Introduction of Legumes in the Pastures on Oxisols in the Eastern Colombia Plain Using Macro-Pellets

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ABSTRACT

One of the authors developed a new type of seed-pellets, "macro-pellets" with are almond-sized matrix fertilizers with the legume seeds stuck on the surface by an adhesive. The effect of the macro-pellets on the establishment of introduced legumes was examined in a native savanna and in an improved pasture dominated by *Brachiaria humidicola* in the Llanos Orientales of Colombia. The macro-pellets were placed at a very low density in both pastures, with different methods of land preparation.

The use of the macro-pellets resulted in a satisfactory early establishment of legume seedlings, regardless of the differences in land preparation in both pastures. Although *Centrosema brasilianum*, grew vigorously after early establishment, it was selectively consumed by the grazing animals, so that the coverage was markedly reduced during the dry season. *Desmodium ovalifolium*, which was slightly less palatable during the rainy season, gradually invaded the pasture dominated by *B. humidicola*, and covered more than 60% of the whole area under minimum tillage 16 months after planting. Under the macro-pellet system adopted in the experiment, even a very low application rate of chemical fertilizer was effective enough to secure the growth of legumes.

Introduction

In the American tropics there are approximately 200 million hectares of under-utilized savanna land of which 80% is predominantly well-drained. The major soils on the well-drained land consist of various groups of Oxisols. In general, Oxisols are very acid with high exchangeable aluminium levels, very low exchangeable base capacity and very low phosphate availability (Cochrane *et al.*, 1985).

In the lowlands of eastern Colombia, approximately 12 million hectares of well-drained Oxisols covered with savannas on very flat to gently undulating land are used as grasslands with scattered trees and fingers of forest along the creeks and rivers. Traditionally, the grasslands were almost exclusively used for extensive beef cattle ranching. Dominant grasses in the savanna are *Trachypogon* spp., *Andropogon* spp., etc. (Blydenstein, 1967). The contents of N, P, Ca, Mg, etc. in these grasses are low reflecting the low fertility of the soils. The nutritive value and palatability become extremely low at the time of grass regrowth wich reached 35 cm or more of the plant height after burning. The liveweight of the grazing animals decreases by about 25 kg during the dry season due to the marked decrease of the nutritive value of the grasses. Animal productivity is very low in the savanna (Palandines and Leal, 1978), that is, annual liveweight gain is approximately 75 kg/ha and carrying capacity 0.2 AU/ha. The low nutritional value of the native grasses also results in a decrease of the reproduction rates for beef cattle.

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The studies carried out at CIAT led to the conclusion that animal production markedly increased when the animals were grazed on improved pasture (CIAT, 1987). However, the traditional methods of pasture improvement involve the use of a large quantity of fertilizer and lime to improve the fertility and reduce the acidity of the soil. In the traditional method in which heavy offset-disk is used to prepare the seed-bed and control the native plants, the cost of fertilizer and tillage is high (Spain, 1978). Furthermore, since the land is located far from urban areas and lacks access roads, the transportation of the materials for pasture establishment is costly. Therefore, the studies carried out at CIAT have been focused on the reduction of cost and risk of soil erosion during the period of establishment (Sanchez and Salinas, 1981 ; Spain *et al.*, 1985). The principal strategy for low-cost pasture establishment aims at the reduction of the cost of land preparation, fertilizer, seed and planting. The system of establishment of the forage species by surface sowing at a low density and application of a small amount of fertilizer on the undisturbed savanna is one of the effective low-cost improvement methods. However, this method cannot be applied successfully in the savanna.

Surface sowing of seeds coated with fertilizer showed some advantages in pasture establishment (Hirota *et al.*, 1989 ; Silcock and Smith, 1982), but the effectiveness of the fertilizer used for coating was negligible (Cook, 1980). To improve the nutritional conditions of the seedlings for a long period of growth, a large amount of fertilizers must be used, resulting in a thick coating layer of concentrated fertilizer. However, such coating impairs germination and is associated with chemical injury to the seedlings. In practice, therefore, the coating layer should be thin and soft, and the amount of fertilizer should be limited. One of the authors developed a new type of seed preparation i. e. seeds stuck on the surface of matrix fertilizer, almond-sized, using on adhesive hereafter abreviated to "macro-pellets", (Fig.1) (Mitamura *et al.*, 1988).

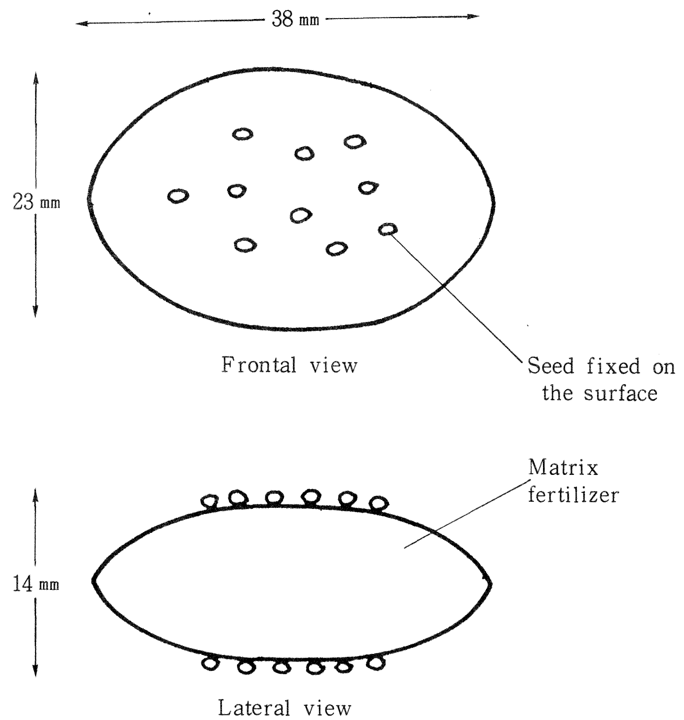


Fig. 1 Schematic representation of the macro-pellet tested at Carimagua in 1985-1988.

The macro-pellets are different from the seeds coated with fertilizer, as mentioned above. They do not impair germination or cause chemical injury to the seedlings by direct contact with fertilizer elements at a high concentration both of which often occur when seeds are coated with fertilizer. Therefore, for the preparation of the macro-pellets, high analysis fertilizers should be used. By using fertilizers consisting of nutrient sources with slow solubility, the effect of the macro-pellets may last for a long period of time to promote seedling growth.

The introduction of legumes in a savanna and/or an improved pasture dominated by grasses should contribute not only to the increase of the production and improvement of the quality of companion grasses through fixation and transfer of nitrogen, but also to the increase of animal production through direct consumption of legumes by cattle, particularly in the dry season. Therefore the introduction of legumes in the pastures is especially important for pasture improvement (Maeno, 1985). Although many legumes appeared to be compatible with high-yielding, acid soil-tolerant grasses in the savannas or in the grass-based improved pastures, the introduction of the legumes cannot be maintained for a long period of time. Hence, the effect of the macro-pellets on the introduction and establishment of legumes was examined in a native savanna and in an improved pasture dominated by *Brachiaria humidicola*.

Materials and methods

Experiment 1 (Introduction of legumes in the native savanna)

1 Experimental sites and climate

The experiments were carried out at the National Agricultural Research Station of ICA at Carimagua in the Llanos Orientales (4.5° North latitude and 71° West longitude). The station is located at 175 m above sea level with a mean annual temperature of 26 °C and precipitation of 2,280 mm. Fig. 2 shows the monthly rainfall and mean monthly temperature at the station. The rainy season normally lasts from April until the and of November, and

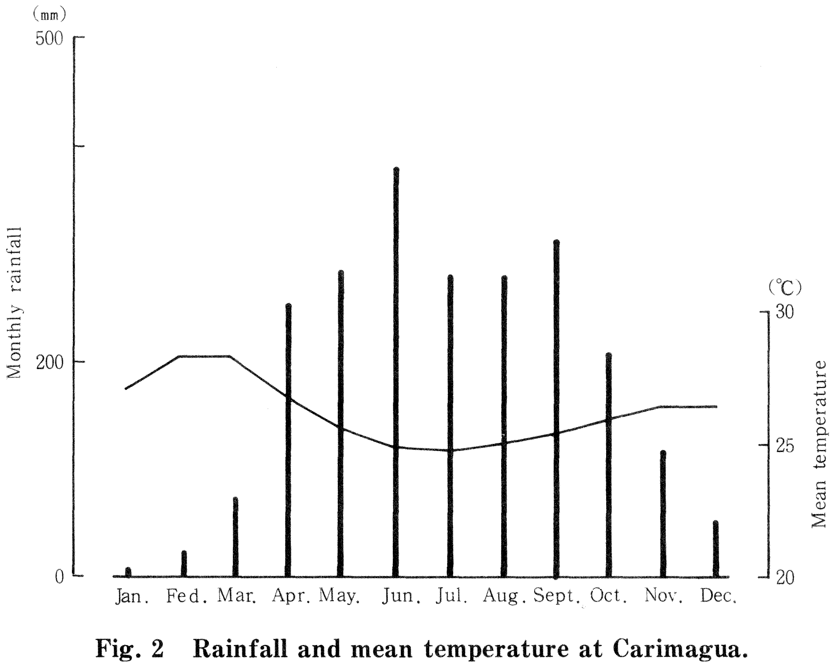


Fig. 2 Rainfall and mean temperature at Carimagua.

the temperature fluctuations are small throughout the year. The two experimental sites were located in the native savanna in this area. The soils at both sites are Oxisols, one consisting of sandy loam and the other of clay loam. Physical and chemical properties of the soils are listed in Table 1. Both soils were acidic, showing a high level of aluminum saturation and a low level of available phosphorus. The sandy loam soil was characterized by a low water-holding capacity.

Table 1 Physical and chemical properties of the soils in the experimental fields

	Horizon (cm)	Clay (%)	Sand (%)	pH (H_2O)	OM (%)	Exchangeable cations (meq/100g)					Al saturation (%)	Available P Bray II (ppm)	Three phase distribution of soil		
						Al	Ca	Mg	K	CEC			Solid	Liquid	Air(%)
Clay loam	0—5	33	12	5.3	3.7	2.2	0.3	0.1	0.1	2.7	83	3.0	43.6	32.1	24.3
	5—10	34	11	5.1	2.1	2.2	0.2	0.1	0.1	2.5	89	2.1	44.5	33.3	22.2
	10—15	36	11	5.1	2.5	2.0	0.1	0.0	0.0	2.2	90	1.3	45.9	33.8	20.4
	15—20	37	10	5.2	2.1	1.8	0.2	0.1	0.0	2.0	88	0.9	43.4	29.9	25.8
Sandy loam	0—5	19	57	5.0	1.4	0.8	0.2	0.1	0.1	1.1	73	2.4	53.5	19.2	27.3
	5—10	20	56	5.3	1.1	0.8	0.1	0.0	0.0	1.0	80	1.9	54.2	19.0	26.8
	10—15	23	56	5.2	1.2	0.8	0.1	0.0	0.0	1.0	80	1.3	53.7	19.5	26.7
	15—20	23	56	5.0	0.8	0.7	0.1	0.0	0.0	0.9	78	1.6	53.9	19.3	26.7

2 Seed-bed preparation

Prior to the field trial, the whole area of the savanna was burned at the end of August, 1985. The following three treatments were applied to prepare the seed-beds: 1) Control, no further treatment; 2) Herbicide, Glyphosate solution was sprayed on each planting spot (50cm ϕ), 30days before sowing; 3) Tillage treatment, minimum tillage which was adopted consisted of one pass of chisel plough, early in September.

3 Macro-pellets

The chemical composition of the matrix fertilizer used is shown in Table 2. It was almost identical with the recommended composition of nutrients for pasture establishment in Carimagua. The matrix fertilizer was highly compressed to reach an almond shape. The pellets weighed 13.8 g each. Twenty seeds of *Stylosanthes macrocephala*, 10 seeds of *Pueraria phaseoloides* and 5 seeds of *Centrosema acutifolium* were separately stuck with a water-soluble adhesive on the surface of the matrix fertilizer.

Table 2 Chemical composition of fertilizers used for the macro-pellet

Common name	Chemical formula	Mineral composition (%)					
		N	P	K	Ca	Mg	S
Multiphosphate	$Ca(H_2PO_4)_2H_2O$, $CaHPO_4 \cdot 2H_2O$, $MgHPO_4 \cdot 3H_2O$	0.0	13.0	0.0	10.7	4.8	0.0
Potassium silicate	$K_2MgSi_3O_6$	0.0	0.0	8.6	5.7	2.4	0.0
Potassium sulphate	K_2SO_4	0.0	0.0	44.8	0.0	0.0	18.3
Gypsum	$CaSO_4 \cdot 2H_2O$	0.0	0.0	0.0	20.3	0.0	16.3
Total composition (%/pellet)*		0.0	5.2	5.0	9.2	3.0	2.2

* Contains 40.0% multiphosphate, 46.3% potassium silicate, 2.3% potassium suphate, and 11.4% gypsum.

4 Sowing of forage legumes

1) Macro-pellets were placed on the soil surface at 1 m distance between 30 cm rows in

early October. 2) Granular fertilizer was applied to each spot (10 cm) and the seeds were sown at the fringe of the applied fertilizer. The amounts of fertilizer elements in the granular fertilizer were the same as those of the matrix fertilizer, and the number of seeds sown was the same for both cases.

Experiment 2 (Introduction of legumes in sown pasture)

1 Experimental site

This site was close to the sandy loam stie of Experiment 1. Physical and chemical properties of the soil in Experiment 2, therefore, were almost the same as those in Experiment 1.

2 Experimental design

The experimental field was originally a degraded grass-based pasture of *B. humidicola* established in 1980. The size of the field was 1.8 ha.

3 Seed-bed preparation

Prior to the field trial, the whole area of the pasture was burned at the end of July 1986, two weeks before the seed-bed perparation. Three types of seed-bed preparations were tested in this experiment : minimum tillage with and without chemical grass-control. Minimum tillage was performed by one pass of chisel plough. The chemical grass-control plot was subjected to spot-application of Glyphosate solution (1m ϕ).

4 Application of macro-pellets with legume seeds

Thirty seeds of *Desmodium ovalifolium*, 12 seeds of *Centrosema brasilianum* and 6 seeds of *Arachis pintoi* were separately stuck on the surface of the matrix fertilizer. The macro-pellets were placed on 2 August 1986, one week after seed-bed preparation. The planting density was 2,500 pellets/ha.

5 Grazing management after planting

Intermittent grazing was repeated with cattle in the pasture during the period September 1986 to 1987 until the introduced legumes were well established. From June 1987, in order to evaluate the animal productivity in the pasture to which legumes had been introduced, heifers were grazed on the enclosed pasture. The stocking rates in this system were 3.3 and 2.2 heifers/ha during the rainy season and during the dry season, respectively.

Results and discussion

1 Introduction of legumes in the seavanna (Experiment 1) (Mitamura *et al*., 1988).

Heavy rain occurred twice during the first week after planting. There was almost no rainfall after the end of November, when the dry season normally began. Table 3 shows the percentage of sowing spots where seedlings grew to the total number of sowing spots and the percentage of the number of growing seedlings to the total number of seeds sown. As shown in Table 3, it was clearly observed that the use of the macro-pellets was very effective in promoting seed-germination and seedling establishment of the three legume species under three different seed-bed conditions (untreated seed-bed as control, seed-bed treated with herbicide, and tillage).

The beneficial effect of the macro-pellets on germination and early establishment was ascribed to the following three factors. First, favourable microenvironmental conditions were present at the interface between the bottom of the macro-pellets and the surface. Seeds were protected form strong sunshine and prevented from drying out. Second, since the matrix fertilizer served as an "anchor" over the seeds, the radicles were able to penetrate

Table 3 Effect of macro-pellet sowing on the number of sowing spots with growing seedlings (expressed in % of the total number of sowing spots) and on the number of growing seedlings (expressed in % of the total number of seeds sown)* observed 2 months after sowing

Soil	Species	No treatment	Herbicide application		Tillage	
		Macro-pellet	Macro-pellet	Spot sowing	Macro-pellet	Spot sowing
Clay loam	*S. macrocephala*	98.3(25.1)*	93.3(30.3)	81.7(19.5)	100.0(39.0)	100.0(31.8)
	C. acutifolium	100.0(70.7)	94.2(70.7)	60.0(30.0)	100.0(61.3)	100.0(63.3)
	P. phaseoloides	91.7(28.3)	90.0(27.3)	43.3(7.3)	98.3(35.3)	96.7(34.7)
Sandy loam	*S. macrocephala*	95.0(32.7)	96.7(28.3)	68.3(7.0)	93.3(15.3)	98.3(23.0)
	C. acutifolium	91.7(31.3)	83.3(38.0)	5.0(1.3)	100.0(77.3)	86.7(61.3)
	P. phaseoloides	68.3(17.0)	71.7(17.0)	11.7(2.0)	100.0(34.0)	98.3(39.0)

more easily into the soil than in the case of seeds loosely placed on the soil surface. Third, the seeds beneath the matrix fertilizer were also protected from heavy rain and were not easily washed away.

The establishment of surface-sown *S. macrocephala* was better than that of other species, presumably because the seeds of the former germinated more rapidly. They were small and flat so that they tended to fall into small soil cracks where the moisture level was higher than that on the soil surface. On the other hand, in the sandy loam site the early establishment of *C. acutifolium* and *P. phaseoloides* in the spot-sown plot with herbicide was remarkably low due to the thickness of the radicles of both legumes which prevented them from penetrating easily into the sandy loam with a small pore volume (Table 1). Tillage increased seedling establishment in both the spot-sown plot and the macro-pellet plot. The increase was greater in the former plot (Table 3) because the seeds sown on the tilled soil were entirely or partially buried in the soil, resulting in an increase of the seed-soil contact area which facilitated the penetration of the radicles into the soil. The seeds were also prevented from being washed out by heavy rain. On the other hand, since in the macro-pellet plot the macro-pellets themselves exerted a beneficial effect, it was natural that the effect of tillage was not conspicuous in the macro-pellet plot.

The effect of herbicide treatment on early establishment was not clear either in the macro-pellet plot or in the spot-sown plot, possibly due to the low density and limited competition of native grasses in the experimental site and the growth of the introduced legumes was likely to be affected after native grasses resumed growth and became larger.

2 Introduction of legumes in sown pasture (Experiment 2) (Ogawa *et al.*, 1990)

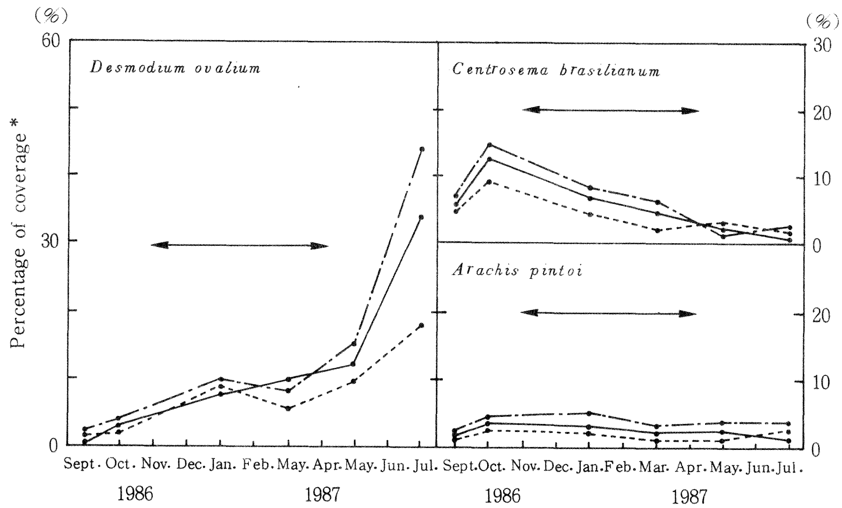
Brachiaria spp. are one the promising grasses that are well-adapted to Oxisols in tropical America, although their compatibility with legumes is low due to their aggressive growth habit (CIAT, 1986. Cochrane *et al.*, 1985., Maeno, 1985). The nutritive value of *Brachiaria*-based pastures is somehow low and the pasture becomes gradually degraded due to the low fertility of the soils. This study was carried out to improve the sown pasture domisated by *B. humidicola* with the introduction of legumes using macro-pellets. Table 4 shows the effect of the tillage and grass control with herbicide on the establishment of the legumes under the macro-pellet system in the grass-based pasture of *B. humidicola*. The use of the macro-pellets resulted in a satisfactory early establishment of the legumes regardless of the differences in the method of seed-bed preparation, with the exception of *A. pintoi* introduced in the no-tillage plot with chemical grass control, presumably because their thick radicles had failed to penetrate into the soil. *C. brasilianum* grew vigorously after early establishment, but was

Table 4 Effect of tillage accompanied by chemical grass control on the establishment of legumes planted with the macro-pellet in the grass-based pasture of *Brachiaria humidicola*, one month after planting (Planting date : 2 Aug. 1986)

Legumes	Percentage of establishment[2)]		
	I [1)]	II	III
Desmodium ovalifolium	90.5	95.2	86.9
Centrosema brasilianum	92.9	92.9	78.3
Arachis pintoi	90.5	95.3	51.2

1) Tillage and grass-control with herbicide
I Minimum tillage with chemical control.
II Minimum tillage without chemical control.
III No tillage with chemical control.
2) Percentage of macro-pellets with viable legume seedlings against the total number of the macro-pellets planted.

damaged by selective grazing. *A. pintoi* could not expand its coverage due its poor abillity to compete with *B. humidicola*. The coverage of *D. ovalifolium* gradually expanded under grazing, and 16 months after planting, it exceeded 60% of the whole area of both plots under the minimum tillage system with and without chemical grass control, while a much lower coverage was observed in the plot of the no-tillage plot with chemical grass control (Fig. 3). This observation indicated that the combination of *D. ovalifolium* with minimum tillage would be the most adequate practice for introducing legumes in the pasture using macro-



Minimum tillage with chemical control
Minimum tillage without chemical control
No - tillage with chemical control
Dry season.

Fig. 3 Effect of tillage and vegetation control with herbicide on changes of the coverage of legumes under grazing in the grass-based pasture of *Brachiaria humidicola*.
*** Estimated in a 1 × 1m quadrate centered around the macro-pellet.**
Planting date : 2 Aug. 1986.

pellets.

Regarding the productivity of the animals, liveweight gains obtained in the pasture during the three grazing peridos are presented in Table 5. In the first and second grazing periods during the dry season, the cattle exhibited low weight gains (174 and 131 g/AU/day) under the stocking rate of 1.4 and 1.1 AU/ha. However, these data do not imply that cattle productivity was low, because it is generally recognized that animals stocked in a grass-based pasture of *Brachiaria* spp. do not gain, or even occasionally lose weight during the dry season at Carimagua. Significant gains of the liveweight (938 g/AU/day) were obtained during the third period early in the wet season under the higher stocking rate of 1.8 AU/ha.

Table 5 Liveweight gain in the pasture of *Brachiaria humidicola* + *Desmodium ovalifolium* association under the alternate grazing system

Grazing period	Grazing days	Stocking rate (AU[1]/ha)	Liveweight gain (g/AU/day)
I Nov. 1987～Jan. 1988	59	1.4	174
II Jan. ～April 1988	119	1.1	131
III April～July 1988	76	1.8	938

1) : AU (Animal unit) = 400 kg liveweight.

Based on these results, it is concluded that the introduction of *D. ovalifolium* with the macro-pellets could contribute significantly to the improvement of cattle productivity in the grass-based pasture of *B. humidicola*. Under the macro-pellet system adopted in this experiment, a very low application rate of chemical fertilizer (2.0 kg P/ha) was effective enough to secure the growth of legumes. In addition, the seed requirement of *D. ovalifolium* was 0.1 kg/ha. Since these requirements amounted to only 5 to 10% of those of the conventional method, such a low level of input may enable to reduce the cost of beef production.

Conclusion

It is anticipated that the macro-pellet method will play a key role in the introduction of legumes at low cost in a native savanna and/or grass-based improved pasture. *D. ovalifolium* is one of the promising legumes to be introduced in the pastures by using macro-pellets.

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