Soil Fertility Management

Adaptability of Introduced Green Manuring Plant Species for Soil Fertility Replenishment

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Abstract
Adaptability of 16 introduced green manuring plant species was seen during 2004-2005 cropping seasons at Adet, Ayehu and Injibara with the objective of selecting the best adaptable and high biomass producing plant species. The plants were evaluated for their biomass, ground cover, weed suppressing ability and presence or absence of disease and insect damage. The experiment was laid down in a randomized complete block design with three replications. Based on the parameters considered, *Tithonia diversifolia, Tephrosia candida, Tephrosia vogelli, Dolichos lablab,* and *Crotalaria grahamiana* produced 26, 25, 21, 22 and 20 tons of fresh biomass ha^{-1} and 5.5, 6.0, 5.0, 4.8, and 4.0 tons of dry leave and twigs biomass ha^{-1} respectively, and also had high ground cover, high weed suppressing ability, and had no disease and insect problem. Therefore, the aforementioned species were

mineral fertilizers in most tropical soils. It is mainly because, green manuring plant species can provide essential nutrients such as N, P, K and trace elements and improve soil structure through intensive root penetration and organic matter accumulation. Some plant species can also access non available P through root exudates or association with mycorhiza (Godbold, 1999 and Rao et al., 1999).

A soil fertility replenishment approach has been developed during the last 1.5 decades by researchers from International Center for Research in Agroforestry and national and International partners working with farmers using resource naturally available in Africa. The practice consists of three components that can be used in combination or separately: i) nitrogen fixing leguminous tree fallows, ii) indigenous rock phosphate in phosphorus deficient soils, and iii) biomass transfer of leaves of nutrient accumulating shrubs (Sanchez and Jama, 2002).

Sanchez (2002) reported that 100 to 200 kg N ha^{-1} was accumulated from interplanting leguminous trees of the genera *Sesbania*, *Tephrosia*, *Crotalaria*, *Glyricida*, and *Cajanus* into a young maize crop and allowed to grow as fallow during dry season in sub humid tropical regions of East and South Africa. The same author added that nitrogen rich leaves, pods and green branches of the tree fallows were hoed into the soil before planting maize at the start of the subsequent rainy season and releases nitrogen and other nutrients to the soil thereby increased maize yield 2 to 4 fold over the control.

Nziguheba *et al*. (2002) also reported that tithonia, lantana and croton recorded larger amount of resin P (112 %, 76 %, and 56 %, respectively) than values predicted by their P content and TSP response curve. They further stated that, the P and N taken up by plants can be turned to the soil in the plant available forms by biomass application. Eastwood and Sartain (1990) also reported that organic anions released from decomposing residues can compete with P for adsorption site making the P more available to crops.

Degradation of soil organic matter (OM) under continuous cropping is a major reason for decreasing soil fertility. Decomposition of OM is the sequence of microbial processes that is enhanced by increasing temperature, aeration, and optimal moisture content. Such conditions prevail particularly under intensive cropping system. Therefore, the most effective means of arranging natural supply of N and organic matter to a soil is the cultivation of suitable legumes and their insitu incorporation at appropriate stage of growth (Tiwari *et al*., 2000).

Nziguheba (*et al*., 2002) reported that despite their P and N concentration, organic residues (green manures) may have additional benefits in increasing P and N availability as compared to chemical fertilizers due to their positive effect on soil physico chemical properties. In addition, green manuring plants can also be used for different purposes such as human food, animal feed, weed suppression and crop pest control.

Hence, in countries like Ethiopia, the use of green manure alone or in combination with chemical fertilizers seems the best alternative to improve soil fertility and sustain production and productivity. However, the use of plant biomass for nutrient replenishment and other purposes require the identification of species with an ability to increase nutrient availability to crops. The objective of this study was, therefore, to select the best adaptable and high biomass producing green manuring herbaceous and shrub legume and non legume species.

Materials and Methods

The adaptation trial of 16 introduced green manuring plant species was carried out at Injibara, Adet and Ayehu research stations representing high and mid altitudes. The species were selected for good adaptation, high biomass and efficiency in suppressing weeds. The green manuring plants for which adaptability was tested were *Crotalaria grahamiana, Crotalaria paulina, Crotalaria junicea, Canavalia ensiformis, Desmodium uncinatum, Gliricida sepium, Tithnia diversifolia, Tephrosia candida, Dolichos lablab, Tephrosia vogelli, Calliandra calothyrsus, Mucuna prunensis, Leuceana trichondra, Leuceana divesifolia, Leuceana pallida* and *Crotalaria* species.

Seeds of most green manuring plants that need cold or hot water treatment before sowing were treated to enhance germination whereas seeds of some green manuring plants that don’t need any treatment were sown directly. The summary is indicated in Table 1.

Table1: Treatments of seeds of green manuring plant species before planting

Species name	Treatment	Time taken for soaking (hours)
Leuceana diversifolia	Soaked in hot water	24
Leuceana pallida	”	24
Leuceana trichondra	”	24
Crotalaria grahamiana	”	12
Crotalaria paulina	Soaked in warm water	6
Calliandra calothyrsus	Soaked in cold water	48
Tephrosia vogelli	”	12
Canavallia ensiformis	”	12
Gliricida sepium	”	6
Tephrosia candida	”	3
Crotalaria junicea	No treatment	-
Desmodium uncinatum	”	-
Tithonia diversifolia	”	-
Dolichos lablab	”	-
Canavallia ensiformis	”	-
Crotalaria species	”	-

Fresh and dry leaf and twigs biomass was determined for the promising plant species. The biomass was determined by taking samples from one meter square, weighed immediately, sun dried and repeatedly weighed until constant weight was achieved to determine dry biomass for *species* other than *Tephrosia candida* and *Tephrosia vogelli*. Whereas, for *T. candida* and *T. vogelli*, the biomass was determined based on the number of trees per hectare (i.e. 10,000 trees per ha). Plant height was also measured using a meter scale for the promising green manuring plant species. Three plants were selected from each plot to measure the height and the average of the three was taken as the plant height of the respective plant species.

Results and Discussion

The results of the experiment indicated that various green manuring plant species included in the experiment had differences in fresh biomass yield, dry biomass yield and plant height (Table 2).

Table 2: Fresh and dry biomass yields of leaves and soft twigs and plant height of green manuring plants species.

Species Name	Mean fresh biomass yield (ton ha^{-1})	Mean dry biomass yield (ton ha^{-1})	Average plant height (meter)	Remark
Crotalaria grahamiana	20.0	4.0	2.28	
Crotalaria paulina	11.0	2.0	2.62	
Tithonia diversifolia	26.0	5.5	4.15	
Tephrosia candida	25.0	6.0	3.97	
Tephrosia vogelli	21.0	5.0	3.28	
Canavallia ensiformis	8.0	2.4	0.79	
Mucuna prunensis	8.0	2.3	1.78	creeping
Dolichos lablab	22.0	4.8	2.20	creeping
Crotalaria species	7.0	1.3	1.90	
Crotalaria junicea	5.0	1.0	1.72	

Crotalaria grahamiana

It germinated very well, had very good establishment and biomass yield as well as ground cover (Figure 1a) both at Adet and Ayehu. However, a few seedlings performed unsatisfactorily at Injibara. *C. grahamiana* suppressed weeds due to its high biomass (Table 2) and dense plant population. It has no insect and disease problem and reached 50% flowering six months after sowing.

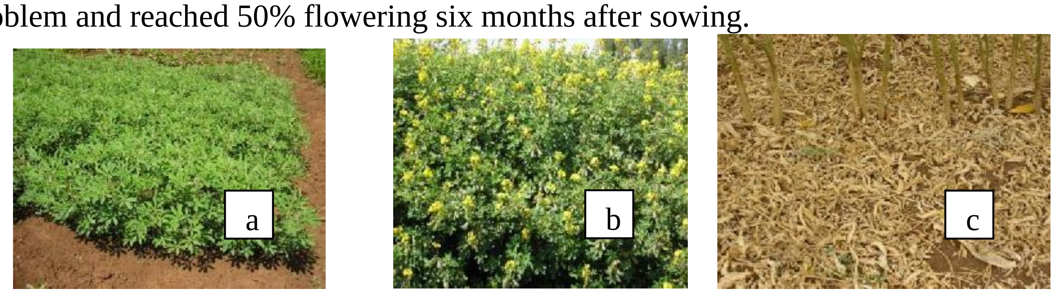

Figure1: Performance of *Crotalaria grahamiana* at vegetative (a) and flowering stages (b) and its leaf foliage (c)

During the second year, the plant started the second round flowering and attained 2.28 m average height 3 months after first seed harvest (Figure 1b). Compared to the first year, both biomass yield and flower initiation were better during the second year. The plant has a complete flowering habit and hence had uniform maturity. It has effective and reasonable number of nodules at 50% flowering. The leaf foliage covered the surface of the soil and could help to improve the fertility of the soil (Figure 1c).

In general, since it established well, produced high leaf biomass, was free from insect and disease, and is not eaten by animals, the plant is found to be suitable for green manuring particularly for improved fallow and biomass transfer. As very recently observed, *C. grahamiana* established and flowered at Injibara after one year and nine months. Hence, if proper management is made, it may be the best solution to improve soil fertility in the high lands too.

Crotalaria paulina

Similar to *C.grahamiana*, it established well and had deep green and soft (easily decomposable) leaves and stems at vegetative stage (Figure 2a) both at Adet and Ayehu, whereas none was established at Injibara. It has also a good plant biomass at Adet & Ayehu (Table 2).

Its leaves were damaged by insects during the seedling stage but, it was not a problem at the later stage. It reached 50% flowering stage 8 months after sowing. The plant has indeterminate flowering habit and hence seed maturity was not uniform. Pod boring insect was observed on the pods. The number of pods per plant is high plant. This might be due to poor performance of the associate rhizobia under such conditions. For the above reasons, though it was early maturing and free from disease, it was not selected as green manuring plant at Adet, Ayehu, Injibara, and cannot be recommended for areas with similar agro ecologies. Therefore, it should be evaluated under lower altitudes than the present experimental sites.

Canavalia ensiformis

It is a biennial and broad leaved plant with good establishment. Even though its leaves were damaged by insects at seedling stage, it has moderate plant biomass yield (Table 2) and ground cover. It also suppressed weeds very well due to its interlocked canopies (Figure 3a).

It started flowering seven months after planting during the first year and reached 50% flowering at 7.5 months and produced large sized seeds from large sized pods. The leaf fall can improve soil fertility for there is reasonable biomass addition to the soil surface (Figure 3b). The plant is suitable for intercropping with row planted crops such as maize, fruit trees etc or can be grown on fallow fields. No nodule formation was observed on roots of 5 representative plants taken from a plot during nodule counting. This may be due to the absence of the symbiont bacteria in the soil. Hence, there may be a need to introduce the symbiont bacteria or search for other ecologies where the rhizobia may be found.

Figure 3: Canavalia ensiformis at a vegetative stage (a) Leaf foliage of *Canavallia ensiformis* covering the soil (b)

Tithonia diversifolia

It is a perennial shrub, succulent, vigorous in growth and has many branches. The leaves are broad and deep green in color. It has very good establishment, high plant biomass yield (Table2) and good ground cover. Better than all the plant species included in the trial, it suppressed weed very well due to its dense canopy cover (Figure 4a).

It stayed vegetative during the first year both at Adet and Ayehu (Figure 4a). However, only few plants flowered 9 months after planting and small amount of seed was collected at Ayehu. Most plants, in both sites (Adet and Ayehu), started flowering one year and 3 months after planting and reached 50% flowering after 1 year and 4 months and its average plant height was 4.15 m. It has indeterminate flowering nature and there was no uniform seed maturity. The seeds are very light and can shatter easily if not closely attended and collected. Tithonia produced flower from all branches and hence large amount of seed can be produced (Figure 4b). However, due to its tall height (Table 2), it was difficult to collect all the seeds and hence there was a great shattering loss. Therefore, canvas should be laid under the plants during seed collection. There was high additions of biomass from leaves to the soil and can replenish soil fertility (Figure 4c). There was no disease and insect pest problem. In general, due to its high plant biomass (leaves and twigs) and freeness from disease and insect pests, the plant can be used as green manuring plant particularly for biomass transfer (by planting on farm boundaries and at sides or floor of gullies) but not for intercropping for it can suppress the associate crop by competing for light and other nutrients.

Fig.4: Performance of *Tithonia diversifolia* at vegetative (a) and flowering stage (b) and leaf foliage (c)

Tephrosia candida

T. candida has very good establishment and ground cover, high biomass yield (Table 2), and has vigorous stand like that of Tithonia. There was no problem of insects and diseases. It has high weed suppressing ability next to Tithonia.

The plant stayed vegetative during the first year and started flowering during the second year i.e. 1 year and 2 months after establishment and reached 50% flowering a month after starting flowering (Figure 5a) and has attained an average plant height of 3.97 m. The plant can be used as alley crop, as boundary plantation for biomass transfer, intercropped with row planted crops or can be planted on fallow lands to replenish the fertility of the soil. It can also be grown on soil conservation structures as biological measure and can check soil and water loss. The twigs and leaf mass can be incorporated to the nearby field or will be taken to other farm as biomass transfer. Foliage from leaves can improve soil structure and increases organic matter content of the soil.

Figure 5 T. candida at flowering stage (a) and Leaf foliage of *T. candida* covering the soil surface (b)

Dolichos lablab

Lablab is a biennial green manuring crop. It has poorly germinated and the leaves were damaged by insects during establishment. However, two months after establishment, it covered the surface and suppressed weeds.

It had high biomass yield (Table 2) and good canopy cover (Figure 6a). The leave foliage can improve soil fertility (Figure 6b). It flowers early, next to *Crotalaria junicea* and *Crotalaria* sp. It has indeterminate flowering nature and no uniform seed maturity was attained. Lablab best suits for gully reclamation for it is fast to cover the sides and floor of the gully and checks erosion. It can also be grown on fallow lands to replenish the fertility of the soil. In addition, it could be intercropped with row planted crops like maize, sorghum and other perennial fruit crops. It is also a good animal feed which can be a supplementary diet to low protein rations.

Figure 6: Performance of D. lablab at vegetative stage (a) and its leaf foliage covering the soil surface (b)

Tephrosia vogelli

It is similar to *Tephrosia candida* except it was earlier in maturity and shorter in plant height (Table 2) and produced large amount of pods per plant. It started flowering during the second year like *T. candida* but only one month earlier. It has however, relatively lower biomass compared to *T. candida* (Table 2).

Mucuna prunensis

Its establishment was very good and produced moderate amount of biomass (Table 2). However, there was insect damage on the leaves during emergence resulting in stunted growth. Like lablab, it is a creeping plant and needs stake support and continuous pruning for proper management. It can be planted intercropped with maize and other row planted crops and perennial fruit trees to benefit the associate crop as well as the next crop. It can also be grown on fallow lands to replenish the fertility of the soil. It flowers 8 months after establishment. The pods are attached to the stem and covered by leaves and hence, needs care during seed collection. The plant has indeterminate flowering habit.

Leucunea trichondra, Leucunea diversifolia, Leucunea pallida, Calliandra calothyrsus, Desmodium uncinatum, Glyricida sepium

These species poorly germinated at Adet and Ayehu and none of them germinated at Injibara. Though germinated at Adet and Ayehu, they were not fit to be used as green manure for they were poorly established and produced poor biomass. The plots were heavily infested by weed. However, they all are good animal feeds and known green manuring plants. Therefore, better ecology that could suit them should be identified.

***Crotalaria* species**

It has poorly established and produced poor biomass (Table 2) compared to other Crotalaria plant species due to low seed rate. However, it could give good biomass under relatively high seed rate and shallow seed depth during sowing. At deep seed depth, since the seed size is very small, it may fail to emerge. It has deep green and soft leaves and twigs which can serve as green manure. There was however, high weed infestation due to sparse plant population. Nevertheless, it is very fast in flowering following *Crotalaria junicea*. It flowers 2.5 months after establishment and reached 50% flowering at the third month. During nodule counting, it was observed that there was reasonable nodule which was effective and large in number next to *Crotalaria grahamiana.* It has large amount of pods per plant and produced large amount of seed. Since it is very fast in maturity, it can benefit the associate crop if incorporated to the soil at 50% flowering. The pods were damaged by pod boring insect. The insect was identified by the entomology section of the Adet ARC as it belongs to the order of Lepidoptera. The insect bores the pod at early stage, grows inside the pod and feeds on the seeds. Therefore, the plant is not selected as green manuring plant until further investigation is made on the entomological part.

Conclusion and Recommendation

For most Ethiopian farmers, who do not use chemical fertilizers or use very small amount (far below the recommended rate) due to high cost, and who do not use organic manures and plant residues for they used them for fuel, thatching, animal feed and construction, green manuring is the best alternative to replenish soil fertility. Therefore, special focus should be given to introduction of green manuring plant species that could fit to different agro ecologies of the country from other countries that have good experience in this regard. Among the introduced green manuring plant species, *Tithonia diversifolia, Tephrosia candida, Tephrosia vogelli, Crotalaria grahamiana, and Dolichos lablab* were adapted very well at Adet and Ayehu followed by *Crotalaria paulina, Canavallia ensiformis, Mucuna prunensis, Crotalaria species, and Crotalaria junicea.* The others were not adapted.

Therefore, the following recommendations can be forwarded:

- Well adapted plant species should be evaluated for their nutrient contribution efficiency ;
- Best agro ecology that suits to those species which fail to adapt in ecologies covered in this experiment should be identified
- Efforts toward introduction of green manuring plant species for different agro ecologies should not be limited,
- Further investigation on the pod boring insect damaging *Crotalaria species* and *Crotalaria paulina* should be made

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