxaca, where mucuna has been spontaneously adopted (Narváez and Paredes, 1994). At IITA, Sanginga *et al.* (1996) reported poor performance of the black variety both with and without P in a degraded soil, while Tian *et al.* (1998) found high biomass production of the black variety. Due to uncertainty about the true identity of the accessions, it is not known whether the variety used at IITA is identical to that in Veracruz. More recently, Chikoye and Ekeleme (2000) reported low leaf area index (LAI) and ground cover by the black-seeded variety from Veracruz, while the LAI and ground cover of the white- and mottled-seeded Veracruz varieties were some of the highest. Difference in biomass production was less clear. These results do, however, suggest that white and mottled mucuna types cultivated in Veracruz produce higher biomass than the black mucuna type. Further, when sole cropped during the more humid first season in the Los Tuxtlas, any of the three mucuna types produces sufficient biomass to increase second-season maize yield.

The similarity of biomass production of white and mottled types, and the fact that except for their seed, they are virtually indistinguishable from each other, raises the possibility that no other difference between them exists. Indeed, preliminary results from a one-year mucuna characterization trial at IITA indicated that both mottled- and white-seeded mucuna produced seeds that were 50 % white and 50 % mottled, while the black-seeded mucuna produced only black seed (Carsky *et al.*, 1998). The IITA characterization trial also lent support to the somewhat slower development of the black variety, whose time to flowering was 158 d while that of white was 143 d, and that of mottled, 146 d. The results of this trial need to be interpreted with caution because the black-seeded variety was produced in a different field and it differed in germination from the white- and mottled-seeded varieties.

The 1996/97 maize yield data confirm the findings of the trial comparing different maize-mucuna systems (Eilittä *et al.*, 2003), regarding the potential for large relative second-season maize yield increases in rotational systems (approximately 30, 50, and 60 % higher yields in the black, mottled and white plots, respectively, than in the control plots). Such a yield increase by mucuna is typical of those reported in the literature for the rotational systems (Carsky *et al.*, 1998). Even with the additional N from the mucuna mulch, the maize in the trial was still clearly deficient, presumably as a result of poor soil fertility and growing conditions in the second season.

The rotational maize-mucuna system in the Los Tuxtlas region of Veracruz allows for a high mucuna biomass production and, subsequently, a strong positive impact on the second-season maize crop. Moreover, such a system seems to be congruent with the traditional practice of not burning fields prior to second-season maize planting. However, forgoing first-season maize production by allocating the more beneficial first season to mucuna production, and the unpredictable, generally less favourable second season to maize production is a risky strategy for the region's farmers. Indeed, for several years before soil fertility declines greatly, total annual maize yield is likely to be higher in the no-mucuna cropping system where only first-season maize or first- and second-season maize are produced. However, as pointed out by Eilittä *et al.* (2003), first-season mucuna may have potential as a short fallow, taking place in only a portion of a farmer's land (excluding those where second-season maize is riskiest), that also permits at least some maize production. The rotational system's potential may also be improved further through on-farm research efforts focusing on short-season maize varieties that would reach maturity before the driest months and the addition of relatively small amounts of inorganic fertilizers.

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