Use of *Tithonia diversifolia* to improve cotton productivity under marginal soils in Uganda

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Abstract

Surface and subterranean application of five tithonia (*Tithonia diversifolia*) rates (0.6, 1.02, 1.63, 2.04 and 2.44 t/ha) was made to cotton at the National Semi Arid Resources Research Institute (NaSARRI) in 2014 and 2015. Surface application was accomplished by spreading the different tithonia rates on the soil underneath the cotton crop. Subterranean application was done by making trenches in the ground under the cotton crop followed by burying the tithonia in the trenches besides the cotton rows. Under surface application in 2015, seed cotton yields obtained from the five different rates were 2071.1, 2151.3, 2257.7, 2275.3 and 2639.0 kg/ha respectively compared to 1846.7 kg/ha from the control. As for the subterranean application in the same year, yields were 2295.3, 2361.7, 2375.2, 2913.2 and 2504.7 kg/ha respectively compared to 1289.7 kg/ha from the control. Yields of 2014 were lower but the trends were similar. Yield responses under surface tithonia application increased linearly with increased rates, while under subterranean method, the peak was at 2.04 t/ha rate. Subterranean application in 2014 significantly (P=0.05) increased cotton fibre length and strength compared to the controls. The longest (27.12 mm) and strongest (29.7 g/tex) fibres were recorded from cotton that received 2.04 t/ha of tithonia compared 25.47 mm and 25.8 g/tex respectively from the no-fertilizer controls. Analysis of soils after cotton harvest showed significantly (P=0.05) higher amounts of residual P where 1.02, 2.04 and 2.4 t/ha of tithonia were applied as surface (3.20, 3.54 and 3.26 ppm respectively) or as subterranean (4.37, 4.13 and 4.00 ppm respectively) compared to the controls (1.92 and 2.86 ppm respectively for surface and subterranean). Residual amounts of K were significantly higher at all rates, except 0.6 t/ha under surface application, and at the rates of 1.63, 2.04 and 2.4 t/ha under subterranean application, compared to the controls. Under

subterranean application, the rate of 2.04 t/ha gave high marginal rate of returns (MRR) value of 167 % and 295 % in 2014 and 2015 respectively. Taking a minimum acceptable MRR value of 100 %, none of the rates under surface application were viable in both years.

Keywords: *Tithonia diversifolia*, subterranean application, surface application, cotton, *Gossipium hirsitum*, phosphorous, potassium, gross margins, benefit/cost ratios and marginal rates of returns.

Introduction

Agricultural soils in Uganda have become increasingly infertile because of increased population and human activities on the land. According to the 2014 Uganda National Housing and Population Cencus, population has grown from 24.2 million in 2002 to 34.6 million in 2014 (UBOS, 2016). Of this population, 80 % is involved in Agriculture compared to 74 % in 2002.

Low productivity, declining soil fertility coupled with low use of improved inputs such as fertilizers, among other factors are cited in the Development Strategy and Investment Plan (2010/11-2014/15) of Uganda's Ministry of Agriculture Animal Industry and Fisheries (MAAIF) as some of the key challenges to increasing agricultural output in Uganda (MAAIF, 2010). One way to address the twin problem of low agricultural productivity on one hand and environmental degradation on the other, is fertilizer use –both organic and inorganic, especially in low income countries where fertilizer use is lowest (Smaling et al., 2006). Use of fertilizers is still low in Uganda, with reports of only 7.6 % of farmers using inorganic fertilizers compared to 25.3 % using organic materials by 2008-2009 (Okoboi and Barungi, 2012). Organic materials, both of animal and plant origin, are abundant in Uganda, but not many farmers have been sensitized to their importance. Appendix 1 shows the nutritional status of some of the various plant materials available for possible use in Uganda for soil fertility improvement.

Appendix 1: Proportions of N, P, K, Ca and Mg in different plants available for improvement of soil fertility in Uganda

Plant/part	**Percentage of nutrient in sample**				
	N	**P**	**K**	**Ca**	**Mg**
Green Mucuna leaves	4.15	0.155	1.88	1.28	0.364
Grey Mucuna leaves	3.77	0.123	1.90	1.51	0.388
Black Mucuna leaves	3.76	0.117	1.97	3.69	0.333
Chrotolaria ochroleuca leaves	4.33	0.200	5.97	1.95	0.603
Chrotolaria pancila leaves	3.71	0.217	4.12	1.49	0.460
Tithonia leaves (old)	4.52	0.130	1.69	2.61	0.871
Tithonia leaves (young)	3.29	0.121	1.56	3.55	0.460
Tithonia heads	3.83	0.132	1.05	2.92	0.277
Tithonia stems	2.23	0.162	2.52	1.43	0.439
Tithonia elsewhere(Agbede et al, 2013)	**1.88**	**0.79**	**3.89**	**3.41**	**0.004**

Cotton is Uganda's third largest export crop after coffee and tea. It is the main source of income for some 250,000 households, who cultivate cotton under rain- fed conditions and with minimal use of inputs, such as fertilizers and chemicals. Since the climate and the soils are very suitable for cotton cultivation, it is a very popular commodity among smallholders with an average farm size of 0.5 hectares. In Uganda, national average yields of seed cotton have increased from 625

kg/ha in 1994 to 1250 kg/ha in 2010, while on the rich volcanic foothills of Mt. Rwenzori in the west, yields of up to 3,750 kg/ha have also been achieved. The difference between yields around Mt. Rwenzori and other areas is due to soil fertility variations.

Tithonia diversifolia is a shrub in the family Asteraceae. Although not native to Africa, it is widely distributed along farm boundaries and roads in the humid and sub humid tropics of Africa, including Uganda. Several uses of the plant in the agricultural perspective have been reviewed by Jama, *et al* (2000). These include fodder, poultry feed, compost, land demarcation, soil erosion control, building materials and shelter for poultry, crop protection from termite damage and other insecticidal applications, treatment of hepatitis, and control of amoebic dysentery. The use of tithonia for soil fertility improvement has become common in many African countries including Malawi (Ganunga, *et al* 1998), Rwanda (Drechsel and Reck, 1998), Kenya (Jama, *et al* 2000) and Zimbabwe (Jiri and Waddington, 1998). This is because the plant can grow freely along farms and homesteads, forms biomass rapidly even after cutting, can be propagated through cuttings, is rich in soil nutrients, and rapidly releases the nutrients to the soil for use by crops. According to Olabode, *et al*, (2000), tithonia decomposed faster compared to Chromolaena and Panicum because of its lower C/N ratio. Compared to other cover crops, tithonia is rich in N and Ca, depending on plant part used (Appendix 1). Jama, *et al* (2000) reported that although tithonia leaves represent only about 15 to 17 % of the total above-ground biomass, the leaves contain about 35 to 40 % of the above-ground plant N and P and about 25 to 30 % of the above-ground plant K. Decomposition and release of these nutrients have been associated with increases in maize yields (Jama, *et al* 2000; Rutunga *et al*, 2001). There are no reports of use of tithonia to improve soil fertility in Uganda, especially for cotton production. In view of the declining soil fertility vis-a-vis abundance of tithonia in the country where fertilizer costs are too high for farmers, the testing of the plant for possible commercial use was necessary.

The objective of this study was to evaluate the potential of tithonia to improve soils for cotton production in Uganda. The specific objectives were to:

(a) Determine the optimum rate of tithonia application to cotton

(b) Establish the best method of tithonia application for best benefit.

Materials and methods

Trials to test tithonia on cotton (variety BPA 2002) were conducted at the National Semi Arid Resources Research Institute (NaSARRI, 01° 31' N; 33° 27' E; 114 m above sea level) in 2014 and 2015. In both trials, two tithonia application methods, surface and subterranean, were used.

Surface application was accomplished by spreading the different tithonia rates on the soil beneath the cotton crop. Subterranean application was done by making trenches in the ground under the cotton crop followed by burying the tithonia in the trenches besides the cotton rows. The trenches were about 10 cm deep and were made 5 -10 cm away from the cotton plants. Rates of 0.6, 1.02, 1.63, 2.04 and 2.44 t/ha fresh weight of tithonia were applied under the two application methods. These rates were applied in three splits at different growth stages when the cotton was 21, 45 and 75 days old. A no-fertilizer treatment was included as a control. Cotton was planted at the recommended spacing of 75x 30 cm and later thinned to two plants per hole. The experiment was conducted as a Randomized Complete Block Design (RCBD) replicated four times and plots measured 5.25 by 4 metres. Data was taken from the six middle rows leaving out one row on each side of a plot. Seed cotton was picked and weighed for yields then ginned and samples taken for fibre quality analysis. Soil samples were taken from the field before the experiments were planted. Later after cotton picking, other samples were taken from each plot. These were analyzed for nutrient contents. All data was subjected to Analysis of Variance (ANOVA) using GENSTAT statistical package and means separated using least significant difference (lsd). The amount of money paid for plucking and application of tithonia was Uganda Shillings 50 per kilogram, fresh weight. This was used to calculate the costs of tihonia used in the trial under each treatment. The buying price for seed cotton was Uganda Shillings 1,500 per kilo during the two years. These figures were used to calculate the costs of the treatments and the incomes from them, gross margins, benefit/cost ratios and marginal rates of returns (MRR), based on yields during the two years.

Results and discussions

Seed cotton yields

Seed cotton yields for the different treatments in 2014 and 2015 are presented in Table 1. Generally 2015 was a better season, giving higher yields than those of 2014. Yields from the controls were lowest compared to all the other treatments, whether under surface or subterranean application and during the two years.

Under surface application of tithonia, yields increased directly with increased application rates during the two years. In 2014, only the rates of 1.63, 2.04 and 2.4 t/ha significantly increased

yields (P=0.05) above the control, while in 2015 all the rates significantly increased (P=0.05) yields. Surface application of tithonia in our case compares well with mulching, as in the work by Agbede, *et al* (2013) where yam yields were increased with increased tithonia rates. The rates increased soil bulk density, moisture content, N,P,K,Ca and Mg. Similar situations probably occurred in the current study but there could have been significant nutrient losses due to more exposure, hence lower cotton yields.

Yields under subterranean application increased directly with tithonia rates and reached a peak at 2.04 t/ha. At 2.44 t/ha yields starting declining. In 2014 all the rates, except 0.6 t/ha significantly increased (P=0.05) yields above the control while in 2015 all rates did so. The superiority of subterranean method compared to surface could have been a result of reduced nutrient losses to external factors such as erosion by water. Ikerra *et al* (2006) reported maize yields when tithonia was applied as green manure. In our case the subterranean method of application could be compared to that of Ikerra *et al* (2006) and, therefore, conserved and made more nutrients available to cotton than the surface method.

Residual soil nutrients

After the experiments in 2014, large amounts of soil phosphorous (P) were recorded from the different plots compared to the levels at the start of the experiment (Table 3). Rates of 1.02, 2.04 and 2.4 t/ha caused significantly higher levels of residual P in the soil compared to the control under both application methods. All these levels were higher than the case at the start of the experiments. This implies that tithonia was able to provide sufficient P to the soil, which in turn was able to take care of plant requirements and leave a balance, in spite of losses to other factors.

Levels of residual potassium (K) were much lower at the end of the trials than was the case at the start and amounts under subterranean application was higher than under surface (Table 4). Under surface application, all rates except 0.6 t/ha significantly increased (P=0.05) K levels above the control while under subterranean, only rates of 1.63, 2.04 and 2.4 t/ha did so.

Fibre characteristics

Of all the fibre characteristics analyzed, treatments significantly (P=0.05) affected only length and strength (Table 2).

Upper-half mean length (UHML) of cotton fibres gives an indication of fibre lengths. Results from this study shows that application of different tithonia rates increased cotton fibre lengths compared to the controls but only the rate of 2.04 gave significant increase (P=0.05). The longest fibres (27.12 mm) were recorded from cotton treated with 2.04 t/ha.

All tithonia application rates improved cotton fibre strength compared to the controls. However, a significant (P=0.05) increase was caused only by a rate of 2.04 t/ha. Fibre strength values from the different tithonia rates were not significantly different amongst themselves.

Economics of tithonia use

Tables 5 and 6 present information on costs of the different treatments, gross margins, benefit/cost ratios and marginal rates of return (MRR) associated with them during the two years.

Rates of 1.02, 2.04 and 2.44 t/ha under surface application in 2014 (Table 5) resulted into lower gross margins and so were dominated by the first rate of 0.6 t/ha. The highest gross margin was obtained following application of 0.6 t/ha of tithonia. This was followed by the rate of 1.63 t/ha. The marginal rate of return (86 %) was highest following application of 0.6 t/ha, but were below the accepted minimum value of 100 %.

Under subterranean application in 2014, rates of 0.6, 1.63 and 2.44 t/ha resulted into lower gross margins so were dominated by the control. The highest gross margin was obtained by application of 2.04 t/ha followed by 1.02 t/ha. The highest marginal rate of return (167 %) was realized following an application of 2.04 t/ha. In 2015 rates of 1.02, 1.63 and 2.44 resulted into lower gross margins and these rates were dominated by the first tithonia rate of 0.612 t/ha. The highest marginal rate of return (392 %) was realized following an application of 0.612 t/ha.

Conclusion and recommendations

This study has shown that application of tithonia to cotton improves soil fertility and increases seed cotton yields. It also improves cotton fibre length and strength, and leads to residual P and K in the soil, following cotton harvest. These reserves can be useful for subsequent crops as is usually the practice in Uganda, where cotton is commonly followed with cereals like finger millet and maize. Subterranean method of application was more superior to surface application and this was attributed to the possibility of the method to conserve the nutrients released from tithonia and make them more available to the crop. Results from economic analysis also support recommendation of tithonia for use on cotton, especially where other factors such good whether are conducive for high yields. Taking a minimum acceptable MRR value of 100 %, none of the rates under surface application were viable in both years. The subterranean option with high

marginal rate of returns (MRR) value of 167 % and 295 % in 2014 and 2015 respectively at the rate of 2.04 t/ha seemed to be the best, economically.

There is, however, need for the experiment to be continued under different agro ecologies to ascertain the incremental benefits that will result from use of tithonia under the different application methods and rates.

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Table 1: Effects of application methods and rates of tithonia on seed cotton yields (kg/ha) at NaSARRI in 2014 and 2015

Treatment	Surface application		Subterranean application	
	2014	**2015**	**2014**	**2015**
0.61 t/ha of tithonia	1,278.3	2,071.7	1,886.7	2,295.3
1.02 t/ha of tithonia	1,298.3	2,151.3	2,244.7	2,361.7
1.63 t/ ha of tithonia	1,544.3	2,257.7	2,275.7	2,375.2
2.04 t/ha of tithonia	1,598.7	2,275.3	2,639.7	2,913.2
2.44 t/ ha of tithonia	1,736.0	2,639.0	2,438.7	2,504.7
Control	898.3	1,846.7	1,796.3	1,289.7
Mean	**1392.3**	**2207.0**	**2213.6**	**2289.9**
Lsd	**416.3**	*560.3*	**423.0**	*636.3*
Cv (%)	**18.4**	18.3	**12.2**	18.0

Table 2: Effects of subterranean tithonia application on cotton fibre lengths and strength at NaSARRI in 2014

Treatment	UHML (mm)	Strength (g/tex)
0.61 t/ha of tithonia	26.22	27.6
1.02 t/ha of tithonia	26.27	28.2
1.63 t/ ha of tithonia	25.92	27.9
2.04 t/ha of tithonia	27.12	29.7
2.44 t/ ha of tithonia	26.73	27.5
Control	25.47	25.8
Mean	**26.29**	**27.78**
Lsd	1.41	2.5
Cv	3.6	6.3

Table 3: Effects of application methods and rates of tithonia on residual soil phosphorous (ppm) after cotton harvest at NaSARRI in 2014

Treatment	**P (ppm) under surface application**	**P (ppm) under subterranean application**
0.61 t/ha of tithonia	2.67	3.83
1.02 t/ha of tithonia	3.20	4.37
1.63 t/ ha of tithonia	2.77	3.96
2.04 t/ha of tithonia	3.54	4.13
2.44 t/ ha of tithonia	3.26	4.00
Control	1.97	2.86
Mean	**2.90**	**3.85**
Lsd	*0.84*	*1.11*
Cv (%)	28.7	30.1
Level at start of experiment	*1.30*	*1.30*

Table 4: Effects of application methods and rates of tithonia on residual soil potassium (ppm) after cotton harvest at NaSARRI in 2014

Treatment	**Surface application**	**Subterranean application**
0.61 t/ha of tithonia	52.3	69.4
1.02 t/ha of tithonia	56.9	65.3
1.63 t/ ha of tithonia	60.5	79.9
2.04 t/ha of tithonia	64.8	82.7
2.44 t/ ha of tithonia	61.5	80.0
Control	45.2	54.3
Mean	**56.9**	**71.9**
Lsd	*10.1*	*19.8*
Cv (%)	18.3	28.3
Level at start of experiment	*296.5*	*296.5*

Table 5: Effects of surface application of tithonia on economics of cotton production at NaSARRI in 2014 and 2015

2014						
Tithonia rate (t/ha)	**Cost (UGX/ha)**	**Mean seed cotton yield (Kg/ha)**	**Mean income (UGX/ha)**	**Gross margins (UGX/ha)**	**Benefit/Cost ratio**	**MRR (%)**
Control	0	898.3	1,347,450	1,347,450		
0.612	306,000	1,278.3	1,917,450	1,611,450	5.27	86
1.02	510,000	1,298.3	1,947,450	1,437,450	2.82	D
1.632	816,000	1,544.3	2,316,450	1,500,450	1.84	20
2.04	1,020,000	1,598.7	2,398,050	1,378,050	1.35	D
2.44	1,250,000	1,736.0	2,604,000	1,354,000	1.08	D
2015						
Tithonia rate (t/ha)	**Cost (UGX/ha)**	**Mean seed cotton yield (Kg/ha)**	**Mean income (UGX/ha)**	**Gross margins (UGX/ha)**	**Benefit/Cost ratio**	**MRR (%)**
Control	0	1,846.7	2,770,050	2,770,050		
0.612	306,000	2,071.7	3,107,550	2,801,550	9.2	10
1.02	510,000	2,151.3	3,226,950	2,716,950	5.3	D
1.632	816,000	2,257.7	3,386,550	2,570,550	3.2	D
2.04	1,020,000	2,275.3	3,412,950	2,392,950	2.3	D
2.44	1,250,000	2,639.0	3,958,500	2,708,500	2.1	D
Treatment Costs: Plucking & applying Tithonia @ 50/kg; Cotton prize: Sh. 1,500/kg. D= dominated						

Table 6: Effects of subterranean application of tithonia on economics of cotton production at NaSARRI in 2014 and 2015

2014						
Tithonia rate (t/ha)	**Cost (UGX/ha)**	**Mean seed cotton yield (Kg/ha)**	**Mean income (UGX/ha)**	**Gross margins (UGX/ha)**	**Benefit/Cost ratio**	**MRR (%)**
Control	0	1796.3	2,694,450	2,694,450		
0.612	306,000	1886.7	2,830,050	2,542,050	8.3	D
1.02	510,000	2244.7	3,367,050	2,857,050	5.6	154
1.632	816,000	2275.7	3,413,550	2,597,550	3.18	D
2.04	1,020,000	2639.7	3,959,550	2,939,550	2.88	167
2.44	1,250,000	2438.7	3,658,050	2,408,050	1.93	D
2015						
Tithonia rate (t/ha)	**Cost (UGX/ha)**	**Mean seed cotton yield (Kg/ha)**	**Mean income (UGX/ha)**	**Gross margins (UGX/ha)**	**Benefit/Cost ratio**	**MRR (%)**
Control	0	1,289.7	1,934,550	1,934,550		
0.612	306,000	2,295.3	3,443,950	3,136,950	10.25	392
1.02	510,000	2,361.7	3,543,550	3,032,550	5.94	D
1.632	816,000	2,375.2	3,563,800	2,746,800	3.37	D
2.04	1,020,000	2,913.2	4,369,800	3,349,800	3.28	295
2.44	1,250,000	2,504.7	3,757,050	2,507,050	2.00	D
Treatment Costs: Plucking & applying Tithonia @ 50/kg; .Cotton prize: Sh. 1,500/kg; D= dominated						