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Assessing the Land Equivalent Ratio (LER) of Two Leguminous Pastures (CLITORIA and SIRATRO) Intercropping at Various Cultural Practices and Fencing at ZALINGEI –Western Darfur State - Sudan

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ABSTRACT

Four experiments were conducted for two consecutive seasons (2009/2010 and 2010/2011) in a semi-arid Savannah zone, at the University of Zalingei perimeter, two kilometers east of Zalingei town Western Darfur State. The aim of the research was to assess the land equivalent ratio of two leguminous pastures species viz. Clitoria (Clitoria ternatea) and Siratro (Macroptilium atropurpureum) intercropping at various cultural practices and fencing under rained conditions. The influence of tillage (conventional and conservation tillage), weeding (mechanical weeds control) and enclosures versus open grazing system treatments was determined. The experimental design used was spilt-plot design with three replicates, in which mechanical weed control was assigned to the sub-plot and tillage systems (conventional and zero-tillage) to the main plots. Data were collected on forage yield (fresh and dry matter production) and land equivalent ratio. The results indicated that, cultural practices and enclosure significantly increased total forage yield (fresh and dry matter production) which was coupled with high land equivalent ratio (i.e. over 1.0)

Keywords: *Savannah zone, Zalingei Town, forage production, tillage*.

1. INTRODUCTION

The inclusion of one or two extremely palatable plants with other of lower palatability could result in over utilization and eventual elimination of the favored species (Plath, 1954). Seed mixture of species appears to have several advantages over stands of a single species (Cox and Cole, 1960). There are certain advantages of mixture over pure stands, these include, different rooting habits may result in more different use of soil moisture and nutrients from various soils depths, seasonal production is likely to be more uniform, a mixed diet is likely to be more desirable and produce greater gains, mixtures may have greater longevity and some plants of mixtures may have favorable influences on others such as nitrogen fixation (Nichols and Johnson, 1969).

Managing the complexity of interactions that are possible when more of the elements diversity is present in the farm system is a key part of reducing the need for external inputs and moving toward sustainability (Andrews and Kassam, 1976). A Primary and direct way of increasing diversity of an agro-ecosystem is the intercropping system that allows interaction between individuals of the different crops and varieties (Dariush, et al 2006).

It has been recognized that during recent years that intercropping i.e. growing two or more crops together on the same area) can often produce high yields than sole crops, but there can be problems in assessing the degree of yield advantage (Mead and Willey, 1980). Intercropping can add temporal diversity through the sequential planting different crops during the same season. According to Dariush, et al (2006) an important tool for evaluating the intercropping system is so called land equivalent ratio (LER). Land equivalent ratio is defined as the relative land area required as a sole crop to produce the same yields as intercropping (Mead and Willey, 1980). Providing that all other things being equal measures of the yield advantage obtained by growing two or more crops or varieties as intercrop compared to growing the same crop or varieties as a collection separates monoculture (Andrews and Kassam, 1976).

Generally, LER measures the levels of intercrop interference going on the cropping system. Theoretically, if the agro- ecological characteristics of each crop in a mixture are exactly the same the total LER should be 1.0 and the partial LERs should be 0.5 for each. On other hand, a total of LER of higher than 1.0 indicates the presence of positive inter-specific interference that exists in the mixture is not as intensive as the inter-specific interference that exist in the monoculture (Dariush, et al 2006). However, Kutrata, (1986) stated that an LER value of 1.0 indicating no difference in yield between the intercrop and the collections of monocultures and any value greater than 1.0 indicates advantage for intercrop. While LER of 1.2 indicates that the area planted to monoculture would need to be 20% greater than the area planted to intercrop for the two to produce the combined yield.

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2. MATERIALS AND METHODS

Four experiments were carried out during the course of the study 2009/2010-2010/2011. Two experiments each season, which include:

* Protected (enclosure) in which experiment was protected by a fence made of branches of trees (Acacia melifera and other thorny species).
* Unprotected (open), the field was left to be grazed by small flocks. The two sites were close to each other in order to avoid soil variation.

The treatments consist of two tillage systems which include:

* Conservation or no tillage in which the soil left unplowed.
* Conventional tillage, the soil was ploughed by using Baladi plough, in order to disturb and pulverize the soil and to increase its volume.

Weeding was carried out several times during the experimental period (manually) by using hands hoes to destroy the noxious weeds. Six treatments were used, these include:

* Weeded Clitoria (CW)
* Un-weeded Clitoria (CW0).
* Weeded Siratro (SW).
* Un-weeded Siratro (SW0).
* Weeded Clitoria and Siratro (SCW).
* Un-weeded Clitoria and Siratro (SCW0).

Because the top soil surface of the site is often crusted, which may resist to water infiltration and hence affect seed germination, pre-seeding, tillage operation was carried out using spring toothed cultivator, for both sites in order to improve infiltration characteristic of the soil and prepare well tilt seedbed. (The operation was done just after the first rain shower). The treatments were randomly assigned as follows:

T0: (CW, CW0, SW, SW0, SCW, SCW0).
T: (CW, CW0, SW, SW0, SCW, SCW0).

The experimental design used was Spit-plot design in which the two tillage systems were assigned to the main plots and the weed control treatments were assigned to the sub-plots. Treatments were replicated three times to make a total of 36 plots in each site (2x6x3). (Plot size is 10x10 meter).

2.1 Planting

Seeding of the rangeland was carried out by the two pasture legumes (Siratro and Clitoria seeds). Seeding was done immediately after the rain showers on the 25th of July for each season (in rows) at a rate of 5kg/Fed. (Tahir, 2003). Seeding was carried out during the two consecutive rainy seasons. Some seeds were sown in an open range and other was sown in enclosure range.

2.2 Forage Fresh Yield

A quadrat of one meter square was randomly thrown over the growing plants in each plot, and the shoots inside the quadrat were cut and weight using spring balance. The forage fresh yield was then obtained in ton /ha.

2.3 Dry Matter Production

The marked area that used for fresh weight was cut, weighed air-dried for 15 days to reach a constant weight. Then reweighed, and the dry matter was expressed in ton /ha.

2.4 Total Forage Production

The entire plot in each treatment for the two experimental sites was cut separately (at maturity) bundled, air- dried and weighed. The total forage production was expressed in ton /ha.

2.5 Land Equivalent Ratio Determination

The land equivalent ratio of the two experiments was calculated for the fresh and dry matter production throughout the two growing seasons and for the two systems used. LER was determined according to the equation below as stated by Mead and Willey (1980); Dariush et al, (2006).

2.6 Land Equivalent Ratio

$$LER = LA + LB = \frac{YA}{SA} + \frac{YB}{SB}$$

L_A and L_B are the LERs for the individual crops (Clitoria and Siratro).

Y_A and Y_B are the individual crop yields in intercropping, where S_A and S_B are their yields as sole crops. The partial LERs are then summed up to give the total LER for the intercrop.

2.7 Statistical Analysis

Statistical analysis of the data collected was performed using analysis of variance as described by Gomez and Gomez (1984). Duncan's multiple range tests was used for mean separation.

3. RESULTS

3.1 Total Fresh Yield Production (Tons/ha)

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Generally, weed control improved the total fresh yield of the two leguminous species under study either when grown as a sole crop or in mixture during the two growing seasons. It was observed that weed control significantly increased the total fresh yield of sole Clitoria, sole Siratro and Clitoria Siratro mixture by 43.8%, 19.1% and 31.52%, respectively during the first season inside the enclosure system, while no statistical differences were recorded between the treatments as a result of weed control during the second season of the same closed system (Table 1). Moreover, total fresh yield produced as a result of weed control was significantly higher in weeded plots versus un-weeded ones during the two growing seasons for the open system as shown in Table 1. In general the total fresh yield produced inside the enclosure of different treatments was higher than that of the open system during the two growing seasons by 7.12% and 11.75%, respectively.

Although there was an increase in total fresh yield reaching up to 9.29 tons/ ha; as a result of tillage, conventional tillage showed no significant influenced on total fresh yield for both leguminous species under study throughout the two growing seasons and between the two range systems as shown in Table2.

3.2 Total Dry Matter Yield Production (Tons/Ha)

As illustrated in Table .3, although there was no statistical effect on total dry matter yield of pasture legume plants under study as a result of weed management, weeded plots recorded higher dry matter production of both Clitoria sole, Siratro sole and Clitoria - Siratro mixture by 24.7%, 26.4% and 40%, respectively over un-weeded ones. However, weed control significantly increased the total dry matter production up to 4.05, 4.2 and 4.85 tons/ha. Versus the untreated plots of Clitoria sole, Siratro sole and Clitoria-Siratro mixture during the first and the second season inside the enclosure, respectively.

Concerning, the open system and as shown in Table.3, weed control showed no significant effect on total dry matter production between the different treatments during the first growing season, while weeded plots of Clitoria sole, Siratro sole and Clitoria-Siratro mixture statistically out yielded the un-weeded ones during the second season.

Tillage operation, (conventional tillage versus zero tillage) showed no significant effect on total dry matter, in the open and closed system during the two seasons (Table 4). On the other hand, total dry matter production of weeded plots inside the enclosure substantially out yielded that of the open system throughout the two growing seasons by 6.59% and 10.8%, respectively.

3.3 The Land Equivalent Ratio (LER) of Clitoria and Siratro Intercropping

As illustrated in Tables 5 and 6, the total fresh LER production substantially exceeded that of the sole production for both Clitoria and Siratro during the two seasons of growth. However, the total fresh LER of the treatment TW0 (conventional tillage zero weeding) was recorded higher LER for both the closed and open systems by 2.18 and 2.33, respectively, over T0W0 (zero tillage zero weeding) inside the enclosure system during the first season. On the other hand, LER for fresh yield during the first season of the open system the treatment T0W0 (zero tillage zero weeding) scored the highest value (2.51) (Tables 5 and 6). During the second growing season the LER values were generally lower than those of the first growing season. Values of LER obtained from the treatment TW0 (conventional tillage zero weeding) of both closed and open systems were 1.44 and 1.67 LER, respectively, more than T0W (zero tillage weeding) treatment.

Concerning, the dry matter production, as represented in Tables 7 and 8, results showed that the mixture or intercropping of Clitoria and Siratro combinations had resulted in substantial effect on total LER. Maximum and minimum LER values of 1.48 and 1.10 were attained from the treatments TW0 (conventional tillage zero weeding) and T0W0 (zero tillage zero weeding) intercropping combinations inside the enclosure system during the first season, respectively. While inside the open system maximum and minimum total LER values of 1.83 and 1.24 were obtained by treatments TW0 (conventional tillage zero weeding) and TW (conventional tillage weeding) combinations of the first season, respectively (Table 7). During the second growing season it was observed that the total LERs of both Siratro and Clitoria intercropping combinations were drastically higher than their cropping monocultures. Maximum and minimum LER values of 1.86 and 1.06 inside the enclosure and 1.99 and 1.54 inside the open system were obtained by treatments TW (conventional tillage weeding), T0W0 (zero tillage zero weeding) of closed and TW0 (conventional tillage zero weeding) and T0W0 (zero tillage zero weeding) of the open system, respectively (Table 8). Generally, the actual partial LER values of the treatment TW0 (conventional tillage zero weeding) in all of intercropping combinations during the two growing seasons and the two systems is higher than that of the other treatments.

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Table 1: Effect of treatments on total fresh yield (tons/ha.)(weed control)

Treatments	2009/2010.		2010/2011	
	Closed	**Open**	**Closed**	**Open**
CW	9.81ab	9.21ab	9.08a	8.54ab
CW0	5.51ab	4.38ab	6.71a	6.28ab
SW	5.22ab	7.19abc	10.08a	7.49ab
SW0	4.17b	4.04c	8.21a	5.45b
CSW	14.15a	10.78a	11.99a	10.76a
CSW0	9.69ab	9.57a	8.83a	9.93ab
SE ±	0.36	0.26	0.24	0.35
C.V%	26.58	9.21	12.86	21.46

Means followed by the same letter (s) within a given column are not significantly different at ($p<0.05$) level according to Duncan's multiple range test

Table 2: Effect of treatments on total fresh yield,(tons/ha.) Tillage system.

Treatments	2009/2010.		2010/2011	
	Closed	**Open**	**Closed**	**Open**
T0	8.25a	7.84a	9.01a	7.67a
T	7.93a	7.22a	9.29a	8.49a
SE ±	0.76	0.34	1.12	0.43
C.V%	46.13	27.17	59.95	25.88

Means followed by the same letter (s) within a given column are not significantly different at ($p<0.05$) level according to Duncan's multiple range test.

Key:

CW: Clitoria weeded. CW0: Clitoria un-weeded.
SW: Siratro weeded. SW0: Siratro un-weeded
CSW: Clitoria and Siratro mixture weeded.
CSW0: Clitoria and Siratro un-weeded.
T0: Zero Tillage (No tillage)
T: Tillage

Table 3: Effect of treatments on total dry matter, (tons/ha.) (Weed control)

Treatments	2009/2010.		2010/2011	
	Closed	Open	Closed	Open
CW	4.05ab	3.56a	3.27a	2.93bc
CW0	3.69ab	3.08a	2.46a	2.12de
SW	4.20ab	3.44a	3.22a	2.37cd
SW0	2.87b	3.04a	2.37a	1.72e
CSW	4.85a	4.80a	5.07a	4.77a
CSW0	4.01ab	4.13a	3.03a	3.41b
SE ±	0.21	0.17	0.09	0.14
C.V%	32.13	28.48	17.06	29.10

Means followed by the same letter (s) within a given column are not significantly different at ($p<0.05$) level according to Duncan's multiple range test.

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Table 4: Effect of treatments on total dry matter, (tons/ha.) (Tillage system)

Treatments	2009/2010.		2010/2011	
	Closed	Open	Closed	Open
T0	4.17a	3.37a	3.19a	2.74a
T	3.72a	3.93a	3.28a	3.03a
SE ±	0.13	0.14	0.31	0.04
C.V%	19.89	23.52	58.33	8.17

Means followed by the same letter (s) within a given column are not significantly different at ($p<0.05$) level according to Duncan's multiple range test

Key:

CW: Clitoria weeded. CW0: Clitoria un-weeded. SW: Siratro weeded.
SW0: Siratro un-weeded CSW: Clitoria and Siratro mixture weeded.
CSW0: Clitoria and Siratro un-weeded. T0: Zero Tillage (No tillage) T: Tillage

Table 5: LER fresh yields (Ton/ha.) First season 2009/2010

System	Closed			Open		
LER Treatments	L_A Clitoria	L_B Siratro	Total L_A+L_B	L_A Clitoria	L_B Siratro	Total L_A+L_B
T0W	0.97	1.08	2.05	0.73	0.68	1.41
T0W0	0.99	0.92	1.91	0.89	1.62	2.51
TW	0.71	0.99	1.70	0.63	0.67	1.30
TW0	0.83	1.35	2.18	1.29	1.04	2.33

Table 6: LER fresh yields (Ton/ha.) 2nd.season 2010/2011

System	Closed			Open		
LER Treatments	L_A Clitoria	L_B Siratro	Total L_A+L_B	L_A Clitoria	L_B Siratro	Total L_A+L_B
T0W	0.53	0.49	1.02	0.73	0.54	1.27
T0W0	0.66	0.37	1.03	0.78	0.72	1.50
TW	0.86	0.42	1.28	0.75	0.65	1.40
TW0	0.94	0.50	1.44	1.08	0.65	1.67

Key:

T0W: Zero Tillage Weeded T0W0: Zero Tillage Zero Weeding
TW: Tillage Weeded TW0: Tillage Zero Weeding

Table 7: LER dry matter yields (Ton/ha.) First season 2009/2010

System	Closed			Open		
LER Treatments	L_A Clitoria	L_B Siratro	Total L_A+L_B	L_A Clitoria	L_B Siratro	Total L_A+L_B
T0W	0.69	0.48	1.17	0.59	0.84	1.43
T0W0	0.67	0.43	1.10	0.61	0.69	1.30
TW	0.48	0.86	1.34	0.42	0.82	1.24
TW0	0.52	0.96	1.48	0.92	0.91	1.83

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Table 8: LER dry matter yields (Ton/ha.) 2nd.season 2010/2011

System	Closed			Open		
LER Treatments	L_A Clitoria	L_B Siratro	Total L_A+L_B	L_A Clitoria	L_B Siratro	Total L_A+L_B
T0W	0.74	0.59	1.33	0.79	0.94	1.73
T0W0	0.67	0.39	1.06	0.93	0.61	1.54
TW	0.96	0.89	1.85	0.93	0.95	1.88
TW0	1.00	0.55	1.55	0.89	1.10	1.99

Key:

T0W: Zero Tillage Weeded T0W0: Zero Tillage Zero Weeding
TW: Tillage Weeded TW0: Tillage Zero Weeding

4. DISCUSSION

4.1 Effect of Pasture Mixture (Intercropping) And Land Equivalent Ratio

The productivity of Clitoria-Siratro mixture and land equivalent ratios (LERs) were assessed in terms of fresh and dry matter production throughout the two growing seasons and the two grazing patterns used viz, enclosure and open systems. Results showed that the LER values of fresh yields and dry matter production for both Clitoria-Siratro mixtures substantially exceeded that of their corresponding monoculture. Since the idea of land equivalent ratio in most cases, is the most important comparison between yield of the main crop in mixture and its yield in pure stand, it is rather expected that the combination of component species in mixture will be more productive than the species grown as a sole crops.

The result obtained were strongly coincided with the definition of land equivalent ratio in that the combination of component species in the mixture were more productive than the same species when grown as sole crops. However, the LERs ratio, in almost all cases, were greater (over one) than the sole which interpreted as advantage of mixture over sole. Similarly, Mazaheri and Overysi (2004) documented that an LER of 1.0 or less indicating that no difference in yield between the intercrop and the collections of monoculture, while any value greater than 1.0 indicates that yield advantage for intercropping. Moreover, Mead and Willy, (1980); Dariush et al (2006) confirmed that LER is taken as a measure of relative yield advantage for example LER of 1.2 indicates that the area planted to monocultures would need to be 20% greater than the area planted to intercrop to produce the same combined yields (i.e. 20% more land would be required as a sole crop to produce the same yield as intercropping). In addition, more researches were carried out to demonstrate the advantage of intercropping versus sole crops. Ta, and Fari (1987) indicated that results of mix-cropping timothy with alfalfa significantly increased both herbage and nitrogen concentration when compared to timothy grown in a pure stand. Whereas Sengul, (2003) realized that legume mixtures with one or two grass species gave higher dry matter yield than the single crop. The superiority of the mixtures was also reflected in their large N harvests compared to pure stands of alfalfa and pure grasses. Furthermore, the protein concentration of the hay from the mixtures was higher than that of pure stand. The LER values of grass mixtures were higher in both single and binary grass mixtures in presence of Medicago (1.10, 1.22) and Onobrychis (1.08, 1.11, respectively) than those of their pure stands.

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