Research Article
Forage Agronomic Evaluation and Biological Compatibility on Grasse: Legume Intercropping in North Gondar Zone, Ethiopia

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Abstract: The objective of the experiment was carried out to assess forage agronomic evaluation and biological compatibility of grass/legume intercropping for better biomass yield and quality in North Gondar zone. During the experiment Randomized Complete Block Design (RCBD) was employed and the plot size was 2 m×5 m. Relative Yield Total (RYT) was also found to be more than one in all cuts at SP3. In seed proportion three at cutting stages two, the highest value was recorded about 1.72 indicating yield advantages of 72% in forage mixture as compared to sole cropping of forage species. In all observation the higher the legume proportion the relatively lower the Neutral Detergent Fiber (NDF) up to (50:50) ratio. The contents of ADF were high at HS3. Acid Detergent Lignin (ADL) was found to be higher at HS3 and the lowest value was obtained at HS1 and SP3. In general, the fiber contents were increased with increasing the stages of harvesting as a whole. With all these findings the experiment result of this study was showed that the combination of SP3 and harvesting at milk stage could be considered as the best association of grass/legume mixture as it resulted in no biological competition on soil resources.

Keywords: Agronomic evaluation, compatibility, Ethiopia, intercropping, relative crowding coefficient, relative yield total

INTRODUCTION

Ethiopian has a large livestock population and diverse agro-ecological zones suitable for livestock production and for growing diverse types of food and fodder crops. However, livestock production has mostly been subsistence oriented and characterized by very low reproductive and production performance; this is due to primarily shortages of quality and quantity of animal feed (Malede, 2013). Livestock production in the tropics can be increased through increasing the productivity per animal and per unit land area. A major factor in increasing livestock productivity will be the improvement of animal nutrition and feed supplies, especially in case of ruminant animals. Improved animal disease and parasite control, breeding and management will also be important, but initially a major emphasis must be placed on providing better nutrition (Whiteman *et al*., 1980).

Natural grazing land of the area consists of largely wide range of grasses, legumes and other herbaceous species. According to Daniel (1990), the existing feed stuffs in Ethiopia, native pasture and crop residues are poor in quality and provide insufficient protein, energy, vitamins and minerals. Animals' thrive predominantly on high-fiber feeds, which are incomplete in nutrients (nitrogen, sulfur, phosphorus, etc) necessary for microbial fermentation (Osuji *et al*., 1993).

Pressure on the land resource of tropical and sub-tropical countries has increased as the number of people supported by the land has risen. Thus, cultivation of uplands, which are marginally suited to annual crops, has led to diminishing of soil fertility and crop yields. Continuous cultivation of the same types of crop has led to the development of intransigent problems of diseases, pest and weed infestation. Tropical forages are playing a vital role in the development of sustainable cropping system and a best methods of forage improvement has arisen by using intercropping of annuals crops and perennial legumes in sole cropping patterns makes it possible to manipulate the outcome of competition (Humphrey, 1994).

If the price of animal products rises, farmers may adjust their planting schedules in favor of forage crops and commercial livestock production could be only achieved through the feeding of quality forage. The livestock producer's primary goal in forage management should be maintaining forage quality at a stage that will support desired gain or production. In addition to maintaining optimum harvesting stages, growing of grass species in mixture with legume species is economically feasible approach to improve the quality and quantity of forages for feeding animals. The combination of grass and legume species improves CP content and dry matter yield of forages. Moreover, the important feature of the mixture is enhancement of

seasonal distribution of forages, because legumes remain green long in the dry season (Prasad and Singh, 1991). The performance of the mixture depends on their compatibility and initial seed rate proportions of grass and legume species (Willey and Rao, 1980). Low seed rate results in a poor stand and prolonged time required for development of satisfactory grass-legume mixed pasture and high seed rates are in conspicuous because it incurs higher cost (Prasad and Singh, 1991).

Grass species and the legume have been identified to have a promising potential for pasture improvement. In addition, the MOA for adoption by dairy cattle owners is testing the different legume species. However, information on their agronomical management such as the stage of harvesting and optimum level of seeding rate for maximum biomass production for mixed pastures to improve yield and quality of forage is generally inadequate. Therefore, this study was designed with the following objectives:

- To study the forage biological compatibility for maximum biomass yield, quality and biological efficiency of forage intercropping in the study area.

MATERIALS AND METHODS

Description of the study area: The experiment was conducted at Janguakebele in Dembia district, North West Ethiopia, 36 km from Gondar to GorgoraTana road. The area experiences one main rainy with long rainy season extending from half of March to the mid October. But the effective rainfall is started from May to half September. The mean annual rainfall was 1150 mm with a peak in June and July having an average of 105 rainy days. The mean maximum and minimum temperatures 26.7°C and 13°C correspondingly. The area lies at an altitude of 2010 m.a.s.l. The major criteria used for the selection of the experimental area were the proportion of livestock especially local dairy cows and crossbred dairy cattle are more available in the study area at the radius of 5 km from the farming area to the milk shade area in the town, in addition there is a shortage of improved forage species and due to grazing land has been shifting of in to crop land as human population increased as geometric rate hence forage intercropping is unquestionable.

Soil characterization of the experiment site: The soil type of the experiment site is dominantly 65 and 35% black and red brown soil, respectively. They are generally vertisol, gentle slope and well drained. The surface soil characterization was done by taking samples from different places of the experimental site diagonally at the depth of 0-20 cm, thus the samples were compiled and duplicate for chemical analysis. Soil pH at the soil: water ratio of 1:2.5. Organic carbon content (%) by Nelson *et al.* (1982). Total N was

determined by Bremner and Mulvaney (1982). Available phosphors by Olsen method (Olsen *et al.*, 1954). Therefore, the analysis of surface soil resulted the pH value was 6.2 which is a little acidic, organic carbon 2.01 organic matter, total nitrogen and extractable phosphorus were also 3.5, 0.6% and 9 ppm of the surface soil sample analysis respectively. Characterization of surface soil indicated that suitable for the plant growth, organic carbon, total nitrogen and extractable phosphorus could be also considered as high to medium level of soil nutrients.

Land preparation and sowing: Land was ploughed in March and April and harrowed in June 2004 cropping year. The varieties were grass and Legume using 120 kg and 25 kg seed rate for grass and legume correspondingly. In both varieties the plot size was 12 m×5 m (Main plot) and 2 m×5 m for sub plot treatments. The seed was purified; select the weed and other dead, irregular in shape for to increased germination percentage. Therefore, the seed was mixed according to their respective seed proportion treatment combination and broadcasted on a well-prepared seedbed on the experimental site.

Experimental design and treatments: The experiment was conducted with three stages of cutting in the main plot and five seed rate proportions in sub plots in red soil and all together 20 treatments were put and replicated four times.

Seedling and tiller counts: Seedling counts for both species were done one week after emergence from the quadrants having (0.5 m×0.5 m) area from each plot. It was carried out initial plant stand after seven days of growth by measuring quadrants and summarized the mean value at the different seed proportion treatments taken from each plot for both grass and legume mixture. Tillering count for grass was measured at 45 days of growth by taking 0.5×0.5 m sample area from each the entire plots and count the number of tillers found from individual plants and then after, calculate the average number of tillers per meter square.

Plant height and heading date of plants: Ten plants of grass and ten plants of legume were harvested every 20 days from ground level, to measure the height, fresh and dry matter weight and measured to assess the rate of change of height over the growing period. Height was expressed in centimeters by measuring the height of ten randomly selected plants from the ground level to the tip or apex of the plant every 20 days of interval of plant growth. The forage from each plot was weighed first and then separated in to grass, legume and weed to estimate proportions of leaf and stem of grass from each plot in the different seed proportion.

Dry matter accumulation was also determined every 20 days of plant growth therefore the samples was dried to constant weight at 65°C in forced oven dry

for 72 h at Gondar, Soil Laboratory Center and measured the changes in g/10 plants. For dry matter yield determination, the fresh weight of each plot was measured in the field using 20 kg measuring capacity balance in the field just after cutting. Sub-samples of each treatment were dried in the oven at 65°C for 72 h to determine the dry matter contents of the forages at Gondar Soil Laboratory Center. The dry matter yield was then determined by multiplying fresh yield tone per hectare by the respective percentage in oven dried sub-sample and divided by formula the area (Temedo, 1994).

Biological compatibility in the mixture:
Relative Yield Total (RYT): The Relative Yield (RY) for grass and legume was assessed using the equation of DeWit (1960):

$$RYG = DMYGL/DMYGG \quad RY_G = \frac{DMY_{GL}}{DMY_{GG}}$$
$$RYL = DMYLG/DMYLL$$

where, DMY_{GG} is dry matter yield of grass (G) as a sole crop, DMY_{LL} is dry matter yield of legume (L) as a sole crop, DMY_{GL} the dry matter yields of any annual grass component (G) grown in mixture with any annual legume (L) and DMY_{LG} is dry matter yield of any annual legume component (L) grown in mixture with any annual grass (G). Relative yield total and land equivalent ratio (LER) was calculated according the formula of De Wit (1960):

$$RYT = (DMY_{GL}/DMY_{GG}) + (DMY_{LG}/DMY_{LL})$$

Relative Crowding Coefficient (RCC): The parameters of relative crowding coefficient was calculated to determine the competitive ability of the annual grass and legume in the mixture to measure the component that has produced more or less DMY than expected in annual grass-legume mixture according to De Wit (1960):

$$RCC_{GL} = DMY_{GL}/(DNY_{GG} - DMY_{GL})$$
$$RCC_{LG} = (DMY_{LG}/DMY_{LL}) - DMY_{LG}$$

This is only for 50:50 seeding rate while other than this:

$$RCC_{GL} = DMY_{GL} \times Z_{LG} / (DMY_{GG} - DMY_{GL}) \times Z_{GL}$$

where,
Z_{LG} = The sown proportion of legume in combination with grass
Z_{GL} = The sown proportion of grass in combination with legume
RCC_{GL} = Relative crowding coefficient of grass/legume mixture
RCC_{LG} = Relative crowding coefficient of/legume grass mixture

Aggressivity Index (AI): The dominance or aggressive ability of the annual grass against the annual legume in a mixture was described by calculating Aggressivity Index (AI) as indicated by McGilchrist and Trenbath (1971):

$$AI_{GL} = (DMY_{GL}/DMY_{GG} - (DMY_{LG}/DMY_{LL})$$

Biological efficiency of forage intercropping: Botanists defined plant interference as the response of on individual plant or species to its environment and modified by the presence of another individual plants or species (Donald, 1963). Interference occurs among plants of the some species in pure stands and among plants of different species in intercropping systems. Such interference can be non-competitive or complements. Non-competitive interference occurs when different plants shore a growth factor (light, water and soil nutrients) that is present in sufficient amount so that it is not limiting (Tilahun, 2002).

A competition function is proposed as a measure of intercrop competition to indicate the number of times by which one component crop is more competitive than the other (Willey and Rao, 1980). This competition function could be use full, to compare the competitive ability of different crops and to measure competitive changes within a given combination which can identity which plant character is associated with competitive ability therefore it could determine what competitive balance between component crops is most likely to give yield advantage. The competition functions which have been widely used are relative crowding coefficient (De wit and Van den Bergh, 1965).

RESULTS AND DISCUSSION

Relative Yield Total (RYT) or Land Equivalent Ratio (LER): Harvesting of forage at milk stages resulted with the value of 1.72. This is equivalent to 72% more yield advantage at seed proportion three as compared to sole cropping (Table 1).

When these two component crops were sown with equal seed proportion (50:50) and harvested at dough stage, the Relative Yield Total (RYT) was 1.19 and the yield advantage was found to be 19 and 15% with respect to seed proportion three and seed proportion two correspondingly. Harvesting of forage at boot stages and sowing equal proportion of grass/legume mixture accounted for the maximum RYT of 1.14 that indicated a yield advantages of 14%, in which the contribution of grass was 78% and legume 36% that of their respective pure stands.

This RYT does not only give a better indication of the relative competitive ability of the component crops, but also it indicated the actual advantages due to intercropping. The intercropping system resulted in

Table 1: Relative yield total advantage on grass-legume intercropping

| | Harvesting stages | | | | | | | | |
| | HS1 | | | HS2 | | | HS3 | | |
Seed proportion	RYG	RYL	RYT	RYG	RYL	RYT	RYG	RYL	RYT
SP2	0.22	0.49	0.71	0.25	0.74	0.99	0.26	0.89	1.15
SP3	0.78	0.36	1.14	0.87	0.85	1.72	0.56	0.63	1.19
SP4	0.38	0.37	0.75	0.36	0.26	0.62	0.72	0.27	0.99

HS1-3 = Harvesting stage from one to three; SP3-5 = Seed Proportion from three to five; RY = Relative Yield; RYT= Relative Yield Total; LER = Land equivalent ratio

Table 2: Relative Crowding Coefficient (RCC) on for age mixture

| | Harvesting stages | | | | | | | | |
| | HS1 | | | HS2 | | | HS3 | | |
Seed proportion	Y	Z	K(YxZ)	T	V	K(YxZ)	T	V	K(YxZ)
SP2	0.86	1.89	1.63	1.02	0.95	0.97	1.08	2.65	2.86
SP3	1.21	0.55	0.67	2.21	1.75	3.87	1.27	1.68	2.13
SP4	0.62	0.95	0.59	0.58	1.03	0.60	0.86	0.10	0.95

RCC = Relative Crowding Coefficient; K = Coefficient; Y = Grass; Z = Legume; T = Product

Table 3: Aggressivity index on agronomic practice under forage intercropping

| | Harvesting stages | | | | | |
| | HS1 | | HS2 | | HS3 | |
Seed proportion	T/V	V/T	T/V	V/T	T/V	V/T
SP2	+0.63	-0.63	+0.49	-0.49	+0.54	-0.54
SP3	+0.11	-0.11	0	0	+0.07	-0.07
SP4	+0.50	-0.50	+0.52	-0.52	+0.45	-0.45

T/V = Grass/Legume; AI = Aggeressivity Index

higher cumulative total biomass yield than either of the pure stand crop, which resulted in higher relative yield total value than the sole cropping. The higher cumulative total biomass yield was supposed to be resulted due to increase in light use efficiency of the intercrops, which resulted in higher cumulative leaf area of the intercrops.

Usually yield advantage occurs because component crops differ in their use of growth resources. It means that when they are grown in combination they are able to complement each other and make better overall resource than when they are grown separately. This indicated that, in some way, the component crops are not competing for exactly the same resources (Temado, 1994).

The finding this study is in line with the findings of Ibrahim *et al.* (1993), conducted in sorghum lablab intercropping reported by Jaballa (1995) also stated that intercropping treatments had higher combined leaf area than sole crop treatments.

Relative Crowding Coefficient (RCC): The biological compatibility of the two component crop species in relation to RCC indicated that, when the forage crop mixture was harvested at milk stage, under different seed proportion conditions, grass was found to be a dominant species over legume, but product of RCC of 50:50 grass and legume appeared to at an acceptable range, since the same has been computed for crowding

coefficient greater than one with the product of 3.87 (Table 2).

The product of crowding coefficient further indicated an advantage of mixing grass and legume either at 25:75 or 50:50 due to the fact that these patterns had produced products of crowding coefficient greater than one with the value of 3.87 at HS2 and SP3, respectively. The trend in the product of RCC of mixture harvested at dough stage was almost inferior to harvesting at milk stage. It appeared that among all the stages of harvesting, cutting at milk stages of grass/legume mixture SP3 (50:50) accounted for the maximum products of RCC (K = 3.87) as well as RY of both components was greater than one (Table 2).

Dominance or Aggressivity Index (AI): The experiment showed that aggressivity index at seed proportion three indicated that both species had the value almost exactly zero, in the case of HS2 the value becomes zero this indicating both crops were equally competitive (Table 3). However, in any other situation the two crops had equal numerical value, except the sign differences of which the dominant one becomes positive while the dominated was negative and the greater numerical value the bigger the difference between the actual and the expected yield.

Agronomic experiences indicate that nutrients and water are more generally limiting then light in the tropics. One possibility to yield advantages is that

component crops may exploit different soil layers and thus in combination they may exploit a greater total volume of soil due to horizontal or vertical root system stratification (Sanchez, 1975). Even though the growing periods are similar, component crops may have their own peak demands for nutrients at different stages of growth, a temporal effect which may help to ensure that demand does not exceed the rate at which nutrients can be supplied. A rather different temporal effect could occur where nutrients released from one crop as a result of senescence of plant parts are then made more readily available to on other crop (Willey, 1975).

Probably the main way that complementarities can occurs when the growth patterns of the component crops differ in time so that the crops make their major demands on resource at different times. Growing component crops with contrasting maturities, so that they complement rather than they compete for the resources at the sometime given better temporal use of resources. Andrew (1972) reported 80% yield advantage with 85 day pearl millet and 150 days sorghum and Kronth *et al.* (1976), obtained up to 73% yield advantage with varies 80 to 100 day crops and 180-day pigeon pea. Whereas Reddy *et al.* (1980) also found that 31% yield advantage with 82-day millet and 105-day groundnut (Donald, 1963).

CONCLUSION

In all stages of cutting of herbage the relative yield total result more than one at seed proportion three and had a greater yield advantage indicated 14, 72 and 19% correspondingly. The relative crowding coefficient also more than one at cutting stage two and three and aggressivity index become zero at cutting stage two and seed proportion three. Growing component crops with contrasting maturities, hence the biological compatibility was so effective so that they complement rather than they compete for the resources at the sometime given better temporal use of resources in the environment.

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