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Agronomy Evaluations in Regional Trials

The objectives of this section are:

a) To evaluate germplasm adaptation to different ecosystems through the International Network of Regional Trials.

b) To conduct agronomic evaluations of promising germplasm going to and coming out of the Network.

c) To test and develop methodology to be implemented in the Network through the different levels of evaluation in the Regional Trials.

The International Network of Regional Trials

The Network has now assembled 13 Regional Trials A for first evaluation of a large (100-120) number of accessions in the five main ecosystems of tropical America (Llanos, Cerrados, poorly drained savannas, tropical rain forest and semi-evergreen seasonal forest). Table 1 shows the location of participant institutions responsible for the trials, the represented ecosystems, and the planting date of each trial. Eleven of the 13 trials have to this date been established, and 10 of them have reported data. The information being gathered from this first level of Network evaluations is under statistical analysis in order to select the best materials in terms of survival under the prevalent conditions of each site. Table 2 lists the grass and legume accessions classified as excellent or good in Regional Trials A in the savanna ecosystems. Legume and grasses classified as excellent or good in the tropical forest ecosystems are listed in Tables 3 and 4.

The previous two tables for the tropical forest ecosystems depict the outstanding behavior of Stylosanthes guianensis common type (136 and 184) as well as some "tardío types" and the good performance of Desmodium ovalifolium 350. In general, a large number of legume accessions are regarded as potentially good in the humid tropics. In the case of grasses, the good performance of Andropogon gayanus 621 is quite apparent and the even better performance of the other two Andropogon gayanus (6053 and 6054) entries. The excellent performance of some Brachiarias should be pointed out also, particularly Brachiaria humidicola 6013 which is spreading out rapidly into the Amazon ecosystems, especially in Brazil, where it is known as "Quicuio da Amazônia".

Progress has been made also in terms of Regional Trials B. These trials are designed to evaluate seasonal productivity of the promising material coming out from the two major screening sites of the Tropical Pastures Program (Carimagua and CPAC) as well as from Regional Trials A. Location, participant institutions and persons responsible for the trials, ecosystem, and planting date of each Trial are presented in Table 5. Thirty six Regional Trials B were established out of 54 seed

Table 1. Network of Regional Trials (type A) in tropical America.

Country	Location	Institution/person responsible	Ecosystem*	Planting date
Colombia	Macagual	ICA/A. Acosta	TRF	VI-80
	Leticia	CIAT-ICA/G. Sierra	TRF	III-80
	Orocué	HIMAT-CIAT/P. Argel	PDS	VI-80
Brazil	Boa Vista	PROPASTO-CPATU/E.A. Serrão	WDHS	VI-80
	Corumbá	EMBRAPA/A. Pott, J.A. Comastri	PDS	XI-80
	Jataí	EMGOPA/E. Barbosa	WDTS	XII-80
	Paragominas	PROPASTO-CPATU/E.A. Serrão	SESF	IV-81
	Tabuleiro	CEPLAC/J. Marques Pereira	TRF	XI-80
Peru	Pucallpa	IVITA/L. Pinedo, C. Reyes	SESF	III-80
Venezuela	El Tigre	FONAIAP/D. Sanabria	WDHS	VII-80
	Apure	FONAIAP/R. Torres	PDS	X-81
Nicaragua	Nueva Guinea	MIDINRA/A. Cruz, C. Avalos	SESF	VII-80

* TRF = Tropical rain forest; PDS = poorly drained savannas; WDHS = well drained isohypterthermic savannas (Llanos); WDTS = well drained thermic savannas (Cerrados); SESF = semi-evergreen seasonal forest.

Table 2. Legumes and grasses classified as excellent or good in the Regional Trials in tropical savannas.

Well drained savannas Isohyperthermic (Llanos) RTA "El Tigre" Venezuela	Poorly drained savannas RTA "Orocué" Colombia	 RTA "Corumba"* Brazil
Legumes:		
Excellent		
Aeschynomene brasiliana 9684	Desmodium gyroides 3001	Aeschynomene americana 7562
Centrosema brasilianum 5180	Desmodium ovalifolium 350	Calopogonium mucunoides 7367
Centrosema macrocarpum 5274		Vigna adenantha 4016
Stylosanthes guianensis 1280**		
Stylosanthes guianensis 1283**		
Stylosanthes guianensis 1523**		
Good		
Centrosema pubescens 5053	Aeschynomene sp. 8057	Aeschynomene americana 9881
Stylosanthes macrocephala 1582	Cassia rotundifolia 7792	Aeschynomene histrix 9690
Stylosanthes macrocephala 2133	Desmodium heterophyllum 349	Aeschynomene sp. 8057
Stylosanthes capitata 1097	Pueraria phaseoloides 9900	Calopogonium mucunoides 9161
Stylosanthes capitata 1315		Vigna lasiocarpa 4044
Stylosanthes capitata 1342		Vigna sp. 9143
Stylosanthes capitata 1693		Vigna vexillata 9546
Stylosanthes capitata 1728		
Stylosanthes capitata 1943		
Stylosanthes guianensis 1493**		
Stylosanthes sp. 2115		
Zornia brasiliensis 7485		
Zornia sp. 7485		
Grasses:		
Excellent		
	Brachiaria humidicola 679	
Good		
Andropogon gayanus 621	Brachiaria brizantha 665	
Brachiaria decumbens 606		

* Only one repetition
** "tardío"

Table 3. Legumes classified as excellent or good in the Regional Trials A in tropical forest ecosystems.

Tropical rain forest		Semi-evergreen seasonal forest	
RTA "Leticia" Colombia	RTA "Macagual" Colombia	RTA "Pucallpa" Peru	RTA "Nueva Guinea" Nicaragua
Legumes:			
Excellent			
C. macrocarpum 5065	A. histrix 9666	Centrosema sp. 5112	
D. ovalifolium 350	A. histrix 9690	S. guianensis 136	
S. guianensis 184	C. macrocarpum 5065	S. guianensis 184	
S. guianensis 1175	D. gyroides 3001		
Z. latifolia 728	D. ovalifolium 350		
	Desmodium sp. 3019		
	G. striata 964		
	P. phaseoloides 9900		
	S. guianensis 136		
	S. guianensis 184		
	S. guianensis 1175		
	S. guianensis 1283*		
Good			
A. histrix 9666	C. brasilianum 494	A. histrix 9666	A. histrix 9666
A. histrix 9690	C. brasilianum 5234	C. brasilianum 5180	C. pubescens 438
C. pubescens 438	C. pubescens 438	C. macrocarpum 5065	C. pubescens (common)
Centrosema sp. 5112	Centrosema sp. 5112	C. mucunoides 9161	D. gyroides 3001
C. pubescens 5118	C. pubescens 5118	C. mucunoides 9892	L. leucocephala (native)
D. gyroides 3001	C. pubescens 5126	C. pubescens 438	M. atropurpureum 4048
D. heterophyllum 349	D. ovalifolium 3673	C. pubescens 5126	S. guianensis 136
D. heterophyllum 3782	S. macrocephala 1281	C. schiedeanum 5066	S. guianensis 184
D. ovalifolium 3673	S. capitata 1019	D. heterocarpon 365	S. guianensis 1175
P. phaseoloides 9900	S. capitata 1097	D. heterophyllum 349	S. hamata 147
S. capitata 1019	S. capitata 1315	D. ovalifolium 9179	Z. latifolia 9179
S. capitata 1078	S. hamata 147	G. striata 964	
S. capitata 1097	S. viscosa 1132	G. striata 9339	
S. capitata 1405	S. viscosa 1790	P. phaseoloides 7182	
S. guianensis 136	Z. latifolia 728	S. capitata 1315	
S. guianensis 1283*	Zornia sp. 935	S. hamata 147	
Z. latifolia 9179	Zornia sp. (native)	V. adenantha 4016	
Z. latifolia 9199		Zornia sp. 7475	
Zornia sp. (cv. Tarapoto)			
Zornia sp. 7475			

* "tardío"

Table 4. Grasses classified as excellent or good in the Regional Trials A in tropical forest ecosystems.

Tropical rain forest		Semi-evergreen seasonal forest	
RTA "Leticia" Colombia	RTA "Macagual" Colombia	RTA "Pucallpa" Peru	ERA "Nueva Guinea" Nicaragua
Grasses:			
Excellent			
B. decumbens 606	*A. gayanus* 621	*A. gayanus* 6053	*P. maximum* (cv. Colonial)
B. humidicola 6013	*A. gayanus* 6053		
	A. gayanus 6054		
	B. brizantha 667		
	B. humidicola 6013		
Good			
A. gayanus 6053	*A. micay* 6050	*A. gayanus* 621	*A. gayanus* 6054
B. brizantha 665	*B. decumbens* 606	*A. gayanus* 6054	*P. maximum* (common)
B. brizantha 667	*B. ruziziensis* 654	*P. maximum* 604	
B. ruziziensis 655	*B. ruziziensis* 656	*P. maximum* 697	
B. ruziziensis 656	*P. maximum* 604		
P. maximum 673	*P. plicatulum* 600		
P. plicatulum 6046	*P. purpureum* 672		
T. andersonii 6051	*S. sinensis* 6263		
	T. andersonii 6051		

Table 5. Network of established Regional Trials B in tropical America.

Country	Location	Institution/person responsible	Ecosystem*	Planting date
Bolivia	Valle del Sacta	Univ. M. San Simon/J. Espinoza	WDHS	X-80
Brazil	Barrolandia	CEPLAC/J. Marques Pereira	TRF	XII-80
	Maraba	PROPASTO-CPATU/E.A. Serrão-A. Camarao	WDHS	V-81
	Paragominas	PROPASTO-CPATU/E.A. Serrão, M. Diaz Filho	TRF	IV-81
	Porto Velho	PROPASTO-CPATU/E.A. Serrão, C.A. Goncalves	TRF	II-81
Colombia	Carimagua	CIAT/R. Gualdrón	WDHS	V-80
	Guayabal, Pto. Gaitán	CIAT/C. Castilla, A. Carabaly-Gómez	WDHS	V-80
	El Paraiso, Pto Gaitán	CIAT/C. Castilla, A. Carabaly-Gómez	WDHS	V-80
	El Viento, Pto. Gaitán	CIAT/C. Castilla, A. Carabaly-Gómez	WDHS	V-80
	Caucasia	Univ. Antioqua/L.F. Ramírez	TRF	VII-80
	Puerto Asís	Fondo Ganad. Putumayo/D. Orozco	TRF	I-80
	Quilichao	CIAT/H. Giraldo, A. Ramírez	SESF	XI-79
	Orocué	HIMAT-CIAT/A. Carabaly-Gómez, C. Castilla	PDS	VI-81
Costa Rica	Buenos Aires	Min. Agric. y Ganad./V.M. Prado	TRF	VIII-80
Ecuador	El Napo	INIAP/K. Muñoz	TRF	IX-80
	El Puyo	ESPOCH/M. Freire	TRF	V-80
Guyana	Moblissa, Ebini	Livestock Dev. Co./J.M. Wilson	TRF	IX-80
	Lethem, Rupununi	Livestock Dev. Co./J.M. Wilson	WDHS	X-80
Mexico	Arriaga, Chiapas	INIA/F. de León Espinosa, A. Ramos	WDHS	VII-81
Nicaragua	El Recreo	MIDINRA/A. Cruz, C. Avalos	TRF	VIII-80
Panama	Calabacito	INIAP/M. A. Avila	WDHS	X-80
	Los Santos, Chiriquí	Univ. Panama/J. Quintero	WDHS	VII-80
	El Chepo	Univ. Panama/J. Quintero	WDHS	VI-81
Peru	Yurimaguas	INIPA-NCSU/D. Bandy, M. Ara	TRF	XI-80
	Tarapoto	INIPA-COPERHOLTA/W. López	TRF	II-81
	C. Educativo, Tarapoto	INIPA-COPERHOLTA/W. López	TRF	II-81
	Alto Mayo	INIPA/E. Palacios, W. López	TRF	XI-81
Surinam	Coebiti	Fac. of Nat. Resources/R.F. Druiventak, F.W. van Amson	SESF	
Trinidad	Centeno	CARDI/N. Persad	TRF	X-80
USA	Hawaii	Univ. of Hawaii/A.S. Whitney	TRF	VI-80
Venezuela	Guachi	Univ. de Zulia/I. Urdaneta, J. Landaeta	TRF	V-80
	Mantecal	FONAIAP/R. Torres	WDHS	V-80
	Calabozo	MAC/C. Sánchez	WDHS	VIII-80
	Atapirire	FONAIAP/D. Sanabria	WDHS	VII-80
	Jusepín	UDO/C. Alcalá, M. Corado	WDHS	VI-80
	La Esperanza	Univ. de Zulia/I. Urdaneta, R. Paredes	WDHS	X-80

* WDHS = well-drained isohyperthermic savannas; TRF = tropical rain forest; SESF = semi-evergreen seasonal forest; PDS = poorly drained savannas.

packages sent accounting for 67% initial success. Out of the 36 established trials 23, or 64% of the total, are being evaluated already.

Data received from Network participants are being processed by means of a statistical analysis package developed by the Biometrics Section of the Data Services Unit, using the SAS package as a base. The computer output for each location includes an ANOVA test and DUNCAN mean separation for the different harvesting ages (3, 6, 9, and 12 weeks of regrowth) in two seasons of the year (maximum and minimum precipitation). The data is also fitted with a linear and quadratic model in order to estimate seasonal rates of growth for each accession under test. Information on changes in number of plants, coverage, and diseases and pest effects, are also analyzed statistically. Processed data is sent back to the participants within the next month after it is received.

The first multilocational data analysis from Regional Trials B has been done using a modification of the Environmental Index developed by Eberhart, S.A. and Russell, W.A. (1966)*. The Environmental Index (EI) was computed with the following formula: $EI = P_1 - P$, where: P_1 is the local overall yield mean and P is the overall yield mean including all the locations in the analysis. This modified formula eliminates the dependence of the X and Y axis by excluding, in the calculation of the two means, the values of the entry under consideration. In this manner the X axis of the regression, corresponding to dry matter production is independent of the Y axis which corresponds to the Environmental Index. EI gives an indication of how superior or inferior a location is relative to mean productivity in all locations, expressed as mean dry matter production of all entries at each location, excluding the one being tested. This method assumes that the best integrating sensor of the attributes of the location's environment (soil, climate, pests, etc.) is the mean performance of the germplasm in the trial. Obviously, legumes have to be treated separately from grasses because their productivity is different.

An example is presented in Figure 1 of regression analysis (dry matter production vs. EI) with four ecotypes of Stylosanthes capitata for the Llanos of Colombia, using six points representing locations. Four of the points correspond to Regional Trials B with the same level of fertility (22 kg of P + 41.50 kg K), while the other two points correspond to a trial in Carimagua which was run with a low (11 kg of P + 20.75 kg K) and a high (33 kg P + 62.25 kg K) level of fertilization. The intercept is an estimate of the mean productivity of an ecotype throughout different trials in the ecosystem and the slope represents changes in performance of that ecotype with changes in EI. The chosen Stylosanthes capitata accessions have a narrow range of intercepts which means that all produce similarly throughout the Llanos ecosystem of Colombia. However, a large difference is apparent in slopes, indicating degrees in which the four S. capitata ecotypes perform with changes in the locations' general quality of the environment. More specifically,

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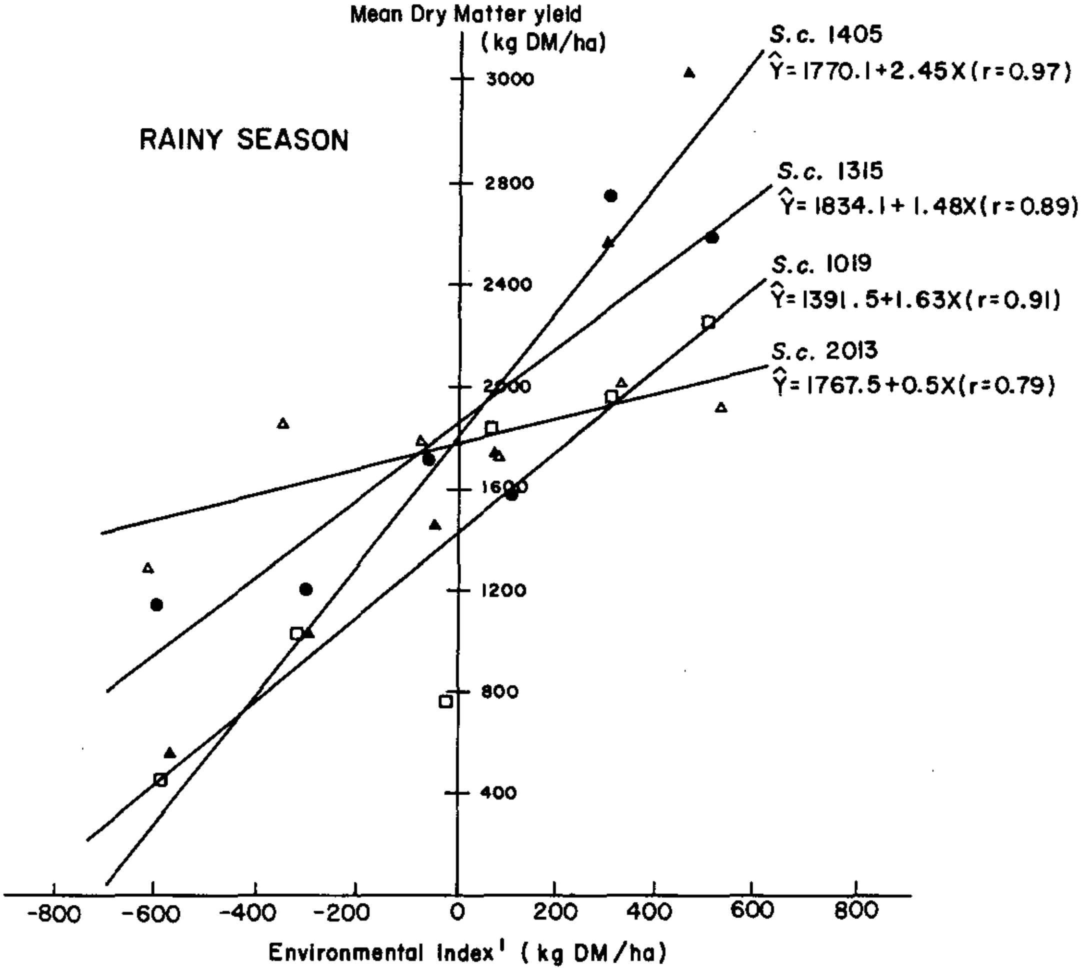
*Eberhardt, S.A.; Russell, W.A. 1966. Stability parameters for comparing varieties. Crop Science. 36-40.



[1] EI = Environmental Index = Mean by locality minus general mean of the different trials
Note: each entry has different IA due to the exclusion of its production in the means.

Figure 1. Adaptability of four accessions of S. capitata throughout the Colombian Llanos. Mean of six points included.

while Stylosanthes capitata 1405 has a very high response to general quality of the location environment, S. capitata 2013 responds less to these changes in environment and Stylosanthes capitata 1315 and 1019 respond similarly and intermediately relative to 1405 and 2013.

This study of the species and entries of promising material's adaptability across locations has clear implications for the success of adoption by producers. It follows that the Program should emphasize the selection of accessions with the highest production throughout the ecosystem (intercept) and least changes in performance throughout the different locations (slope). However, there is no clear definition yet of the magnitude of the slope for selection of germplasm; tentatively, germplasm with slopes in the order of 1.5 or less could be taken as having wide range adaptability.

A multilocational analysis including six locations in the Llanos of Colombia and all grasses and legumes commonly tested in Regional Trials B has been done using growth rates rather than dry matter production. The analysis has been done with information for the rainy season (maximum precipitation period) and dry season (minimum precipitation period), and results are presented in Tables 6 and 7 for location and entries, respectively. Locations included in the Llanos of Colombia were significantly different for both grasses and legumes in terms of mean-growth rates of all entries tested (Table 6). The superiority of Stylosanthes capitata accessions in terms of wide adaptability to the Colombian Llanos ecosystem for both the rainy and dry periods is quite evident (Table 7). This high degree of adaptability of S. capitata as a group is particularly remarkable when one considers the low level of fertilizer used in their evaluation (22 kg of P + 41.50 kg of K). It should be noticed that Desmodium ovalifolium 350 follows S. capitata in terms of growth rate during the rainy season, but outperforms all legumes during the dry season. Among the grasses Brachiaria decumbens and Andropogon gayanus perform very similarly as indicated by the non-significant differences in growth rate in both seasons.

Table 6. Seasonal mean growth rate[1] of legumes and grasses by location (3 RTB + 1 RTB with 3 levels of fertilization) of the Colombian Llanos.

Regional Trials B	Growth rate by season	
	Rainy	Dry
	--------kg DM/ha/day--------	
Legumes		
Carimagua (level A)[2]	25.4 b	4.3 ab
Carimagua (level B)[2]	30.6 a	4.8 a
Carimagua (level C)[2]	34.1 a	4.6 a
Finca "El Paraiso"	24.0 b	2.5 b
Finca "Guayabal"	20.7 b	1.7 b
Finca "El Viento"	12.7 c	2.7 b
Grasses		
Carimagua (level A)[2]	26.3 ab	15.9 a
Carimagua (level B)[2]	29.9 ab	15.0 a
Carimagua (level C)[2]	41.4 a	19.6 a
Finca "El Paraiso"	28.4 ab	3.6 b
Finca "Guayabal"	10.4 b	3.0 b
Finca "El Viento"	18.7 b	4.5 b

[1] Mean of growth rates of 4 regrowth periods (0-3, 3-6, 6-9 and 9-12 weeks)

[2] Fertility levels: A = 11 of P + 20.75 of K; B = 22 of P + 41.50 of K = all other RTB; and C = 33 of P + 62.25 of K.

Table 7. Mean growth rate[1] of legumes and grasses tested in four Regional Trials B in the Colombian Llanos.

Entries	Mean growth rate/season	
	Rainy	Dry
	-------- kg DM/ha/day--------	
Legumes[2]		
S. capitata 1019	26.45 cdef	2.78 d
S. capitata 1315	35.85 ab	4.64 bc
S. capitata 1318	37.25 abc	3.75 bcd
S. capitata 1342	33.95 abcd	4.37 bcd
S. capitata 1405	34.94 ab	3.02 cde
S. capitata 1693	39.22 a	4.32 bcd
S. capitata 1728	35.92 ab	4.10 bcd
S. capitata 1943	27.52 bcde	2.98 de
S. capitata 2013	33.70 abcd	3.71 bcd
C. pubescens 5053	2.91 h	1.38 e
C. pubescens 5126	7.95 gh	2.80 de
C. macrocarpum 5065	11.72 gh	2.85 de
P. phaseoloides 9900	19.32 efg	5.17 b
D. ovalifolium 350	25.12 def	7.70 a
C. gyroides 3001	18.10 efg	3.48 bcde
A. histrix 9690	13.78 gh	4.31 bcd
Z. latifolia 728	17.18 fg	2.72 de
Z. latifolia 9199	17.51 fg	2.74 de
Zornia sp. 9286	15.05 g	2.78 de
Grasses[2]		
B. decumbens	25.9 a	9.6 a
A. gayanus 621	25.8 a	10.9 a

[1] Mean of growth rates of four regrowth periods (0-3, 3-6, 6-9 and 9-12 weeks).

[2] ANOVA and Duncan calculated separately for grasses and legumes.

The EI analysis was much more sensitive with the mean absolute yield that with growth rate. Mean yields correspond to the accumulated DM yield at 3, 6, 9 and 12 weeks of regrowth. Tables 8 and 9 show the linear regression parameters for dry matter production vs. EI on commonly tested legumes in the Regional Trials B of the Llanos of Colombia for the rainy and dry season, respectively.

As mentioned above, Stylosanthes capitata as a group outyields all other legumes; this is indicated by the intercept followed by Desmodium ovalifolium 350. In general, a relatively wide range of slopes is evident not only with S. capitata but with all other species.

Table 8. Rainy season mean yield (intercept) and degree of adaptability (slope) of legumes and grasses in the Llanos of Colombia. Linear regression of dry matter production[1] vs. environmental index (EI)[2] with six points.

Entries	Intercept (kg DM/ha)	Slope	r
<u>Legumes</u>			
S. capitata 1019	1391.5**	1.63**	0.91
S. capitata 1315	1834.1**	1.48**	0.89
S. capitata 1342	1781.4**	1.83**	0.97
S. capitata 1943	1441.5**	0.97**	0.94
S. capitata 1405	1770.1**	2.45**	0.97
S. capitata 1728	1841.7**	1.37**	0.96
S. capitata 1693	2009.1**	1.79**	0.96
S. capitata 1318	1969.1**	2.08*	0.91
S. capitata 2013	1767.5**	0.50*	0.79
Z. latifolia 728	857.0**	0.47 NS	0.69
Z. latifolia 9286	787.2**	0.63 NS	0.79
Z. latifolia 9199	964.0**	0.97*	0.85
C. gyroides 3001	890.3**	0.54 NS	0.70
D. ovalifolium 350	1167.3*	1.11**	0.96
C. macrocarpum 5065	392.7*	0.56*	0.89
C. pubescens 5126	342.1**	0.39*	0.85
C. pubescens 5053	140.0*	0.07 NS	0.42
P. phaseoloides 9900	899.5**	0.93**	0.94
A. histrix 9690	713.4**	-0.41 NS	0.61
<u>Grasses</u>			
A. gayanus 621	1313.4**	0.61 NS	0.65
B. decumbens 606	1376.4**	0.69 NS	0.65

[1] Dry matter mean by location from the yields at four different regrowth ages (3, 6, 9 and 12 weeks)
[2] EI = Environmental Index, explained in the text.

* Significant (P = 0.05)
** Significant (P = 0.01)
NS = Not significant

The same statistical analysis procedure was applied to data obtained by the Regional Network Trials in the tropical forest ecosystems. A comparison of locations in terms of growth rate for the maximum and minimum periods of precipitation (Table 10) indicates the best sites for both grasses and legumes. This could be rated to better fertility and humidity conditions in those locations. The seasonal mean growth rate of some legumes and grasses commonly tested in the 11 Regional B Trials in the tropical forest ecosystem are presented in Table 11.

Table 9. Dry season mean yield (intercept) and degree of adaptability (slope) of legumes and grasses in the Llanos of Colombia. Linear regression of dry matter production[1] vs. environmental index (EI)[2] with six points.

Entries	Intercept (kg DM/ha)	Slope	r
Legumes			
S. capitata 1019	123.6**	0.88**	0.96
S. capitata 1315	232.2**	1.39**	0.98
S. capitata 1342	219.9**	1.90**	0.98
S. capitata 1943	138.5**	0.41 NS	0.74
S. capitata 1405	151.9**	0.71**	0.95
S. capitata 1728	212.7**	1.49**	0.96
S. capitata 1693	227.6**	1.43**	0.98
S. capitata 1318	199.9**	1.17**	0.98
S. capitata 2013	182.0**	0.57*	0.81
Z. latifolia 728	132.7**	0.33 NS	0.62
Z. latifolia 9286	137.8*	-0.08 NS	0.10
Z. latifolia 9199	101.8**	0.40*	0.78
C. gyroides 3001	133.5**	1.09*	0.96
D. ovalifolium 350	212.7**	2.64**	0.97
C. macrocarpum 5065	118.0**	1.19**	0.96
C. pubescens 5126	78.8**	0.78*	0.90
C. pubescens 5053	41.1*	0.34*	0.84
P. phaseoloides 9900	153.5**	1.49**	0.95
A. histrix 9690	214.8**	1.18*	0.88
Grasses			
A. gayanus 621	595.3**	1.55**	0.97
B. decumbens 606	504.0**	0.60**	0.97

[1] Dry matter mean by location from the yields at four different regrowth ages (3, 6, 9 and 12 weeks)

[2] EI = Environmental Index explained in the text

* Significant (P = 0.05)
** Significant (P = 0.01)
NS = Not significant

Table 10. Seasonal mean growth rate[1] of legumes and grasses by locations (11 Regional Trials B) in the tropical forest.

Regional trials B	Growth rate/period of	
	Maximum ppt.	Minimum ppt.
	---------- kg DM/ha/day ----------	
Grasses		
"EL Napo", Ecuador		107.0 a
"El Puyo", Ecuador		76.0 a
"Quilichao", Colombia	100.7 a	82.2 a
"Caucasia", Colombia		25.4 b
"Puerto Asís", Colombia		10.5 b
"Pucallpa", Perú		13.3 b
"Yurimaguas", Perú	58.7 b	
"Tarapoto", Perú	21.0 c	
"El Recreo", Nicaragua	116.9 a	11.1 b
"Guachi", Venezuela	91.2 a	
"Valle del Sacta", Bolivia	93.0 a	
Legumes		
"El Napo", Ecuador		54.2 a
"El Puyo", Ecuador		45.4 a
"Quilichao", Colombia	20.8 c	24.5 b
"Caucasia", Colombia		14.1 bc
"Puerto Asís", Colombia		18.9 bc
"Pucallpa", Perú		9.9 c
"Yurimaguas", Perú	38.6 b	
"Tarapoto", Perú	17.9 c	
"El Recreo", Nicaragua	20.3 c	9.1 c
"Guachi", Venezuela	57.9 a	
"Valle del Sacta", Bolivia	29.8 bc	

[1] Mean of growth rates of four regrowth periods (0-3, 3-6, 6-9 and 9-12 weeks).

Table 11. Mean growth rate[1] of some legumes and grasses tested in 11 Regional Trials B in tropical forest ecosystems.

Entries	Mean growth rate	
	Maximum ppt.	Minimum ppt.
	---------- kg DM/ha/day ---------	
Legumes*		
S. capitata 1405	28.4 b	23.6 bcd
S. guianesis 136	50.5 a	29.1 abc
S. guianensis 184	47.5 a	37.9 a
D. heterophyllum 349	16.9 b	12.5 d
D. ovalifolium 350	34.1 ab	30.6 ab
C. pubescens 438	18.4 b	16.6 cd
P. phaseoloides 9900	25.4 b	21.9 bcd
Grasses*		
P. maximum	68.3 b	-
B. decumbens	73.8 ab	59.8 a
A. gayanus 621	91.4 a	48.6 a

[1] Mean growth rate of four growth periods (0-3, 3-6, 6-9 and 9-12 weeks)

*ANOVA and Duncan separate for legumes and grasses.

As in the case of the multilocational analysis for the Llanos, the interaction location x entry is analyzed by the regression between seasonal dry matter mean yield of each entry vs. the EI. Results of this analysis (Table 12) for the 11 locations of the humid tropic forest ecosystem show Stylosanthes guianensis 136, 184 and Desmodium ovalifolium 350 as the legumes with highest productivity for the maximum period of precipitation. In terms of changes in performance with changes in quality of the environment in each location, Desmodium ovalifolium showed the less steep slope eventhough not significant. In contrast, Stylosanthes guianensis 136 shows the steepest slope, probably due to differences across locations in anthracnose resistance. During the minimum period of precipitation, the slope of Stylosanthes guianensis 136 is reduced in magnitude, but it increases in the case of Desmodium ovalifolium 350. This could be the result of reduced effect of anthracnose in some of the locations in the case of S. guianensis 136, and of different water holding capacity of the soils and length of the dry period in the different locations in the case of Desmodium ovalifolium 350.

Andropogon gayanus is the more productive grass during the maximum and minimum periods of precipitation and shows the greatest range of adaptation as indicated by a non-significant slope during the maximum period of precipitation; like Brachiaria decumbens, it shows a moderate slope during the minimum period of precipitation.

Table 12. Seasonal mean yield (intercept) and degree of adaptability (slope) of some legumes and grasses in 11 locations of the tropical forest ecosystems. Linear regression of dry matter production[1] vs. environmental index (EI)[2].

Entries	Maximum ppt.			Minimum ppt.		
	Intercept (kg DM/ha)	Slope	r	Intercept (kg DM/ha)	Slope	r
Legumes						
S. capitata 1405	1336.1*	1.02 NS	0.75	1015.3**	1.32**	0.99
S. guianensis 136	1980.7**	2.62*	0.91	1523.2**	1.45**	0.94
S. guianensis 184	2001.8**	1.17 NS	0.77	-	-	-
D. heterophyllum 349	1046.9*	0.45 NS	0.59	649.3**	0.71**	0.91
D. ovalifolium 350	1961.5**	0.64 NS	0.70	1598.9**	1.12**	0.93
C. pubescens 438	938.8**	0.53 NS	0.77	866.3**	0.26 NS	0.72
P. phaseoloides 9900	1186.9*	0.46 NS	0.59	1127.8**	0.57*	0.85
Grasses						
P. maximum 604	2809.2**	1.30*	0.93	1317.0*	0.62*	0.98
B. decumbens 606	2557.5*	-0.01 NS	0.05	2602.4**	1.35**	0.98
A. gayanus 621	3929.5*	-0.02 NS	0.08	2896.9**	0.98*	0.91

[1] Dry matter mean by location from yields at four regrowth ages (3, 6, 9 and 12 weeks)
[2] EI = Environmental Index explained in the text.

* Significant (P = 0.05)
** Significant (P = 0.01)
NS = Not significant

The use of the Environmental Index (EI) technique is very useful to show germplasm performance in different locations. However, it is recognized that the methodology for analysis of the interaction location x entry should be based on physical and biological information from each location. In other words, the analysis should separate the effects of weather, soils, pests and diseases in order to explain behavior of the germplasm under test. Consistent with this, the International Regional Trials Network is recording, in addition to entry performance by season and location, soil chemical analysis of the site, weather parameters from the closet meteorological station, and diseases and pests observed during the trial.

The information being recorded through Regional Trials A and B is very valuable to assess not only the adaptability of the materials throughout ecosystems, but also to set solid bases for extrapolation and exchange of information among institutions participating in the International Regional Trials Network.

Supportive Agronomic Research

Various factors and characteristics of pasture plants determine productivity and persistence under grazing, among them, seasonal productivity which is measured by Regional Trials B throughout the Network. Selected legume and grass species being tested in RTB are simultaneously evaluated at the Quilichao Station to study their growth pattern and changes in forage quality during periods of positive and negative water balance. Two trials are conducted, one for grasses and one for legumes. This section reports on the growth curves for two different periods of extreme water balance. The Pasture Quality and Nutrition section is reporting data pertaining to the same trial on quality analysis and relative acceptability of these materials to the grazing animals. The growth curves of nine grasses are presented in Figure 2. The X axis scale used in the dryer period is four times larger than the Y axis scale used in the rainy period. The growth rates of the five Brachiaria species are presented in the bottom part of Figure 2. It should be noticed that Brachiaria decumbens 606 is the only Brachiaria that performs similarly to Andropogon gayanus 621 and Panicum maximum 604 in terms of drought tolerance and response to the first rains.

Figure 3 shows the growth curves of 12 legumes in two different water balance periods. During the rainy period Desmodium ovalifolium 350 (bottom of Figure 3) had a linear growth rate. However, during the dry period it did not grow and responded only moderately to the first rains.

Looking at the Stylosanthes species (center of Figure 3), Stylosanthes guianensis 184 and Stylosanthes hamata 147 had similar growth rates during the rains and during the negative water balance periods, with a strong reaction to first rains. Stylosanthes capitata 1315, had the slowest growth rate during the rainy period, and was the only Stylosanthes that did not grow during periods of negative water balance, but it strongly reacted to the first rains.

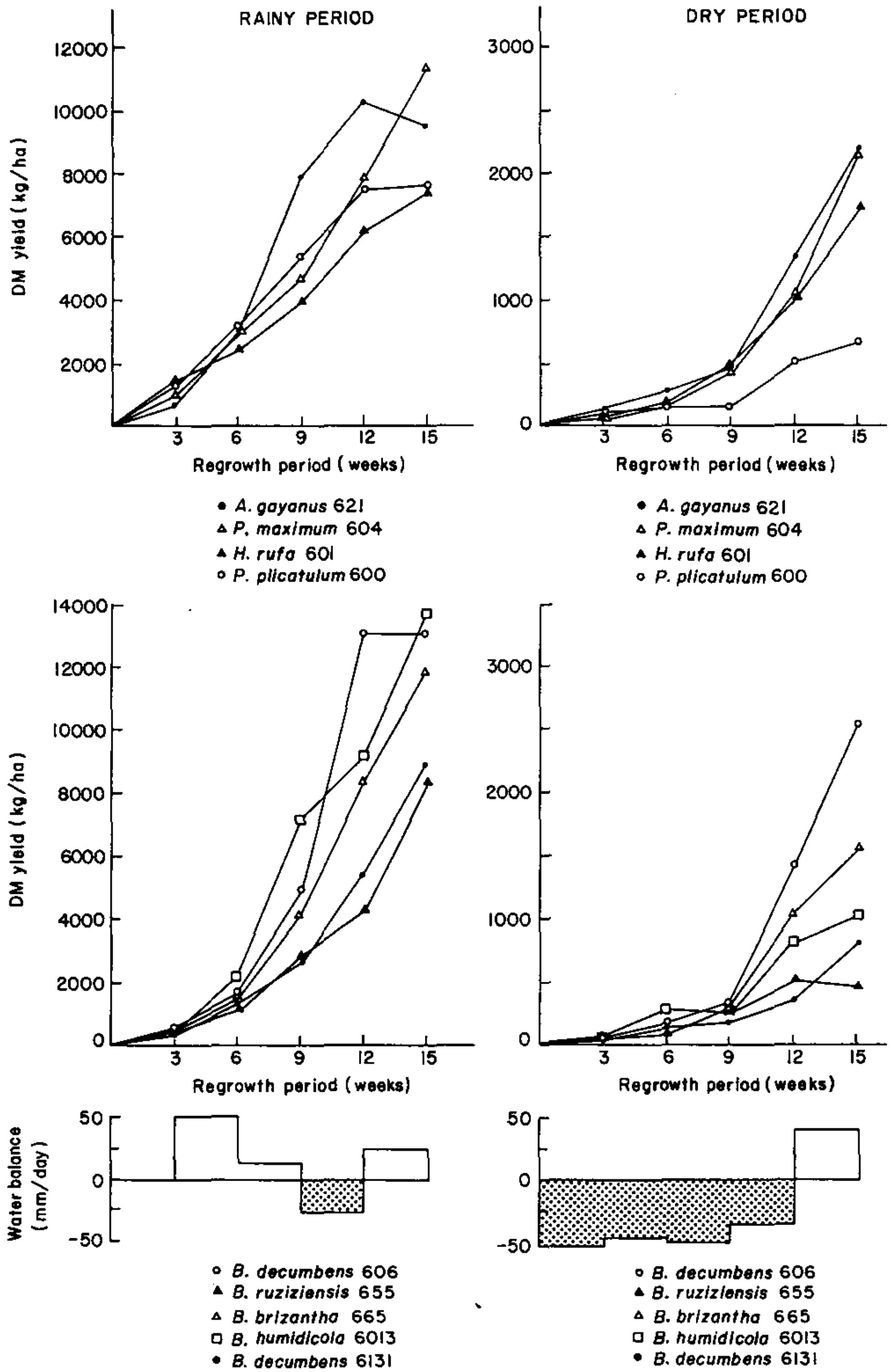


Figure 2. Growth curves of nine grasses affected by two different water balance periods (rainy and mostly dry). Notice that the X scale is four times bigger in the curves for the drier period.

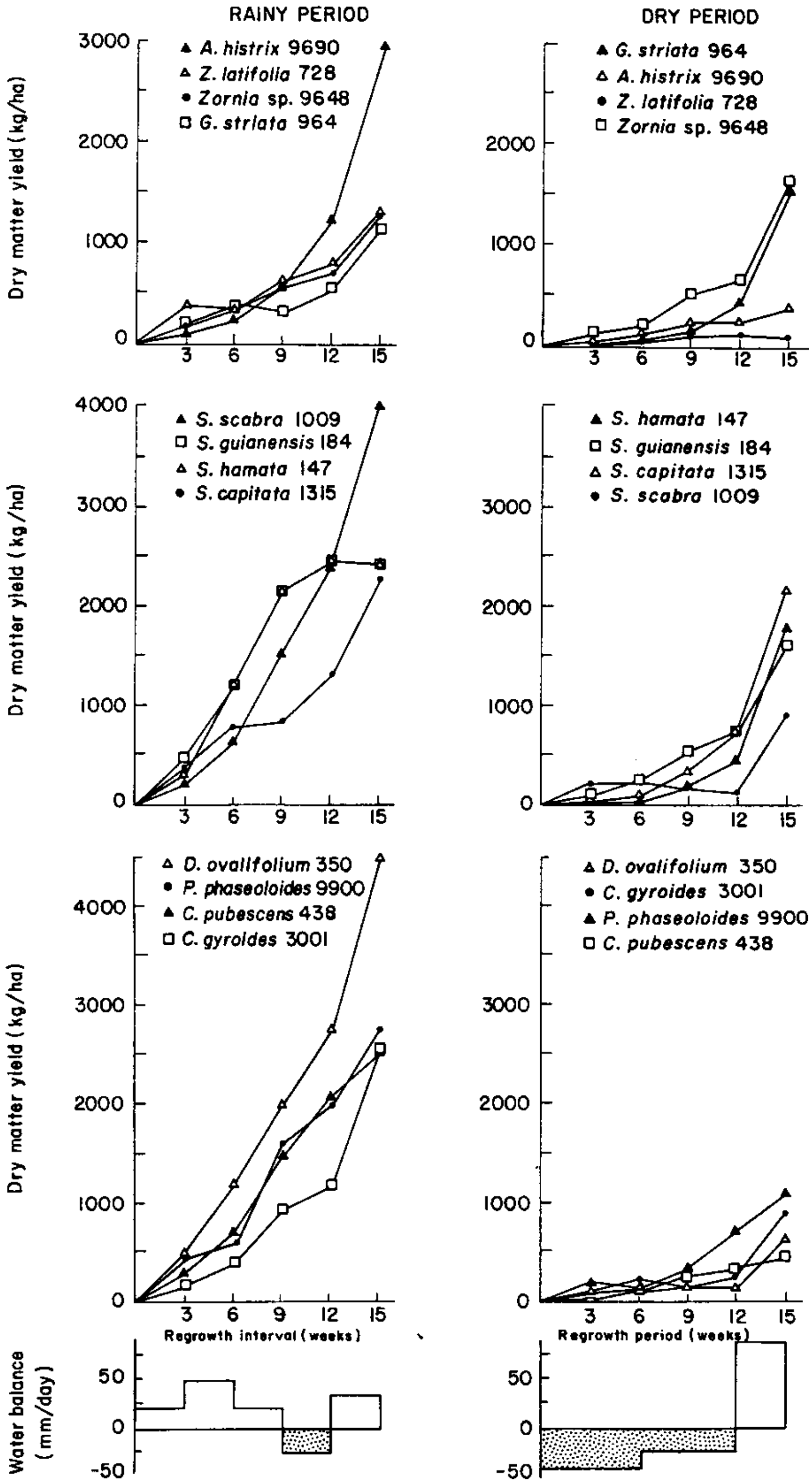


Figure 3. Growth curves of 12 legumes affected by two different water balance periods (mostly rainy and dry).

The legume Galactia striata 964 (top of Figure 3) is a well known drought-tolerant species, and this is confirmed by this study which shows that it grew during the dry period even at a faster rate than in the rainy period.

In order to study the potential compatibility of grass-legume mixtures, two trials were conducted, one to test nine legumes associated with two grasses, in monoculture, and the other to test six grasses associated with two legumes, in monoculture, with and without nitrogen fertilization.

Relative dry matter yield of the components in each plot are shown in Figures 4 and 5 for the associations of the six grasses with Desmodium ovalifolium 350 and Stylosanthes capitata 1315. In Figure 4 the three Brachiaria species show different degrees of aggressiveness as indicated by the growth of Desmodium ovalifolium and Stylosanthes capitata in different proportions in the mixture. It would seem that Brachiaria humidicola is a grass that requires time to show its aggressiveness in full potential, as indicated by the high proportion of legumes at the first cuttings.

In the case of bunch type grasses (Andropogon gayanus 621, Hyparrhenia rufa 601 and Panicum maximum 604), the proportions of Stylosanthes capitata in the association was similar. However, when the associated legume was Desmodium ovalifolium, Hyparrhenia rufa seemed to be the weakest grass, as indicated by greater proportion of Desmodium ovalifolium through the eight cuts.

To complement the information on relative competition between grasses and legumes, root studies are carried out by sampling the interphase between the lines of grasses and legumes in each plot. This attempts to study root interaction, as indicated by occupation and utilization of the soil. As a summary, Table 13 shows values for the eighth cut of a Root Efficiency Index (REI) calculated by dividing the root dry matter present in the 40 cm top soil by the top dry matter production. This index is interpreted as an indication of the amount of roots required for the plant to produce certain amount of aerial dry matter, and consequently it is an important indicator of aggressiveness or ability of the plant to occupy and use the soil. In this context, Brachiaria humidicola 6013 is the grass with the greatest REI, in other words, with the ability to locate more roots in the soil as compared to other grasses. A comparison of means across grasses for the different competition treatments with legumes, indicates little differences, possibly with the exception of Desmodium ovalifolium, with the lowest REI (2.73).

In order to evaluate the nitrogen contribution of legumes to the grasses, chemical analyses of the sward components in the different plots were done on each of the cuttings. Table 14 shows the seasonal nitrogen yields of six grasses when associated with Desmodium ovalifolium 350, Stylosanthes capitata 1315 and in monoculture with an without nitrogen fertilization (100 kg per hectare).

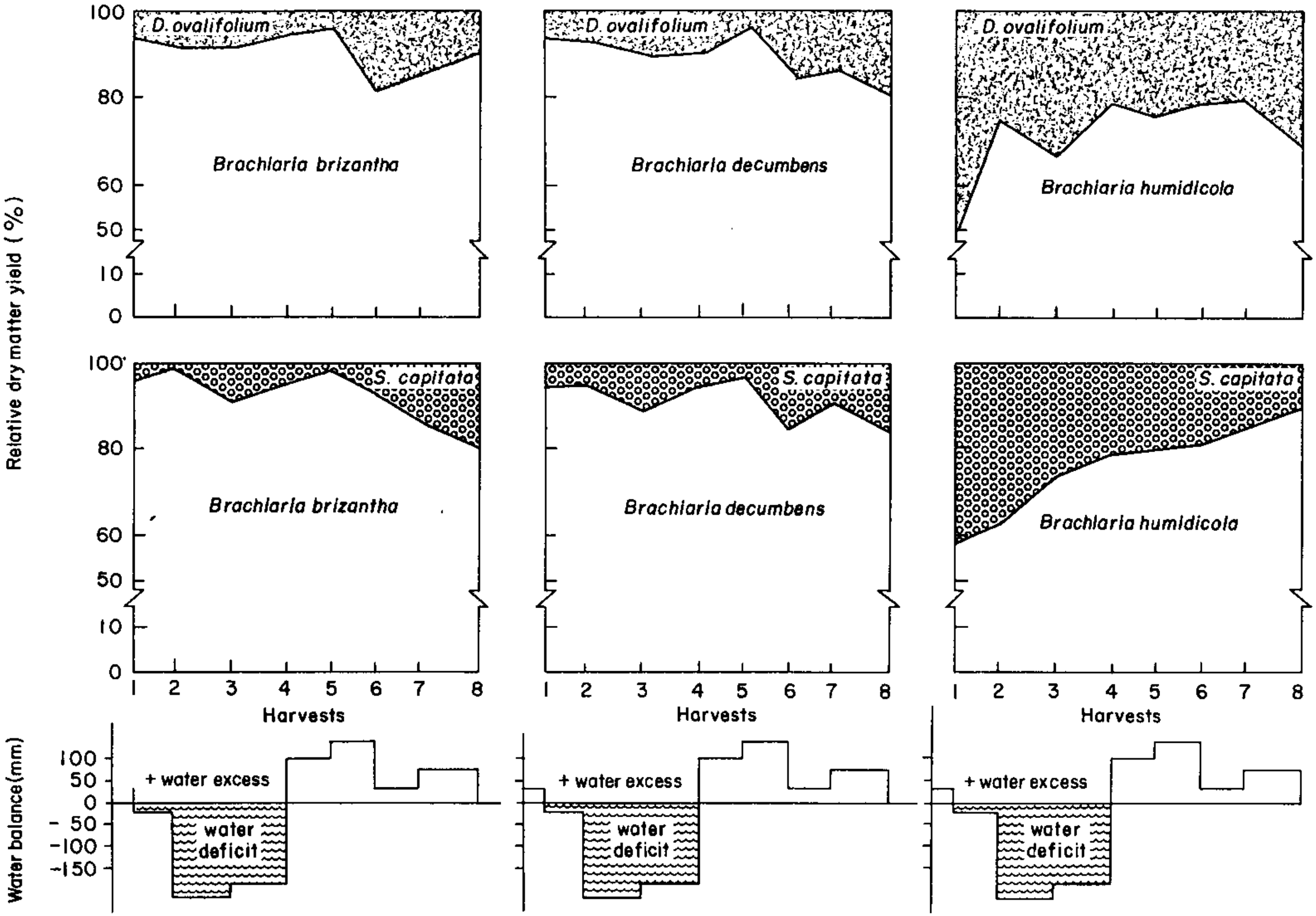


Figure 4. Relative dry matter production of prostrate grass species and companion legumes.

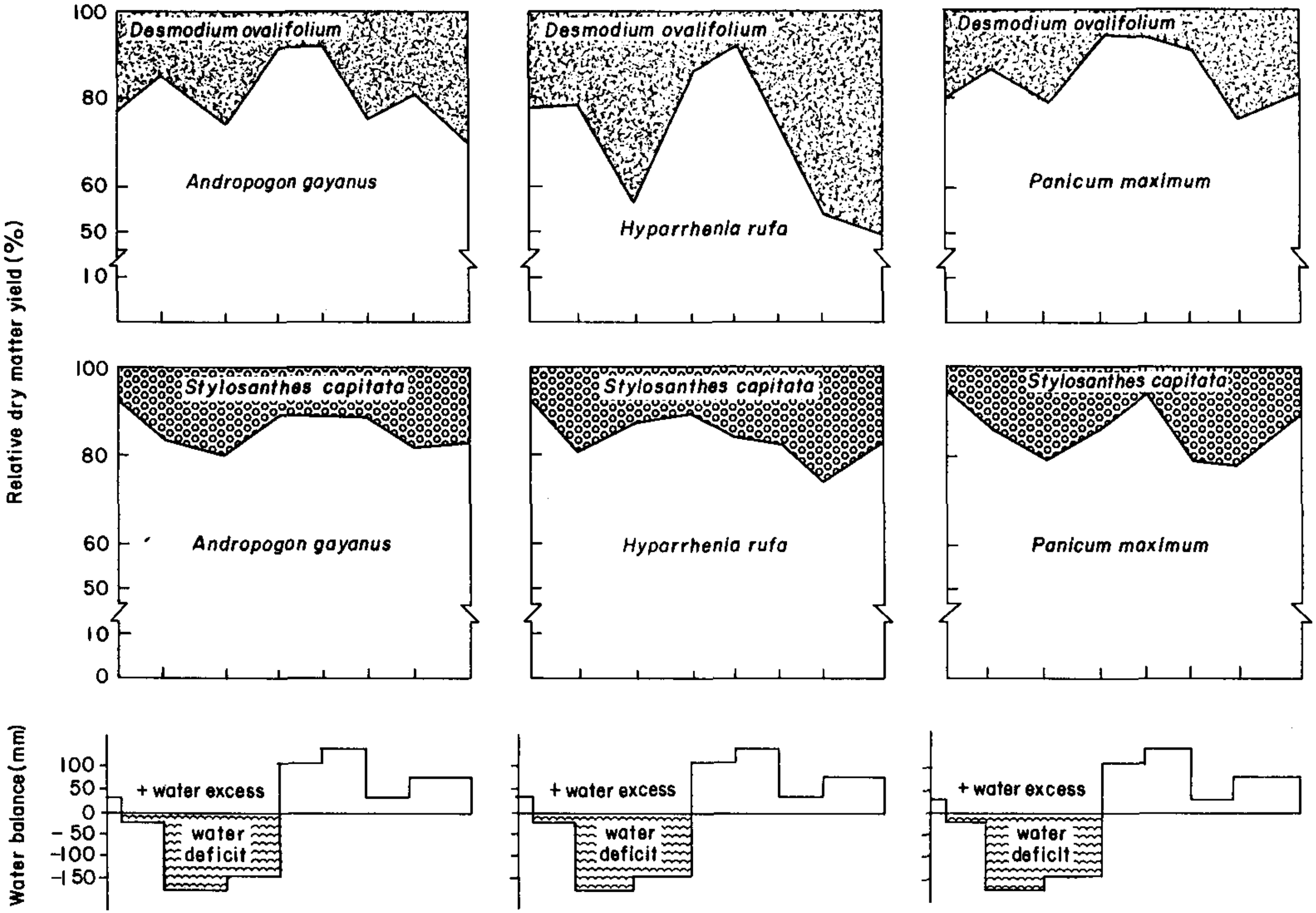


Figure 5. Relative dry matter production of bunch type grasses and companion legumes.

Table 13. Root efficiency index (REI) of six grasses when associated with Desmodium ovalifolium 350, Stylosanthes capitata 1315 or in monoculture, with and without fertilization with 100 kg of N/ha. Measure at eighth cut (15 months after planting).

Treatment of competition	Andropogon gayanus	Hyparrhenia rufa	Panicum maximum	Brachiaria brizantha	Brachiaria decumbens	Brachiaria humidicola	Mean
	REI = (kg root DM/kg top DM)						
Desmodium ovalifolium	1.23	1.40	2.47	2.46	2.55	6.27	2.73
Stylosanthes capitata	1.26	1.44	2.56	3.12	3.22	8.60	3.36
Grass + nitrogen	1.28	0.99	2.37	3.47	2.77	7.60	3.08
Grass without nitrogen	1.53	1.30	3.16	3.12	2.89	7.67	3.28
Mean	1.32	1.28	2.64	3.04	2.85	7.53	

Table 14. Seasonal N yields (kg N/ha) of six grasses when associated with *Desmodium ovalifolium* 350, *Stylosanthes capitata* 1315 or in monoculture with and without fertilization with 100 kg of N/ha.

Treatment of competition	Grasses						Mean
	P. maximum 604	*A. gayanus* 621	*H. rufa* 601	*B. decumbens* 606	*B. brizantha* 665	*B. humidicola* 6013	
	kg N/ha						
Rainy season							
D. ovalifolium	23.4	34.0	20.4	28.6	27.0	21.4	25.8a
S. capitata	26.6	30.6	41.7	27.4	23.1	20.8	28.4a
Grass + N	29.8	31.9	30.1	26.5	22.1	30.3	28.5a
Grass	13.1	19.2	17.3	14.3	12.8	15.6	15.4b
Mean	23.2b	22.0b	29.0	27.4a	24.2ab	21.3b	
Dry season							
D. ovalifolium	12.1	10.2	15.2	8.4	16.2	15.9	13.0a
S. capitata	15.0	7.3	13.1	11.8	17.2	16.1	13.4a
Grass + N	12.3	7.5	12.1	12.1	10.0	13.4	11.2b
Grass	7.7	5.5	9.6	7.6	10.4	7.5	8.1c
Mean	11.8bb	7.6c	12.5ab	10.1bc	13.4a	13.2ab	

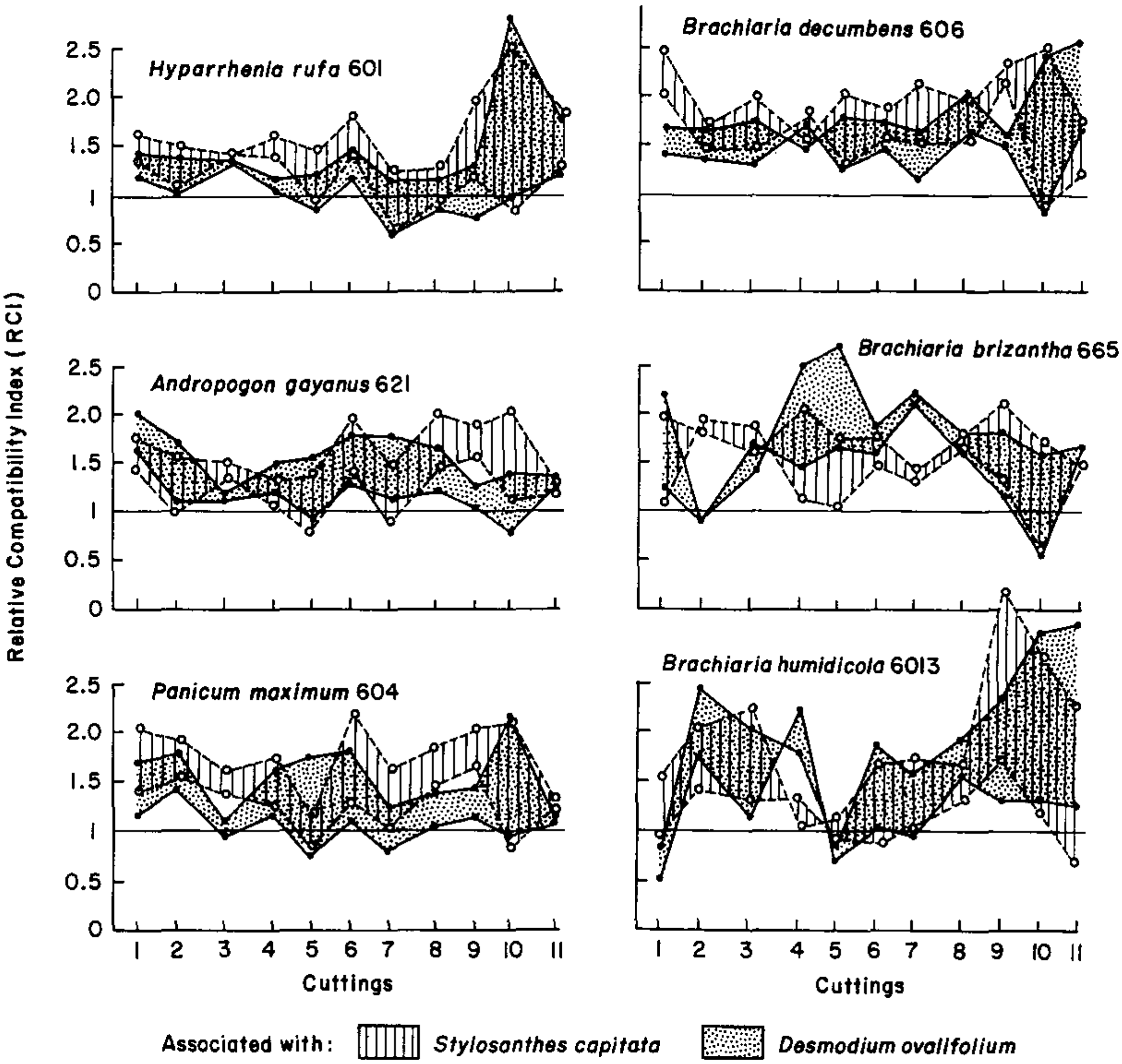


Figure 6. Changes with time of Relative Compatibility Index (RCI) of six grasses when associated with Desmodium ovalifolium 350 and Stylosanthes capitata 1315 in Quilichao.

A Relative Compatibility Index (RCI) was calculated to indicate the degree of yield of such species in association vs. the productivity of the same species in monoculture. The RCI was calculated by dividing DM yield of the species associated vs. DM yield of the species in monoculture. In the case of grasses, two controls were used with and without nitrogen fertilization. Consequently, two RCI are calculated for each grass under competition by two companion legumes. An RCI of 1 represents a situation of equilibrium in which the species is not affected by the companion species. An RCI above 1 indicates that the species is benefited by the companion species in the association, whereas an RIC of less than 1 indicates that the species is negatively affected by the companion species. In general, the productivity of grass was in most cases favored by the association with a legume (Figure 6). The two extreme situations were Hyparrhenia rufa 601 (the less aggressive grass) and Brachiaria decumbens 606, always benefited by the companion legume. Andropogon gayanus 621 seemed in most cases to benefit by the companion legumes except with Desmodium ovalifolium. In Figure 6, the difference between the two RCI's calculated using the two nitrogen levels of the monoculture as the denominator, shows the range of benefit due to the nitrogen contribution. The difference from RCI=1 explains the reduced competitive ability of the associated legumes.

The same RCI calculations have been done with data recorded from the experiment in which nine legumes are associated with Andropogon gayanus 621 and Brachiaria decumbens 606. Figure 7 shows RCI changes with time for the nine legumes under the influence of associated species. It is clear that all legumes have a high tendency to be negatively affected by the companion grass (RCI$<$1). This is an important difference with grasses which normally benefit from the companion legume.

Desmodium ovalifolium 350 is the legume with highest RCI throughout the period of evaluation; in other words, it is the most aggressive legume in the study. It also shows the largest difference in RCI between the two companion grasses as it was only slightly affected by Andropogon gayanus as compared with Brachiaria decumbens, in which case it reached a somewhat stable level after the fourth cut.

The information obtained in this clipping trial has to be interpreted with caution, since it is only meant to indicate the potential aggressiveness or compatibility among grasses and legumes eliminating factors such as trampling, preferential grazing and perenniality of species which strongly affect the compatibility and productivity of a mixture under grazing.

Methodological Studies

The section is currently testing alternative methodologies and sampling techniques that could be used in Regional Trials C and D, in which animals are introduced in the evaluations.

A prototype of a Regional Trial C which attempts to evaluate the effect of three grazing pressures on five grass-legume mixtures (Andropogon gayanus 621 with Centrosema pubescens 438 and Stylosanthes capitata 1405; Panicum maximum 604 with Centrosema pubescens 438 and Stylosanthes capitata 1405; and Brachiaria decumbens 606 with Desmodium ovalifolium 350) has completed six months under grazing. This trial is conducted simulating rotational grazing with a three-to-four-days grazing period followed by six weeks (rainy) or eight weeks (dry) resting periods. Figure 8 shows the changes in dry matter availability in two mixtures of Centrosema pubescens with Andropogon gayanus and Panicum maximum. As a consequence of the three grazing pressure treatments applied (2.4 and 6 kg of DM on offer per 100 kg of liveweight), botanical composition of the pasture changed with time. Starting from similar DM availabilities, after the first six months of grazing, DM on offer has changed drastically as shown in the last August evaluation.

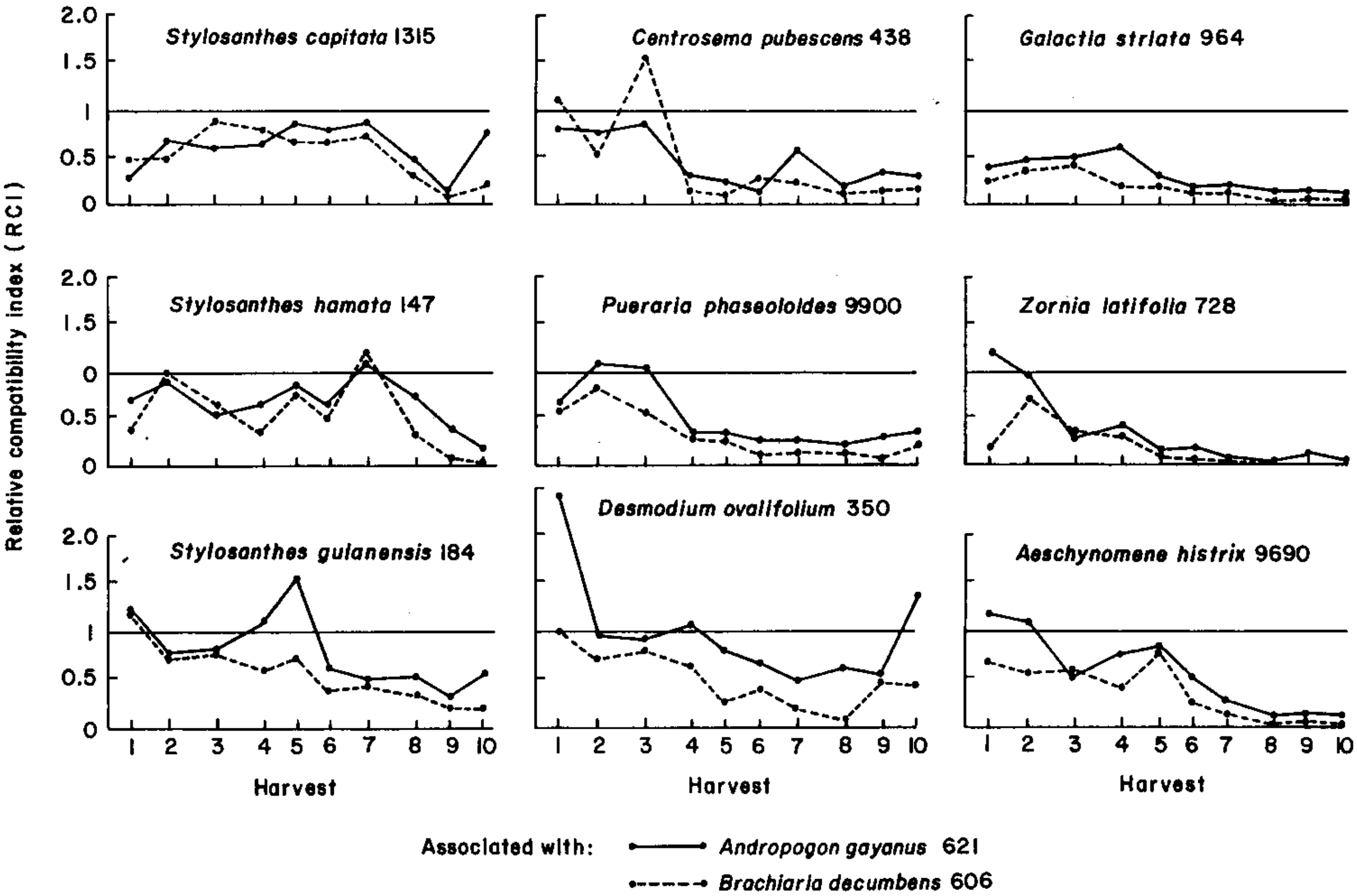
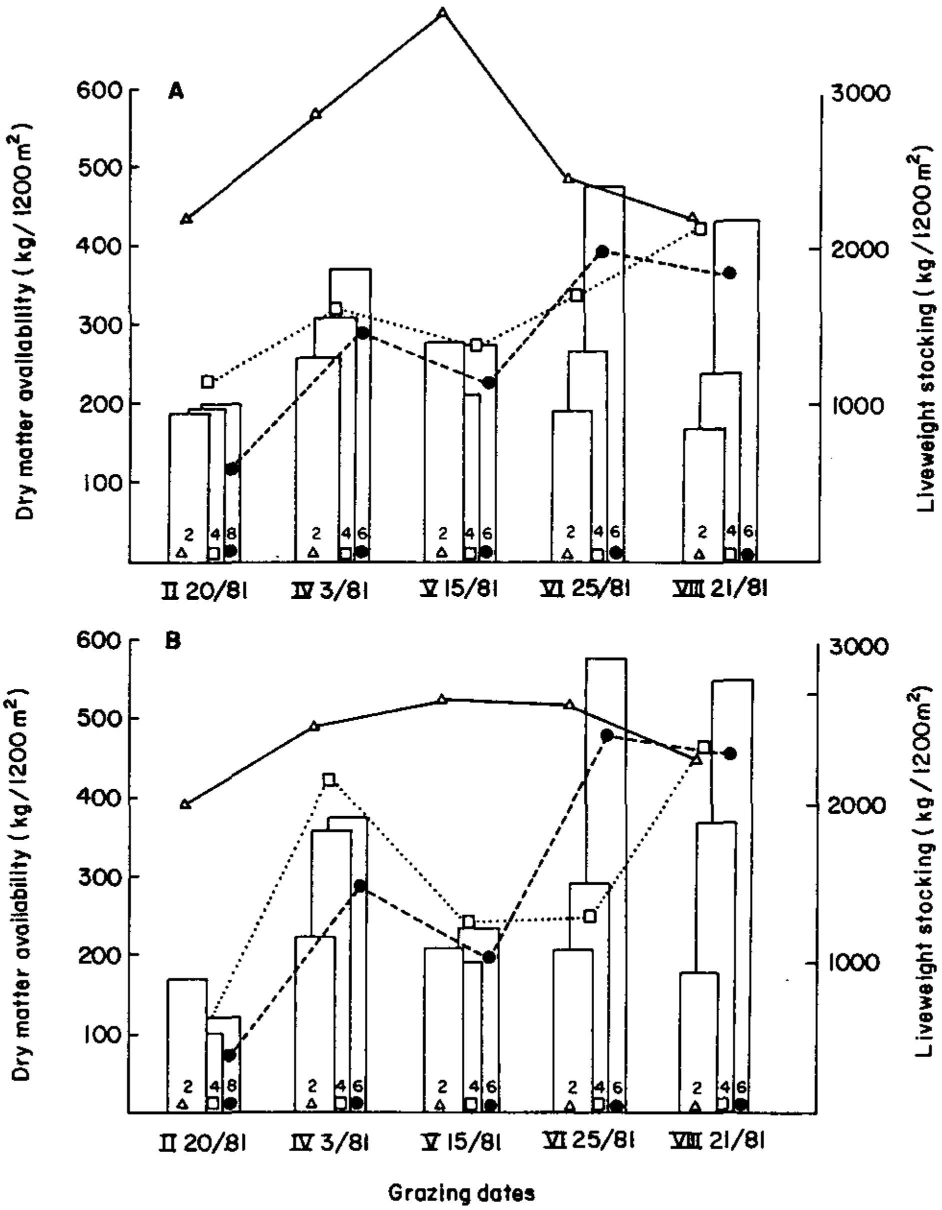


Figure 7. Changes with time of Relative Compatibility Index (RCI) of nine legumes when associated with Brachiaria decumbens 606 and Andropogon gayanus 621 in Quilichao.



A *Andropogon gayanus* 621 + *Centrosema pubescens* 438

B *Panicum maximum* 604 + *Centrosema pubescens* 438

Figure 8. Dry matter (grass-legume) availability changes in two mixtures under three different grazing pressures (2,4 and 6 kg MS/100 kg liveweight) applied rotationally.

Measurements of the botanical components in the mixture are done during the grazing period to monitor changes with time of botanical composition of the different mixtures under the different grazing pressures. At this point, it is too early for a definite picture of the treatment effects on botanical composition. However, this information should prove very valuable after one or more years to get information on the range of productivity (carrying capacity) and persistence of the mixtures under different defoliation regimes. Obviously, this type of information for a few selected associations will allow the Network researcher in charge to chose for a Regional Trial D, not only the best pasture mixture in terms of total productivity but that having the widest range of tolerance to under- or overgrazing.

In designing a Regional Trial D, there are basically two options: 1) using fixed grazing pressures and, 2) using fixed stocking rates. The choice of either one technique to evaluate the productivity of pasture in terms of animal gains, should not be, by any means, a dogmatic decision. The advantages and disadvantages of either approach are related to the potential productivity of the ecosystems (soil fertility, dry season length, carrying capacity level of native species, etc.) and the prevalent animal production system (intensity of management, level of stocking rate required, other sources of feed availability, type of animal, etc.). Methodologies should be assembled in each case to respond to specific ecosystems and production systems.

In order to try one of the alternatives an old trial was used. This included three pastures: 1) Andropogon gayanus 621 + Panicum maximum 604 + Hyparrhenia rufa 601 + Brachiaria decumbens 606 in blocks, with five repetitions in the same paddock; 2) Andropogon gayanus 621 + five Centrosema pubescens ectoypes sown in separate mixtures also with five repetitions within the same paddock; 3) the four grasses indicated above in mixture with Stylosanthes guianensis, Centrosema pubescens, Pueraria phaseoloides and Galactia striata. Starting in December 1980, a pure stand of Andropogon gayanus 621 was added to this trial. These four pastures are grazed using a "put and take" or constant grazing pressure management, adjusting the stocking rate to the availability of forage plus an estimate of the growth rates obtained with enclosed areas.

The changes in botanical composition of one of the four paddocks (Andropogon gayanus 621 + Centrosema pubescens) is shown in Figure 9. Since the beginning of 1980 the proportion of grass and legume has been stable in terms of green dry matter, varying from 15 to 20% of legume on offer. These results show a high degree of compatibility of the two species when properly managed. Figure 10 shows the accumulated gains per head and per hectare on the four pastures. Gains per head have increased linearly in all paddocks as expected, with small inflections between July and September 1980, when a long and drastic dry period occurred. This drought effect is more clearly shown in terms of animal gains per hectare where number of animals per paddock was drastically reduced during that period. The mean animal gains are around 550 g/an/day and 1700 g/ha/day.

An important aspect of this trial is to make measurements in the paddocks that could be used to predict animal performance. A first analysis of the data shows some interesting results. The relationship between animal gains per hectare and per head with total dry matter on offer (TDMO) for the paddock of Andropogon gayanus 621 with the five Centrosema pubsecens is presented in Figure 11. The TDMO, usually measured in grazing trials, had no relationship with animal gains and even shows less gains with more DMO. When "present green dry matter on offer" (PGDMO) is correlated to animal gains (Figure 12), the situation

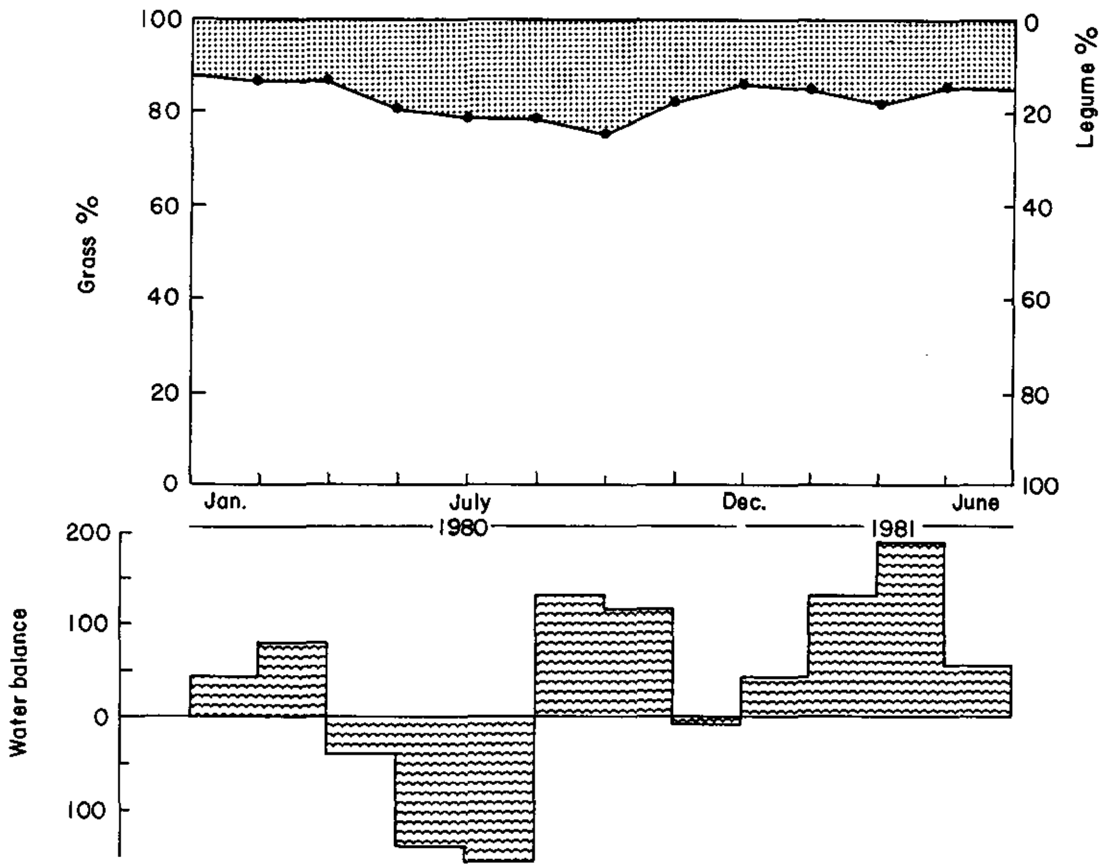
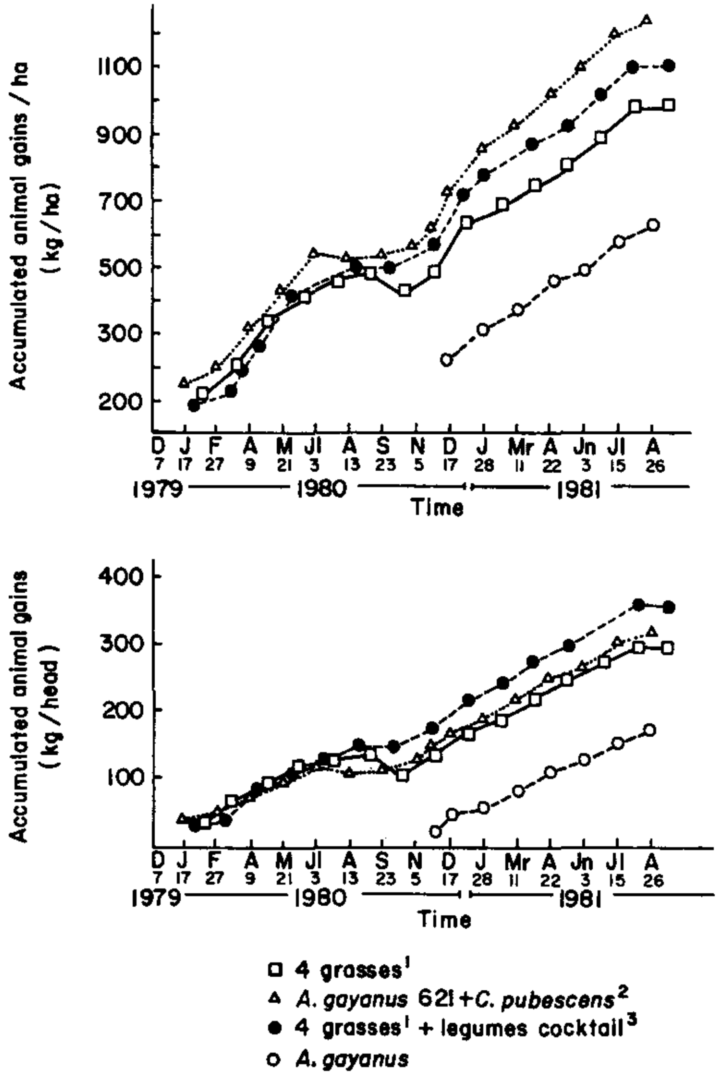


Figure 9. Changes in botanical composition of an Andropogon gayanus + Centrosema pubescens paddock based on green DM on offer.

improves drastically as indicated by the r , and the relationship becomes logical. This PGDMO is obtained by discarding dead material from the samples taken in the pasture. Furthermore, when daily average regrowth is added to the PGDMO, or "true green dry matter on offer" (TGDMO), variation in animal weight grains is better explained (Figure 13).

Several other botanical separations are being done as well as chemical analyses on resulting materials. It is expected to have enough information in the future to be able to select those measurements on pastures that provide the highest prevailing value of animal performance, so that they can be used by the Network participants.

As a closing statement, it is important to mention that one of the most critical constraints to research on pasture evaluation in tropical America is the lack of a reliable methodology, compatible with the national institution resources, with the productivity potential of different ecosystems, and with the feed resources of the prevailing production systems. It is then important for the Tropical Pastures Program to emphasize research in the methodology field.



[1] *A. gayanus* 621; *P. maximum* 604; *H. rufa* 601; and *B. decumbens* 606 in blocks of each in the paddock

[2] *C. pubescens* 438, 442, 469, 455 and 456 sown in 5 replicated blocks in mixture with *A. gayanus* 621

[3] Legume cocktail made of: *S. guianensis*, *C. pubescens*, *P. phaseoloides* and *G. striata*

[4] Gains/head = mean weight gains from "testers"

[5] Gains/ha = (gains/head) (No. of grazing animals)

Figure 10. Accumulated gains per head[4] and per ha[5].

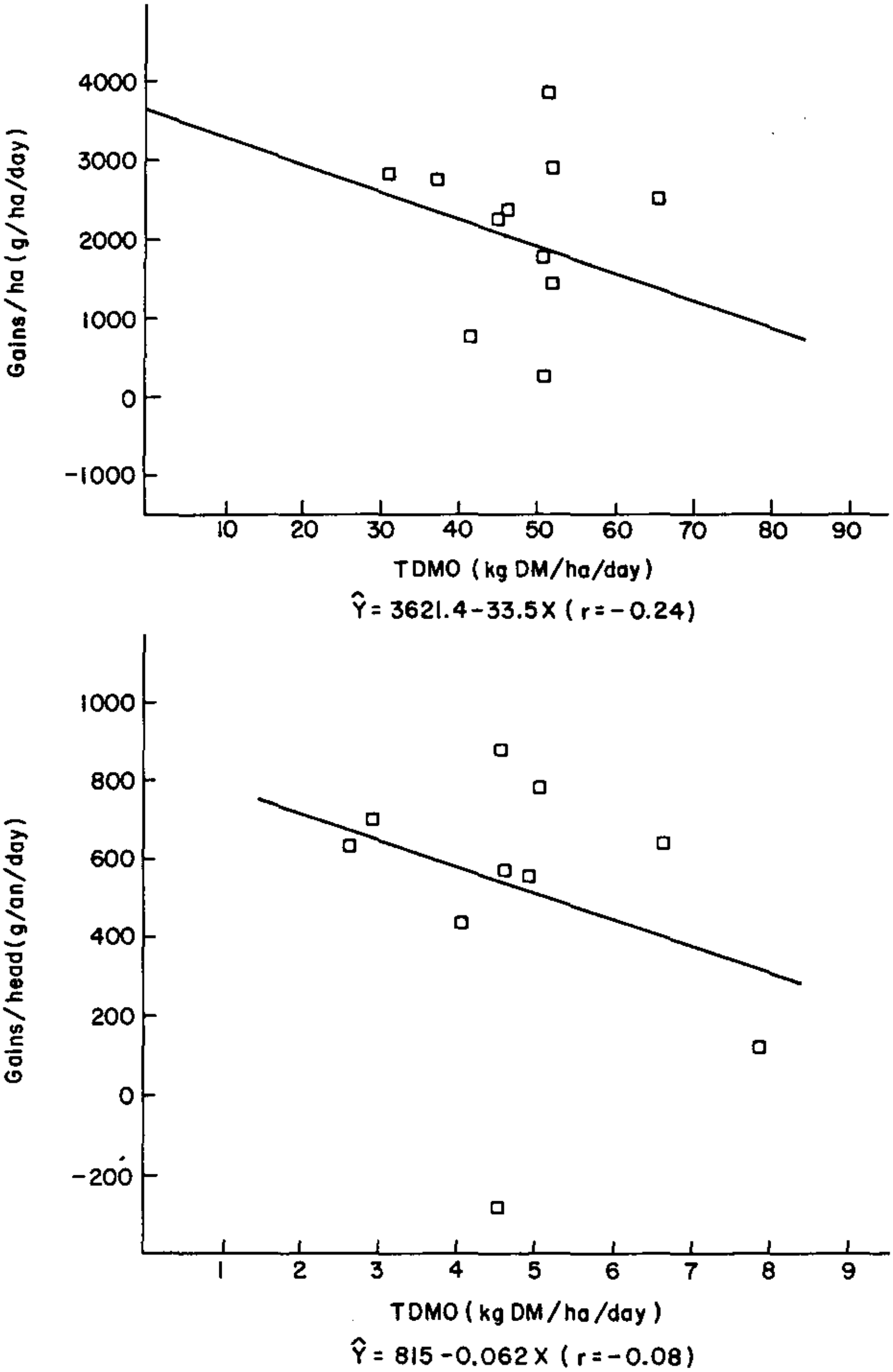


Figure 11. Relationship between animal gains per ha and per head with total DM on offer (TDMO) in a continuously grazed Andropogon gayanus 621 + Centrosema pubescens paddock.

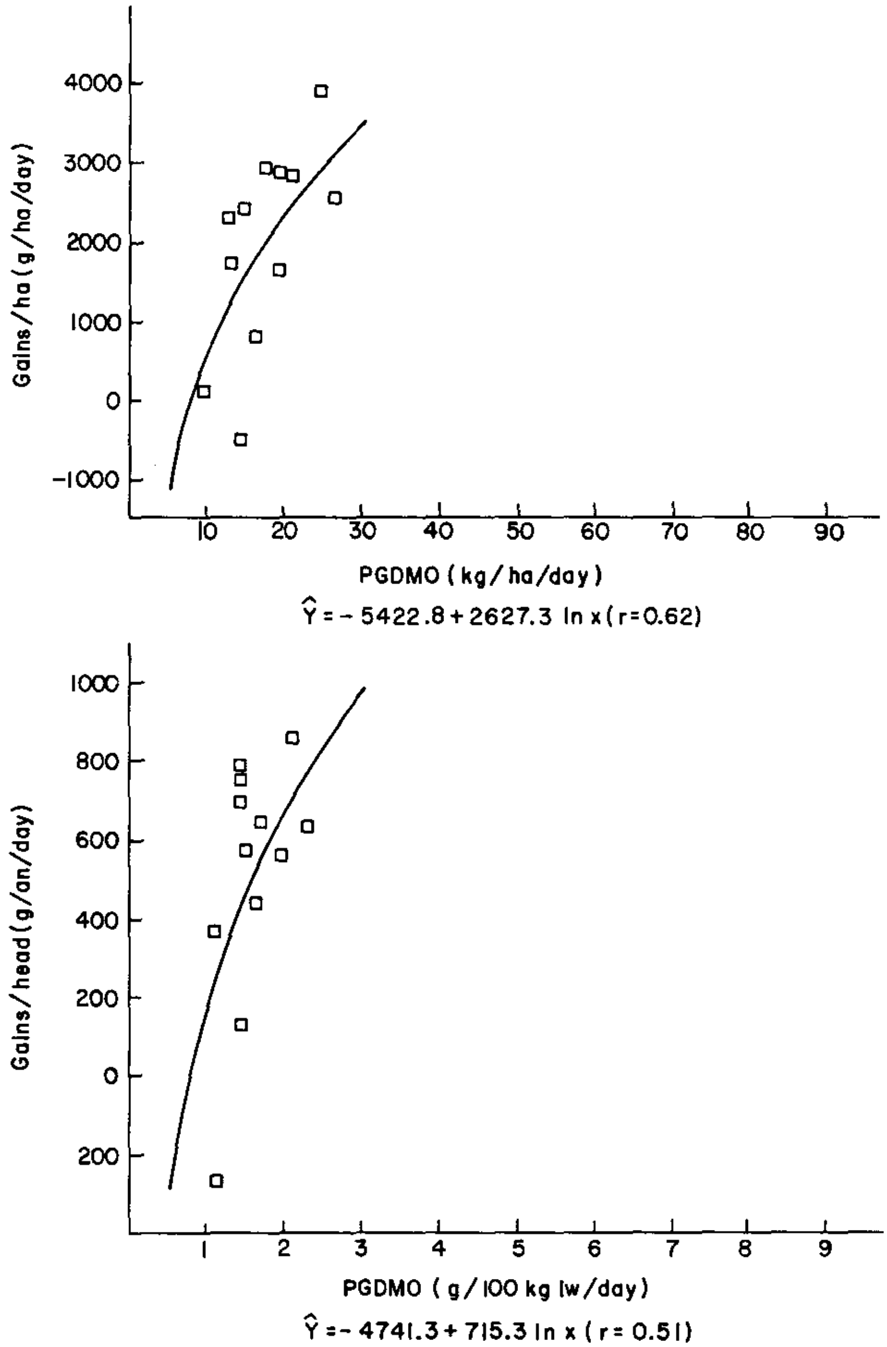


Figure 12. Relationship between animal gains per ha and per head with present green dry matter on offer (PGDMO) in a continuously grazed Andropogon gayanus 621 + Centrosema pubescens paddock.

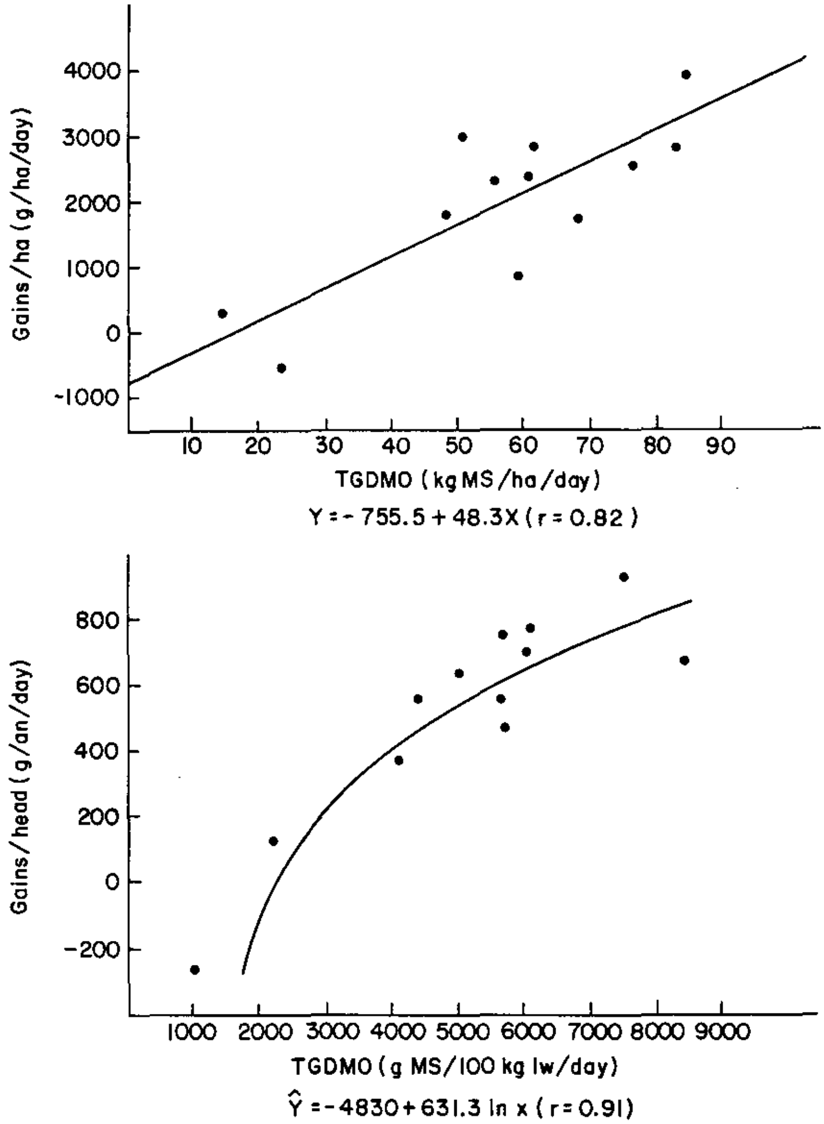


Figure 13. Relationship between animal gains per ha and per head with true green DM on offer (TGDMO) (present DM on offer + regrowth) in a continuously grazed Andropogon gayanus 621 + Centrosema pubescens paddock.