Scientific Paper

Effect of polycropping on the establishment of three tropical grasses, on a Vertisol soil of the Cauto Valley

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ABSTRACT: In order to evaluate the influence of polycropping on the establishment of grasses, on a Vertisol soil, three tropical grasses (*Panicum maximum* cv. Likoni, *Cenchrus ciliaris* cv. Biloela and *Chloris gayana* cv. Callide) and five legumes (*Vigna radiata*, variety mung bean; and *Vigna unguiculata*, varieties: Cubanita-666, Lina, INIFAT-93 and IITA precoz) were sown in polycrop and monocrop systems. The design was split plots, with four replications and 18 treatments. The crop combinations did not affect the pasture establishment. There was highly significant interaction ($p < 0,001$) in the seed yield of the grasses, as well as in the grain yield of the legumes; with outstanding results in their polycrops with *P. maximum* cv. Likoni, for the first case, and in *V. radiata* (mung bean) combined with *P. maximum* cv. Likoni and *Ch. gayana* cv. Callide, for the second one. All the combinations showed advantageous equivalent land use indexes, with values higher than one. It is concluded that the use of temporary legumes in polycrop with the grasses did not affect their establishment, and that the seed and grain harvest improved the biological efficiency during the process.

Key words: botanical composition, seed and grain yield, temporary legumes, land use index

INTRODUCTION

The objective of establishing a pastureland is to improve the animal production system so that the process turns out to be advantageous and fast. In this sense, a large diversity of alternatives has been traditionally used, which have allowed –in different ways and at different terms– the fulfillment of the proposed goals, but with a different economic connotation (Gómez, 2004). This process has been defined as one of the most costly investments in livestock production, in which the operations of clearing, soil preparation, cultural activities and seed preparation for sowing are considered the determining activities (Padilla and Ayala, 1986).

Vieito (2001) reported that the use of polycrops constitutes an agroecological practice that significantly increases seed supplies and contributes to the profitability of the establishment process of the pasture *Panicum maximum* cv. Likoni, while Leguía *et al*. (2008) and Ruiz (2011) reported other benefits on the physical condition of soils. On the other hand, emphasis is made on the importance of establishing a favorable combination among the soil and climate conditions with the agrotechnical factors and the characteristics of each variety, to achieve effectiveness in the establishment process of a pastureland (Wencomo and Ortiz, 2010).

The sowing of annual crops in pastures is acknowledged as an economic strategy for the establishment and renewal of pasturelands (Cordoví *et al*., 1999), in which the involved crops should have differences in their requirements, if the competitive coexistence with advantageous yields is to be achieved (Kolmans and Vázquez, 1996). Likewise, emphasis is made on the spatial arrangement of the crops, so that the intercropped or associated species, far from limiting the availability of nutrients, water and air for the base crop, contributes to provide part of these elements, with an efficacious use of the vertical space and that unused by such crop.

Based on the above-mentioned elements, the objective of this study was to evaluate the influence of polycropping on the establishment of three tropical grasses, on a Vertisol soil of the Cauto Valley.

MATERIALS AND METHODS

Soil. The trial was conducted for six months on a soil classified as Vertisol (Hernández *et al*., 2003), whose chemical composition is shown in table 1.

Table 1. Soil chemical composition.

P_2O_5	K_2O	MO (%)	N total (%)	pH (KCl)
mg/100 g of soil				
2,6	48,0	2,91	0,272	7,02

Climate. The climate of the region is classified as tropical, relatively humid (Barranco and Díaz, 1989), with an average rainfall of around 1 000 mm per year and a mean annual temperature of 26,0 ºC (minimum temperature of 19,7 ºC and maximum of 33, 0 ºC). The relative humidity is approximately 77 %; and the east-northeast and north-northeast winds prevail, with average speed of 11 km/hour (Rosell *et al*., 2003). The experimental stage was framed in the rainy season; however, the rainfall was only 341 mm.

Design and treatments. A split plot design was used, with four replications, and 18 treatments (table 2). They were defined from the combinations of five varieties of the *Vigna* genus: *Vigna radiata*, mung bean (a); Vigna unguiculata, variety Cubanita-666 (b); *V. unguiculata*, variety Lina (c); *V. unguiculata* variety INIFAT-93 (d) and *V. unguiculata*, variety IITA precoz (e); with three tropical grasses: *P. maximum* cv. Likoni (1), *Cenchrus ciliaris* cv. Biloela (2) and *Chloris gayana* cv. Callide (3). A control of each of the pastures, without intercropping, was also included. The legumes were also established in monocrop for determining the ELUI (equivalent land use index).

Plot size. A larger plot size, of 10 x 12 m (120 m^2), was used for each grass; while the smaller plot size was 2 x 10 (20 m^2), where the different combinations of intercropping and the control treatment were assigned.

Procedure. The soil preparation was performed through the alternative conventional method (Álvarez, 2011), with the application of plowing, medium and light harrow. The sowing was done through botanical seed in all the crops, with doses of 0,8; 3,4 and 7,6 kg/ha of pure germinable seed (PGS) for the grasses, *V. radiata* and *V. unguiculata*, respectively. In order to determine the PGS the formula recommended by Pérez *et al*. (2000) was used:

$$PGS = \frac{\text{purity (\%) x germination (\%)}}{100}$$

Table 2. Evaluated treatments.

No.	Treatments
1	*P. maximum* cv. Likoni + *V. radiata* var. mung bean
2	*P. maximum* cv. Likoni + *V. unguiculata* var. C-666
3	*P. maximum* cv. Likoni + *V. unguiculata* var. Lina
4	*P. maximum* cv. Likoni + *V. unguiculata* var. INIFAT- 93
5	*P. maximum* cv. Likoni + *V. unguiculata* var. IITA (precocius)
6	*P. maximum* cv. Likoni (control)
7	*C. ciliaris* cv. Biloela + *V. radiata* var. mung bean
8	*C. ciliaris* cv. Biloela + *V. unguiculata* var. C-666
9	*C. ciliaris* cv. Biloela + *V. unguiculata* var. Lina
10	*C. ciliaris* cv. Biloela + *V. unguiculata* var. INIFAT- 93
11	*C. ciliaris* cv. Biloela + *V. unguiculata* var. IITA (precocius)
12	*C. ciliaris* cv. Biloela (control)
13	*Ch. gayana* cv. Callide + *V. radiata* var. mung bean
14	*Ch. gayana* cv. Callide+ *V. unguiculata* var. S-666
15	*Ch. gayana* cv. Callide+ *V. unguiculata* var. Lina
16	*Ch. gayana* cv. Callide+ *V. unguiculata* var. INIFAT- 93
17	*Ch. gayana* cv. Callide+ *V. unguiculata* var. IITA (precocius)
18	*Ch. gayana* cv. Callide (control)

The separation between rows was 50 cm. The pastures and temporary crops, in the combined treatments were sown in alternate rows; while in the control of each pasture a row was left without sowing.

Plant management. A weed control was performed in all the treatments. Neither irrigation nor fertilization was applied during the experimental period (six months).

Measurements and observations. To evaluate the grass establishment, the plant number per square meter was observed at 45 days, by counting those that survived after germination. While the pasture cover (expressed in percentage) was determined through the dry weight range method, proposed by t'Mannetje and Haydock (1963), 180 days after sowing.

Regarding production, the pure seed yield was measured in the pasture accessions and the grain yield in the intercrops.

The seed harvest was performed manually, with a rice sickle. The spikes were placed in knitted polyethylene sacs and were moved to a room to complete the exudate, seed shedding, drying and processing. Afterwards, the seed lots of each plot were separately weighed and the yield was determined (kg/ha^{-1}).

To calculate the grain yield (kg ha^{-1}) the mature pods were harvested. They were dried under sunlight and the grains of each plot were weighed.

The biological efficiency of the polycrop use in the combinations was determined through the calculation of the ELUI (equivalent land use index), proposed by Casanova *et al*. (2001):

$$ELUI = \frac{Px}{Ux} + \frac{Py}{Py}$$

Where:

Px: yield of crop *x* in polycrop

Ux: yield of crop *x* in monocrop

Py: yield of crop *y* in polycrop

Uy: yield of crop *y* in monocrop

If: ELUI > 1, the polycrop is useful; ELUI < 1, it is not advantageous; ELUI = 1 the form of sowing is indifferent.

Statistical analysis. For the mean comparison a variance analysis was applied, according to the factorial arrangement and the Newman-Keuls test (1952).

RESULTS AND DISCUSSION

The number of plants per square meter 45 days after planting differed significantly ($p < 0,05$) among the treatments (table 3); the best result was obtained in the Likoni pasture, in combination with any of the intercropped temporary crops. Although the plant density per hectare was not high, it seems to be sufficient for a good establishment in all the crops, which coincides with the results reported by Benítez *et al*. (2003) when using a higher plant density in the cv. Likoni. The difference found in this indicator, among the species used, did not influence negatively their individual establishment. The best performance in the cover of pasture Likoni, with regards to Callide and Biloela, could have been due to the intrinsic characteristics of each cultivar and to its capacity of adaptation to Vertisol soils; which is supported by the results obtained by Gómez (2004), under similar conditions, after two years of evaluation.

Table 4 shows the botanical composition of the studied pastures. The most outstanding result was reached in Likoni when it was combined with *V. radiata*. This could have been related to the higher number of plants per square meter observed in this species (table 3), which allowed to increase the percentage of covered area at the end of the establishment. However, in all the grasses a

Table 3. Number of plants per square meter of the pasture species 45 days after sowing.

Factor A / Factor B	*P. maximum* cv. Likoni	*C. ciliaris* cv. Biloela	*Ch. gayana* cv. Callide	SE ±
V. radiata (mung bean)	23,7^{a}	14,0^{bc}	11,2^{bc}	
V. unguiculata var. C-666	23,2^{a}	13,0^{bc}	12,0^{bc}	
V. unguiculata var. Lina	21,5^{a}	12,5^{bc}	12,2^{bc}	0,61*
V. unguiculata var. INIFAT-93	22,2^{a}	11,8^{bc}	10,5^{c}	
V. unguiculata var. IITA (precocius)	21,0^{a}	14,8^{b}	13,0^{bc}	
Control grass	21,5^{a}	12,7^{bc}	12,2^{bc}	

a, b, c: values with different superscripts differ at $p < 0,05$ (Newman-Keuls, 1952). *$p < 0,01$

Table 4. Cover percentage of the pasture 180 days after sowing.

Factor B \ Factor A	*P. maximum* cv. Likoni		*C. ciliaris* cv. Biloela		*Ch. gayana* cv. callide		SE ±
	TD	RTD	TD	RTD	TD	RTD	
V. radiata (mung bean)	1,42[ab]	95,9	1,3 [de]	92,7	1,25[def]	90,2	
V. unguiculata var. C-666	1,37[bc]	94,4	1,29[def]	91,8	1,27[def]	90,9	
V. unguiculata var Lina	1,32[cd]	93,7	1,23[efg]	89,1	1,24[efg]	89,3	0,01**
V. unguiculata var. INIFAT-93	1,27[def]	91,1	1,18[gh]	85,1	1,26[def]	90,6	
V. unguiculata var. IITA (precocius)	1,28[def]	91,5	1,24[efg]	89,3	1,22[fg]	88,5	
Control grass	1,29[def]	91,8	1,22[fg]	88,3	1,13[h]	82,0	

TD: transformed data; RTD: re-transformed data; a, b, c, d, e, f, g: values with unequal superscripts differ at $p < 0,05$ (Newman-Keuls, 1952) $^{**}p < 0,01$. The data in percent are transformed according to arcsin √%

cover percentage higher than 80 % was achieved, which is accepted by the literature as an adequate indicator to consider a pastureland as established, four months after being sown (Machado and Olivera, 2003). Regarding this indicator and the yield of the studied grasses, Gómes (2004) reported the best results in Likoni, followed by Callide and Biloela, indicating that the phenotypic differences among the species can be strongly influenced by the genotype. For such reason, it is said that the productive and reproductive potential of pastures and forages depends on the individual capacity of the species and varieties, as well as on the agrotechnical, phytotechnical and management labors to which they are subject, and especially on the climate and soil conditions under which they grow (Gómez, 2004). This coincides with the report by Seguí (1996) about the influence of climate, edaphic and biotic factors on the distribution, adaptation, production and degree of utilization of the cultivated plants.

Seed yield had a highly significant interaction (p < 0,001) among the studied factors (table 5). The crop combinations with *P. maximum* cv. Likoni, as well as the control of the species, showed higher values than those found for the combinations with *C. ciliaris* Cv. Biloela and *C. gayana* cv. Callide, which is in correspondence with the cover percentages. On the other hand, these results could have been influenced by the intrinsic differences among these grasses regarding the physiological requisites for growth, flowering and maturity, which define the biological potential of the seed production of each species; while this potential is determined by other factors such as climate, soil type and incidence of pests and diseases (Ferguson *et al*., 1983).

Such results are in correspondence with those reported by other authors regarding the agroecological benefits and the economic feasibility of the use of polycrops with legumes in pasturelands (Vieito, 2001; Leguía *et al*., 2008).

Table 5. Seed yield of the pasture species (kg ha^{-1}).

Factor B \ Factor A	*P. maximum* cv. Likoni	*C. ciliaris* cv. Biloela	*Ch. gayana* cv. Callide	SE Inter.±
V. radiata (mung bean)	121,7[a]	52,2[cde]	64,8[b]	
V. unguiculata var C-666	116,6[a]	52 0[cde]	60,8[bc]	
V. unguiculata var Lina	112,7[a]	51,4[cde]	57,7[bcd]	3,62***
V. unguiculata var INIFAT-93	118,4[a]	48,4[de]	60,1[bc]	
V. unguiculata var IITA (precocius)	118,7[a]	46,2[e]	56,0[bcde]	
Control grasses	115,4[a]	51,2[cde]	52,9[cde]	

a, b, c, d, e: values with unequal superscripts differ at $p < 0,05$ (Newman-Keuls, 1952)
$^{***}p < 0,001$.

In grain yield, *V. radiata* (mung bean) showed the best performance and significantly exceeded (p < 0,001) the other intercropped legumes (table 6).

The productions of *V. unguiculata* are close to those reported by Zamora *et al*. (2001) in this same region, although they are below the ones informed by other authors in Venezuela and Colombia (Gutiérrez *et al*., 2001; Araméndiz *et al*., 2011), which could have been influenced by the adverse climate conditions that prevail in the zone –mainly the low rainfall occurred in the experimental period– and by the planning frame used, which in this case was at a distance between rows higher than that used by the above-mentioned authors (1,0 m *vs*. 0,70 m). Something similar occurred in *V. radiata* with regards to the report by Madriz and Luciani (2004), although in this species the yields were higher than those of *V. unguiculata*.

The biological efficiency of polycrops was positive and with an ELUI higher than one in all the combinations (table 7). Nevertheless, the highest values were obtained in the combinations of *V. radiata* with each of the studied grasses. This result proves the feasibility of polycrop use during the establishment, which is in accordance with the report by Vieito (2001) in systems of temporary legumes with pasture species, for seed production.

It is concluded that the use of polycrops was more effective in the establishment of *P. maximum* cv. Likoni than in *Ch. gayana* cv. Callide and *C. ciliaris* cv. Biloela, which was in correspondence with the population, cover percentage and seed production achieved for each species in the first harvest. On the other hand, among the companion legumes *V. radiata* stood out, due to its high biological efficiency indexes in the combinations with each of the grasses, which were higher than the values found in the other polycrops.

Table 6. Grain yield of the temporary crops (kg/ha).

Factor B \ Factor A	*P. maximum* cv. Likoni	*C. ciliaris* cv. Biloela	*Ch. gayana* cv. Callide	SE ±
V. radiata (mung bean)	971,2[ab]	882,0[b]	1 082,2[a]	
V. unguiculata var C-666	209,5[efgh]	213,0[efgh]	196,5[fgh]	
V. unguiculata var Lina	123,0[h]	139,5[gh]	213,0[efgh]	40,47***
V. unguiculata var INIFAT-93	340,5[de]	323,2[def]	541,8[c]	
V. unguiculata var IITA (precocius)	323,5[def]	276,8[defg]	373,5[d]	

a, b, c, d, e, f, g: values with unequal superscripts differ at $p < 0,05$ (Newman-Keuls, 1952). *** $p < 0,001$.

Table 7. Performance of the ELUI, according to the intercropping variables.

Factor B \ Factor A	*P. maximum* cv. Likoni	*C. ciliaris* cv. Biloela	*Ch. gayana* cv. Callide
V. radiata (mung bean)	1,83	1,72	2,08
V. unguiculata var C-666	1,68	1,68	1,78
V. unguiculata var Lina	1,42	1,50	1,86
V. unguiculata var INIFAT-93	1,50	1,41	1,89
V. unguiculata var IITA (precocius)	1,74	1,51	1,92

Received: July 18, 2012

Accepted: January 13, 2014