ADDIS ABABA UNIVERSITY
COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCE
DEPARTMENT OF ZOOLOGICAL SCIENCES

Effects of chemical fertilizers and compost on growth and yield of *Guizotia abyssinica* (L. f.) Cass. in potted vertisol at Bichena town, West-central Ethiopia


By
Addisu Edemealem Yitayew

Addis Ababa, Ethiopia

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Addisu Edemealem Yitayew

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Addis Ababa University, Department of Zoological Sciences

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DECLARATION

This is to certify that the thesis prepared by Addisu Edemealem Yitayew, entitled "Effects of chemical fertilizers and compost on growth and yield of *Guizotia abyssinica* (L. f.) Cass. in potted vertisol at Bichena town, West-central Ethiopia", submitted in partial fulfillment of the requirements for the degree of Master of Science in Biology complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Guizotia abyssinica L. f. Cass (synonym *Polymnia abyssinica* L. f.) belongs to Asteraceae (Compositeae). The species is said to have originated in the Ethiopian highlands and has spread to other parts of the world. In Ethiopia, niger seed is cultivated primarily for valuable edible oil for local consumption. Elsewhere, the crop is used in pharmaceutical products and other industrial applications, and as a green manure for increasing soil organic matter. In reality neither farmers nor extension institutions give focus on using improved practices such as optimum fertilizer applications for niger seed production. The present study was undertaken to find out the effects of chemical fertilizers and compost on growth and yield of *G. abyssinica* in potted vertisols at Bichena town, West central Ethiopia. A total of 150 plastic bags (depth 20 cm, diameter 10 cm) were filled with 1 kg vertisol, among which 50 bags contained only vertisol, 50 bags contained soils mixed with DAP and urea and the rest 50 contained soils mixed with compost. The study found out that application of DAP and urea at rates of 50 and 30 kg/ha respectively improved the vegetative growth by 195% compared to the control. Similarly, yield increased by 294%. On the other hand, niger plants grown in soils mixed with compost at rates of 12 tons/ha improved the vegetative growth by 66% and yield increased by 82%. Though, the analysis of variance showed that there was no significant difference ($p \leq 0.05$) among the three treatments for all the germination parameters measured, vertisol mixed with chemical fertilizers (VR + CF) showed the best germination percentage, mean germination time and germination vigor compared to seeds germinated in vertisol mixed with compost (VR + Comp) or in vertisol only. Maximum mean plant height (cm), internodal length (cm), branches/plant, leaf number, leaf area (mm^2), RCD (cm), number of capitulae/plant, number of seeds, seeds weight (g), 1000 seeds weight (g) and total dry weight (g) were 73.8, 39.6, 18, 50, 136, 1.8, 19, 355, 0.9, 2.3, and 5.5 respectively for plants grown in VR + CF. The corresponding values for plants grown in VR + Comp were 41.5, 11.9, 7, 26, 43.2, 1.3, 8, 164, 0.5, 2.2, and 1.9 respectively. The control plants resulted in 25, 5.3, 3, 19, 26.2, 1.2, 4, 90, 0.3, 1.8, and 1.2 respectively. Based on the results obtained, it is concluded that application of optimum amount of chemical fertilizers significantly ($p < 0.01$) improved almost all the growth and yield components of *Guizotia abyssinica*.

KEY WORDS/PHRASES, Capitulae, cross-pollination, edible oil, montmorillonite, niger seed

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TABLE OF CONTENTS

Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ACRONYMS and ABBREVIATIONS

ANRSBA = Amhara National Regional State Bureau of Agriculture

Av. K = Available potassium

Av. P = Available phosphorus

DAG = Days after germination

DAP = Di ammonium phosphate

FAS = Foreign agriculture services (US)

GP = Germination percentage

GV = Germination vigor

ICAR = Indian Council of Agricultural Research

MGT = Mean germination time

NPK = Nitrogen-phosphorus-potassium

NU = Neglected and underutilized

RCD = Root collar diameter

USDA = US Department of Agriculture

VR + CF = Vertisols plus chemical fertilizer

VR + Comp = Vertisols plus compost

1. INTRODUCTION

1.1 Background

Ethiopia is one of the world's major centers for indigenous plant domestication. Indigenous plants are critical in providing clean water, fresh air, fertile soil, food, fiber, fuel, and drugs (Legesse Negash, 1995; Thomas and Balakrishinan, 1999). Because of the little attention given to indigenous crop varieties in favor of improved seed varieties, Ethiopia's indigenous crops are facing a serious of threat of extinction (Yonas Abiye, 2015).

Food is an essential requirement of mankind and plants provide up to 95% of world's food supply, directly or indirectly. But global population projections are a grim reminder that food production must continue to increase and must be doubled in next 35 years (Johnson, 1975). The research output jointly conducted by the Ethiopian Biodiversity Institute (EBI) and the International Biodiversity Institute (IBI) proved that the local varieties have better yields and productivity. Local crops include grains (teff), oilseed (noug), and crops grown for their underground storage organs (yam, enset). Oilseeds are the third major crops after cereals and pulses in terms of cultivation area in Ethiopia (CSA, 2011), accounting for more than 20% of foreign exchange earnings. After coffee, oilseeds are the second largest export earner for the country (USDA FAS, 2010) and more than 3 million smallholders are involved in its production. One of the most important oilseed crops is niger seed (*Guizotia abyssinica*).

Guizotia abyssinica L. f. Cass (synonyms *Polymnia abyssinica* L. f.), commonly known as noog/noug, niger, nyger, nyjer, or niger seed, Ramtil or ramtilla; inga seed; and black seed) is indigenous to Ethiopia and holds significant promise for improving rural livelihood in sub-Saharan Africa. It is an underutilized and high value oilseed crop (Getinet and Sharma, 1996). Niger seed, *Guizotia abyssinica* (2n=30) belongs to family Asteraceae. The genus *Guizotia* consists of six species, of which five, including niger, are native to the Ethiopian highlands. It is an annual oilseed crop mainly grown in India and Ethiopia in rotation with cereals and pulses. It constitutes about 50-60% of Ethiopian and 3% of Indian oilseed production (Seegeler, 1983; Riley and Hiruy Belayneh 1989). The two countries are the first and second niger seed producers and users in the world, respectively. The species is used in intercropping systems, usually produced on poor, coarse texture soils (Chavan, 1961) and contributes to soil conservation. Being a photoperiod sensitive plant (Lin, 2005), it requires short day-length and moderate temperatures, above 30 ^{0}C the rate of growth and flowering are adversely affected and maturity is accelerated (Weiss, 2000). For seed set, the plant depends on cross pollination as they are mostly self-incompatible (Sujatha, 1993); honey bees are the typical vectors in pollination. Niger seed can tolerate high rainfall during the vegetative phase (Weiss, 2000), and in Ethiopia the crop can be grown on waterlogged soils where most crops and all other oilseeds fail to grow, but rainfall at physiological maturity may lead to seed shattering (Getinet and Sharma, 1996). It is extremely resistant to poor oxygen supply in the soil, explained by the development of aerenchyma and the ability to form respiratory roots. While hardly improved, and suffering from low yields and susceptibility to insect herbivores, it contributes up to 50% of Ethiopian oil seed crop.

The growth and yield of niger seed is greatly influenced by a number of physical and chemical factors including bio and chemical fertilizers (Getinet and Sharma, 1996). Research has indicated that Ethiopian soils are generally low in available nitrogen and phosphorus and cannot produce high crop yields unless these are supply. If crops are planted in the same soil year after year, the nitrate supply becomes depleted and the mineral removed from the soil by crops are replaced by the use of fertilizers (Hall and Lesser, 1966). Now, fertility status of most niger soils is declining, but farmers don't yet use fertilizers for niger seed production. That was the question why farmers don't use fertilizers as well as why extension institutions don't advice farmers to use fertilizers for niger seed production under the present serious fertility declining conditions. Therefore, the present study was to evaluate the effect of chemical fertilizers and compost on growth and yield components of niger seed in potted vertisols under nursery bed conditions.

1.2 Statement of the problem

Ethiopia's long history of agriculture has contributed to the diversification of the general agro biodiversity, biodiversity for food and agriculture of the indigenous crops as well as those that reached the country long time ago (Zemedie Asfaw and Abebe Getahun, 2001). Ethiopia is an important biodiversity center in both plants and animals including domesticated species. It is the land of many unique endemic species of mammals, birds, higher plants and other groups. The diversity in cultivated plants in terms of species, varieties and genetic constitution is remarkable. Some important crops (e.g. teff, noug, enset, and many others) have their origins in Ethiopia while some others have their highest center of diversity in Ethiopia (Zemedie Asfaw and Abebe Getahun, 2001). Niger seed (*Guizotia abyssinica)* is among the most important oilseed both in terms of area coverage and volume of production; and the main source of edible oil for local consumption. In reality neither farmers nor extension institutions give focus on using improved practices such as optimum fertilizer applications for niger seed production. Therefore, this study was conducted to evaluate the effect of chemical fertilizers and compost on growth and yield of *Guizotia abyssinica* and in an effort to draw attention to this neglected and underutilized species so it can contribute to food security and income of subsistence farmers.

2. OBJECTIVES OF THE STUDY

2.1 General objective

The general objective of this study was to compare vegetative growth and yield performances of *Guizotia abyssinica* L. f. Cass. plants grown in potted vertisols only, and vertisols with the addition of chemical fertilizers and compost.

2.2 Specific objectives

This study was conducted to:

- Determine and compare biomass of niger seed plants grown in vertisols only, vertisols with chemical fertilizers and those grown in vertisols with compost.
- Determine and compare yields of niger seed plants grown in vertisols only, vertisols with chemical fertilizers and those grown in vertisols with compost.
- To study the effect of different sources of nutrient application on morphological and yield attributing parameters of niger seed.

3. LITERATURE REVIEW

3.1 *Guizotia abyssinica* (L. f. Cass.)

3.1.1 Taxonomy and morphological features

The genus *Guizotia* was named in 1829 by Cassini after a French historian Guizot and has been studied and included in Compositeae (Asteraceae) family according to its taxonomy. It has tribe Helianthoides and sub tribe verbisininae by Baagoe (1974). *Guizotia* is a small genus containing six species with *Guizotia abyssinica* (L. f.) Cass the important oilseed which together with other members of the genus has the somatic number 2n=30. *Guizotia abyssinica* is the only species of economic importance. It is also the only cultivated species of the genus *Guizotia*. Turner and Powell (1962) did the systematic review of *Guizotia* and found it to be quite similar to Jaumea especially in style, branches, achenes and habit and suggested that *Guizotia* borders upon verbisininae, that it might be positioned with members of the Jauminae instead of the usual members of sub tribe Coreopsdinae.

Generally, there is no much work done on niger seed. An in depth treatment of its taxonomy and distribution was done by Baagoe (1974). She reduced the number of species within the genus *Guizotia* to six: *G. abyssinica* (L. f.) Cass., *G. scabra* (Vis.) Chiov. sub sp. scabra and sub sp. Schimperi (Sch. Bip.) Baagoe, *G. arborescens* I. Friis, *G. reptans* Hutch, *G. villosa* Sch. Bip; and *G. zavattarii* Lanza. *Guizotia scabra* contains two subspecies, scabra and Schimperi. *Guizotia scabra* subsp. Schimperi, known locally as 'mech,' is a common annual weed in Ethiopia. There is a controversy on the taxonomical category of *G. abyssinica* and *G. scabra* subsp. Schimperi (Murthy *et al*., 1995). According to Kifle Dagne (1994), *Guizotia abyssinica* is more closely related to *G. scabra* subsp. Schimperi, which is distinguished from other species, belongs to the same genus by ovate outer phyllaries and large achene size. Furthermore, both *G. abyssinica* and *G. scabra* subsp. Schimperi are morphologically very similar, they are both annuals, and are attacked by the same pests and diseases. Both species have 2n=30 chromosomes with a similar karyotype. The hybrid between *G. abyssinica* and *G. scabra* subsp. Schimperi is fertile and forms 15 bivalents in 95% of the pollen mother cells (Kifle Dagne, 1994). This strengthens the assumption that *G. abyssinica* may be evolved from *G. scabra* subsp Schimperi through selection by Ethiopian farmers (Kifle Dagne, 1994). The two wild and cultivated species, can be distinguished from each other by the shape of the paleae and involucres bracts which are narrow and pointed in *G. scabra* subsp Schimperi and broadly ovate in *G. abyssinica* (Rilay and Hiruy Belayneh, 1989). Furthermore, the seeds of niger are much bigger than the seeds of the weedy species. Indeed, *G. scabra* subsp. Schimperi is closer to the *G. abyssinica* than to the perennial *G. scabra* subsp. scabra. On the basis of cytological evidence, Murthy *et al*. (1995) proposed that the two species *G. abyssinica* and *G. scabra* subsp. Schimperi be merged into one species. However, *G. abyssinica* was described by Cassini in 1829 and *G. scabra* in 1841 and the International Rules of Botanical Nomenclature would not support the inclusion of *G. scabra* subsp. Schimperi as a subspecies of *G. abyssinica*. Since *G. scabra* subsp. Schimperi is a wild species, it is unlikely that a wild species was derived from a cultivated species. Therefore, for the time being the original description by Baagoe (1974) of cultivated niger as *G. abyssinica* (L. f.) Cass. should be retained.

Niger seed is a stout, an erect, moderately branched annual dicotyledonous herb that grows up to a height of 2 m (Bulcha, 2007). The root system is usually well developed, with a taproot that has many lateral roots, particularly in the upper 5 cm but since the plant often grow on poor or stony soils, roots seldom develop to their maximum. Niger seed roots show exceptional resistance to water logging, attributed to the existence of arenchyma, which appear to vary with the degree of soil saturation (Prinz, 1976). Germination is epigeal and seedlings have pale green to brownish hypocotyls and cotyledons, remain on the plant for a long time (Seegeler, 1983). The first leaf is paired and small and successive leaves are larger, arranged on opposite sides of the stem but at the top of the stem they are arranged in an alternate fashion. Leaves are 10-20 cm long and 3-5 cm wide. The leaf margin morphology varies from pointed to smooth and leaf color varies from light green to dark green, the leaf surface is smooth. The stem of niger is smooth to slightly rough, hollow and break easily. The color of the stem varies from dark purple to light green and about 1.5 cm in diameter at the base. The number of branches per plant varies from five to twelve and in very dense plant stands fewer branches are formed. The niger flower is yellow and, rarely, slightly green that produce shiny black seeds. The heads are 15-50 mm in diameter with 5-20 mm long ray florets. Two to three capitulae (heads) grow together, each having ray and disk florets. The hermaphrodite disk florets, usually 40-60 per capitulum, are arranged in three whorls. The disk florets are yellow to orange with yellow anthers, and a densely hairy stigma, has two curled branches about 2 mm long. The receptacle, which is surrounded by two rows of involucral bracts has a semi-spherical shape and is 1-2 cm in diameter and 0.5-0.8 cm high. Botanically niger seed is known as achene. The achene is club-shaped, obovoid and narrowly long (Seegeler, 1983). The achenes are black with white to yellow scars on the top and base and have a hard testa.

3.1.2 Origin and geographical distribution

Guizotia abyssinica is originated in the northern high lands of Ethiopia where it grows wild and is cultivated (Baagoe, 1974; Weiss, 2000). It is almost certainly derived from *G. scabra* most likely from subspecies Schimperi through selection and cultivation (Hiremath and Murthy, 1992). All the six species of *Guizotia* are native to tropical Africa and five are found in Ethiopia (Baagøe, 1974). In Africa, *Guizotia abyssinica* is largely found in the Ethiopian highlands, particularly west of the Rift valley. *Guizotia villosa* is concentrated in the northern and southwestern highlands of Ethiopia. *Guizotia zavattarii* is endemic around Mount Mega in southern Ethiopia and the Huri hills in northern Kenya. *Guizotia arborescens* is endemic to the southwest of Ethiopia and Imantong mountain areas on the border between Sudan and Uganda. *Guizotia scabra* subsp. scabra is distributed from Ethiopia to Zimbabwe in the south and to the Nigerian highlands in the west, dissected by the Sudanese desert and Congo rainforest. *Guizotia reptans* is endemic to Mount Kenya, the Aaberdares and Mount Elgon region in East Africa and is the only taxon which is not reported from Ethiopia (Kifle Dagne, 1994b). Baagøe (1974) raised four points about the origin of niger; first, the highest concentration of Guizotia species is in Ethiopia; second, *Guizotia abyssinica* can also be collected in Ethiopia both as a crop plant and as a weed and in natural localities, but in India it has never been collected in natural localities; third, the similarity of the distribution of niger with that of other cultivated crops, and fourth, the historical trade between Ethiopia and India. This would suggest that niger is not native to India and may have been taken from Ethiopia to India by traders. It is believed to have been taken to India by Ethiopian immigrants, probably in the third millennium BC along with other crops such as finger millet (Dogget, 1987). It is important to note that its wild relatives were not taken with it. There are also reports that explain niger to be among the earliest of the domesticated crops in Ethiopia, along with teff (*Eragrostis tef*), Ensete (*Ensete ventricosum*), finger millet, and coffee (*Coffea arabica*) (Riley and Hiruy Belayneh, 1989).

Niger seed is mainly cultivated in Ethiopia and Indian sub continents (Murthy *et al*., 1993) but it is also present in other African and Asian countries (Sudan, Uganda, Zaire, Tanzania, Malawi, Zimbabwe, Nepal, Bangladesh, Bhutan), and the West Indies (Riley and Hiruy Belayneh, 1989). It was also tested in Russia, Germany, Switzerland, France and Czechoslovakia in the 19th century (Weiss, 1983). In France, it is used as a cover crop (Sem-Partners, 2016). In Zimbabwe it has been grown as green manure and for silage (Vaughan, 1970).

3.1.3 Ecological and economic importance

In Ethiopia, niger is cultivated on waterlogged soils where most crops and all other oilseeds fail to grow and contributes a great deal to soil conservation and land rehabilitation because of its mycorrhizal relationship and its potential as a bio-fertilizer. The dried stalks may be used to mulch fruit trees or merely spread out to decompose over the soil surface, serving as a source of organic matter. Due to a possible allelopathic weed-suppressing effect, niger is recognized as an effective green manure cover crop between cereal crops and it can be turned into green manure (Getinet and Sharma, 1996). The residual seed cake after oil extraction has a high manurial value. It is a good precursor for many crops because crops following niger seed have less weed infestation and profit from the large amount of organic matter left in the ground (www. Prota. org). It has less diseases and pests infestation than other oilseed crops.

Niger seed is a valued source of edible oil in Ethiopia, where it is called ‘noug’. In Ethiopia it is the prime supplier of edible oil in most regions, accounting for about half of the total production of vegetable oil. In India it is mainly a substitute for or extender of sesame oil and contributes only 2% in the national edible oil production. It is prepared into chutneys, condiments and porridge, mixed with pulses to make snack foods and ground to produce flour and beverages. In Ethiopia slightly roasted seeds are ground with salt and mixed with roasted cereals to prepare snacks, locally called ‘litlit’ and ‘chibito’, (preferred food for growing youths) which are presented during coffee ceremonies. The seed is warmed in a kettle over an open fire, crushed with a pestle in a mortar and then mixed with crushed pulse seeds to prepare ‘wot’ in Ethiopia (Seegeler, 1983). Niger seed yields pale yellow oil with a pleasant nutty taste. The seed contains about 40% oil with fatty acid composition of 75-80% (typical for other Compositeae family oils, such as safflower and sunflower, and is considered to be among the healthier selections Getinet and Sharma 1996) linoleic acid, 7-8% palmitic and stearic acids, and 5-8%

oleic acid (Getinet and Adefris, 1995), which makes it important in preventing arteriosclerosis in humans (Vaughan, 1970). The Indian types contain 25% oleic and 55% linoleic acids (Nasirullah *et al*. 1982). Niger seed oil is also used for cooking, as illuminant, as lubricant for manufacturing soap and paints (Simmonds, 1976). It also has potential for cosmetics (Vaughan, 1970). It is used for lighting, anointing, painting and cleaning of machinery and substitutes for sesame oil for pharmaceutical purposes (Getinet and Sharma, 1996). The oil from the seeds is used in the treatment of rheumatism by application of oil on the parts where the pain is present. By periodical consumption of the niger seed oil, the risk of the disorder can be avoided (Chopra *et al*., 1986). In traditional medicine, the oil is also used for birth control and for the treatment of syphilis (Hiruy Belayneh, 1991). Niger seed sprouts mixed with garlic and honey are used for the treatment of coughs (www.prota.org). It can also be used as poultices which can be applied to the surface of the body to relieve pain, itching, swelling and inflammation, abscesses, boils, and in the treatment of scrabies (Manandhar, 2002). A medical test for the identification of the fungus *Cryptococcus neoformans*, which causes a serious brain disease, is carried out on a niger seed-based agar medium (www.prota. org).

The niger seed leftover remaining after the oil extraction is an excellent feed for animals. The seed cake, having about 70% in-vitro digestibility, is the most widely used protein supplement in animal feed in Ethiopia. Niger seed meal is reported to be free from any toxic substance and contains more crude fiber than most oilseed meals. The by-product also contains 30% protein and 23% crude protein. In general, the Ethiopian leftovers niger seed contains less protein and more crude fiber than the niger seed leftovers grown in India (Chavan, 1961; Seegeler, 1983). In Western countries, niger seeds are important components of bird seed mixtures (Lin, 2005). The whole niger plant can be used as fodder for sheep, but it is unpalatable to cattle, to which it is only acceptable as silage (Chavan, 1961). In Ethiopia the straw is used as fuel for cooking.

3.1.4 Production

Though niger has long history in its production and various uses in the socio-economic settings the average national yield is very low. The national average productivity is about 0.09 ton/ha (CSA, 2016). Statistical data on the production of niger seed vary greatly and should be interpreted with care. India and Africa, together is estimated to produce 300,000-350,000 tones of niger seeds per annum (Weiss, 2000). India tops in area, production and total exports for niger seed in the world (Bisen *et al*., 2015). The average seed yield in India is somewhere between 177 and 300 kg/ha when grown as intercrop and between 300 and 625 kg/ha if grown in pure stands as against the yield of 600 kg/ha realized in some African countries. Bhardwaj and Gupta (1977) reported seed yield of 1,000 to 1,200 kg/ha on fertile Himalayan soils, 200-400 kg/ha in degraded habitats and 100-200 kg/ha when grown with ragi. In Kenya, monocultural average yield of 600kg/ha (Duke, 1983). In Ethiopia, the area covered by niger in the main season is about 285236 ha, which is 40% of the total area of oil crops (CSA, 2008). The total production is about 159819.7 metric tons, which is about 26% of the total production of oil crops (CSA, 2008). It is cultivated mainly in Gojjam, Shewa, Wellega and Gondar regions and to a lesser extent in Jimma, Wollo, Arsi and Hararghe regions (Getinet and Sharma, 1996). It should be noted that accurate statistics of crop production for Ethiopia are difficult to obtain; however, it is estimated that Gojjam, shewa, Gondar and Wellega are the largest areas of production, accounting for about 90% of the country's total production (Getinet and Nigussie, 1997). The remaining 10% is produced in Wello, Hararghe, Arsi and Bale. According to Getinet and Sharma (1996), the niger populations in Ethiopia fall into three maturity groups referred to as 'Bunigne' niger, 'Mesno' niger and 'Abat'niger. Bunigne is the early maturing type with a shorter growing period of about four months (July to October), while Abat niger takes about seven months to mature (June to December). Mesno niger is late maturing (September to February) but frost resistant unlike the other two (Getinet and Sharma, 1996). Ethiopian niger is a variable species adapted to different environments. It is reportedly produced mainly in mid-altitude and high areas (1600-2200 m or 5249-7218 ft. elevation) but also in lower elevations with enough rainfall, where average daily maxima and minima are 23 and 13 ℃ respectively during the rainy season. It is not grown in high rainfall areas where a too vigorous plant growth would negatively affect seed and oil production; more than 2000 mm rainfall may result in depressed yield.

The niger plant has many limitations which constrain its productivity. The major limiting factors contributing to low productivity of the crop are numerous and complex which include: indeterminate growth habit leading to seed shattering, self-incompatibility, genetically low yielding characteristics, lodging, less or low responsiveness to management inputs, difficulty of pollination behavior, disease, insects and parasitic weeds (Getinet and Sharma, 1996 and Adefris and Adugna, 2004). The availability of limited genetic information and semi-domesticated nature of the crop has been an obstacle for further improvement programs (Dempewolf *et al*., 2008 and 2015). Apart from using all other improved cultural practices, optimum application of fertilizers would increase niger seed production (Amare Aleminew, 2012).

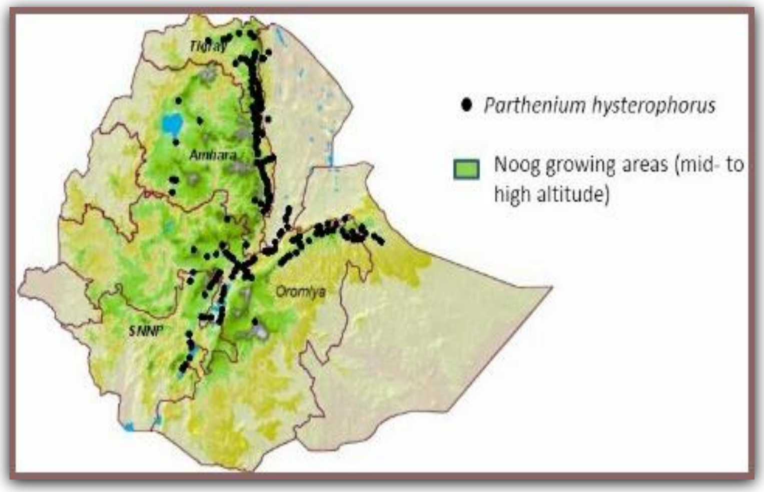


Figure 1: Map of Ethiopia showing the main *Guizotia abyssinica* growing areas (McConnachie, 2015)

3.1.5 Seed harvest and saving

As niger seed ripens over a period of several weeks, it is harvested when plants are still yellow to reduce shattering, which can reduce the yield by as much as 25%. The optimum stage to harvest is when the top leaves starts turning from green to yellow, the fruits are yellow-brown and their moisture content is 45-50% (Hiruy Belayneh, 1987). Harvesting is done manually; the niger stalks are cut below the branches and laid out to dry in the fields for 3 to 4 days and taken to the threshing ground in an upright position for further drying and threshing. As niger seeds are loosely held in the head, threshing is easy. In India it is harvested when the leaves dry up and the head turns black (ICAR, 1992). Following drying, farmers thresh the seeds by grasping the stalks and beating the seed heads on a wooden platform placed over a canvas in the field. Afterward, the shiny, black seeds are cleaned and stored. Niger seed has orthodox seed storage behavior (meaning seeds can tolerate drying and/or low-temperatures) and, when properly dried, can be stored for many years without losing its viability (Hong *et al*., 1996). The method of on-farm conservation could be applied to niger. In Ethiopia at present, the on-farm conservation programs are only practiced for crops with high genetic erosion such as durum wheat and barley. The replacement of local landraces by improved varieties in the farmers' fields is not widespread and therefore on-farm conservation of niger is not urgent.

3.1.6 Mode of reproduction

Niger seed is described as a completely out crossing species. For seed set, the plants depend on cross pollination as they are mostly self incompatible (Sujatha, 1993). It is highly cross pollinated and self incompatible (Hiremath and Murthy, 1986). Thus growers may be recommended to have hives close to the growing area of the crop to facilitate cross pollination by bees. Bees and other insects are the major aids in pollination (Ramachanderan and Menon, 1979) and are required for seed set. The plant is basically self sterile, although some self pollination has been recorded. The physical structure of the niger lower forces cross pollination, but this appears to be reinforced by sporophytic self incompatibility system. Insects are more important than wind as pollinating agents and in India plants that flowered in cages to which bees were introduced had three times as many seeds per head than the plants from which bees had been excluded. There was little or no seed set obtained under bagging with muslin bags, even when the bagged heads of the same plants are rubbed together (Riley and Hiruy Belayneh, 1989).

3.1.7 Factors affecting seed germination

Seeds are central to crop production, human nutrition, and food security. They carry the full genetic complement of the crop and are therefore the delivery system for agricultural biotechnology and crop improvement. The vast majority of crops produced in world agriculture begin with the sowing of a seed to establish a new plant in the field. Successful seedling establishment is the first critical step for crop production, and determines the success or failure of the future harvest. Seed is composed of three generation of plant tissues including the sporophyte that produces an immature seed known as ovule and the gametophyte that develop inside the ovule to produce ova. The third plant tissue of the seed is the new sporophyte embryo. Endosperm is the nutritive substance of the seed up on which the seed embryo feeds as its development (Konging, 1994). Despite these anatomical structures of seed in higher plants, seed morphology differs from one plant species to another, there are small and big seeds, thin, flat, light, papery, dehiscent and indehiscent, smooth and hard seed coat.

Germination is the process by which the embryo wakes up from the state of dormancy and takes to active life. This process, in fact, covers all the changes from the earliest sprouting of the seed till it established itself as an independent plant. The signs of seed germination are redemption essential process, including transcription, translation, and DNA repair followed by cell elongation, and eventually at the time of radicle protrusion, resumption of cell division (Barroco *et al*., 2005). Germination is a two process, where testa rupture is followed by endosperm rupture. Following rupture of micropylar endosperm by emerging radicle, germination is complete (Krock *et al*., 2002; Liu *et al*., 2005). During seed germination various stored substrates are reactivated, repaired if damaged and transformed into new building materials necessary for initial growth of the embryo, its subsequent growth, and seedling establishment in its natural habitat (Koller and Hadas, 1982). External and internal factors are declared to affect seed germination (Raven *et al* 2005). But according to Legesse Negash (1995, 2010), propagation of many indigenous tree species from seed had been difficult due to lack of precise knowledge on their seed biology and germination physiology, because many native plant species have developed survival strategies through evolutionary process for million years, understanding these strategies in the context of seed physiology for successful plant propagation.

3.1.7.1 External factors

Environmental factors such as temperature, light, pH, and soil moisture are known to affect seed germination (Chachalis and Reddy, 2000). Burial depth of seed also affects seed germination and seedling emergence. Some of the most important external factors are water, oxygen and suitable temperature. (I) **Water or moisture**: A dormant seed is generally dehydrated and contains hardly 10 to 15% water in its living cells. The active cells, however, require about 75-95% of water for carrying out their metabolism. Therefore, the dormant seeds must absorb external water to be active and show germination. Besides providing the necessary hydration for the vital activities of protoplasm, water softens the seed coats, causes their rupturing, increases permeability of seeds, and converts the insoluble food into soluble form for its translocation to the embryo (Raven *et al*., 2005). Water also brings in the dissolved oxygen for use by the growing embryo. Entrance of oxygen is also facilitated, and as a result, the rate of transpiration is accelerated. Seed germination incorporate those events that commence with the uptake of water by quiescent dry seed, and terminate elongation of embryonic axis (Bewley and

Black, 1994). Water uptake by a seed is tripe phase, phase I rapid initial uptake; phase II plateau phase, and phase III further increase of water uptake , however, when only germination occurs (Bewley, 1997). The amount of water taken into seed for germination depend anatomical, physiological nature, and plant species, most seeds critical water (moisture) content for seed germination occur i.e. corn *(Zea mays)* 30%, wheat *(Triticimae sativum)* 40%, and soybean (*Glycine max*) 50% (Wash and Nyomora, 2012). If the internal water (moisture) content decrease below or increase above the critical moisture content seed essentially decay. **(II) Supply of oxygen**: Oxygen is necessary for respiration which release the energy needed for growth. Germinating seeds respire very actively/feebly and need sufficient oxygen. The germinating seeds obtain this oxygen from the air contained in the soil. It is for this reason that most seeds sown deeper in the soil or in water logged soils (*i.e.* oxygen deficient) often fail to germinate due to insufficient oxygen. Seeds of many species will not germinate at oxygen level considerably lower than the normal present in the atmosphere. Ploughing and hoeing aerate the soil and facilitate good germination. **(III) Suitable temperature**: Moderate warmth is necessary for the vital activities of protoplasm, and, therefore, for seed germination. Some seeds are sensitive to temperature, while other can germinate in wide range of temperature (Michael, 2005). Though germination can take place over a wide range of temperature (5-40 ^{0}C), the optimum for most of the crop plants is around 25-30 ^{0}C. The germination in most cases stops at 0 and 45 ^{0}C. Above optimum seeds will not germinate because some seed enzymes which are protein in nature are denatured including the seed embryo (Bewley and Black, 1994). For *Guizotia abyssinica* seed the minimum germination temperature is 13 ^{0}C and the optimum temperature is 16 to 20 ^{0}C. Night temperatures should not fall below 2 ^{0}C (www.prota. org). At temperatures above 30 ^{0}C the rate of growth and flowering are adversely affected and maturity is accelerated (Weiss, 2000). It is reported to tolerate an annual precipitation of 660-1790 mm and an annual temperature range of 13.6-27.5 ^{0}C (Duke, 1983). **(IV) Light**: Light also has influence on germination of some seeds, but in most cases light regards germination at the early stages. The presence or absence of light may or may not have effect on seed germination. However, the light factor is not an important factor as water, temperature, and oxygen. According to Neff *et al* (2009), why seeds don't germinate in light is that light is reported to decompose carbolic acid gas, expel oxygen which is germinating factor and fix carbon, thus hardening all parts of seeds which prevent germination. Darkness has no effect to carbolic acid gas, and oxygen remains undisturbed to favor germination.

3.1.7.2 Internal factors

Hormones contained in various developmental stages, the seed, and enzymes are some of internal factors which in one way or another can affect seed germination (Neff *et al*., 2009). Many researchers also agree that seed dormancy period, seed viability (power of germination), and thickness or thinness of the seed coat may affect seed germination and hence are factors for seed germination (Finch-Savage and Leubner-Metzger, 2006). In some plants the embryo is not fully mature at the time of seed shedding. Such seeds do not germinate till the embryo attains maturity. The seeds of almost all the plants remain viable or living for a specific period of time. This viability period ranges from a few weeks to many years. Seeds of Lotus have the maximum viability period of 1000 years. Seeds germinate before the ending of their viability periods. In many plants, the freshly shed seeds become dormant due to various reasons like the presence of hard, tough and impermeable seed coats, presence of growth inhibitors and the deficiency of sufficient amount of food, minerals, and enzymes, etc. Dormancy is a simple operational block to completion of germination of an intact viable seeds under favorable conditions (Bewley, 1997). The seeds of some species are prevented from completing germination because the embryo is constrained by its surrounding structures this phenomenon is known as seed coat dormancy (Legesse Negash, 1993) even though; embryos isolated from these seeds are not dormant. The other type of dormancy is found when the embryos of the seeds are dormant, known as embryo dormancy. The third type of dormancy regulates seed germination by the inner tissue of the seed, which is the embryo, the enclosing endosperm and inner integument layer or both (Hartmann and Kester, 1975). Thus, dormancy must be broken to induce germination and various methods are used for this depending on the plant species and type of dormancy. Dormancy is self-guard for some seeds and seedling for suffering damage of death and allow some seeds to germinate when competition from other plants for light and water. Seeds germinate only after the dormancy is overcome or broken either through natural means such as animal gut activities (Manzano *et al*., 2005), wild fire (Van Staden *et al*., 2000), rainfall (Hartmann *et al.*, 2004) or through artificial means such as scarification, seed coat cracking, removing chemical inhibitors through leaching by water (Legesse Negash, 1995, 2002).

3.1.8 Parasitic weeds, pests and diseases

Niger seed blight caused by *Alternaria* sp. and leaf spot caused by *Cercospora sp*. are the most serious diseases of niger seed. Other diseases recorded are leaf spot caused by *Macrophomina phaseolina* and *Phytophthora* root rot on young seedlings in India and bacterial blight due to *Pseudomonas* spp. in Africa and India. Leaf spot affects the leaves and has the potential to reduce the photosynthetic leaf area of the plant. However, the niger accessions tested probably had more leaves than the plant needed to nourish the flower sinks (Yitbarek and Tiruwork, 1992). Niger seed is a novel biological approaches to overcome against nematodes and arthropods. According to Getinet and Sharma (1996) a total of 24 insects have been recorded on niger seed in both Ethiopia and India, of these the niger flies (*Dioxyna sororcula* and *Eutretosoma* spp.) and black pollen beetles (*Meligethes* spp.) are the most important. Niger fly lays eggs in the disk florets and later, the larvae destroy the flowers. The black pollen beetle eats pollen grains and adversely affects pollination. Some of the insect pests found in Ethiopia are not yet identified. In India, control measures for niger caterpillar, semi-looper, hairy caterpillar and surface grasshopper have been developed (ICAR, 1992). The parasitic weed 'dodder' (*Cuscuta campestris*) causes serious losses of niger seed production throughout Ethiopia (Fessehaie, 1992). Dodder was also a major threat to Indian production (Sharma and Sengar, 1989). Tosh and Patro (1975) reported that dodder can be controlled by the application of the herbicide Chlorpropham as a granulate, at the initiation of dodder germination, and at a rate of 4 kg/ha. A 90% control of dodder was achieved using Propyzamide applied as a post-emergence, 20-25 days after sowing at a rate of 1.5-2.0 kg/ha with no phytotoxicity (Tosh *et al*. 1977, 1978). Dodder could also be controlled by sifting seed before sowing.

3.2 Soil

Soil is a loose material made up of different materials and elements. Major components of soil include (I) Inorganic matter: - this is the non-living thing found in the soil, 45% of the total soil volume. (II) Organic matter: - this is the dead bodies of animals and plants in the soil. Micro organisms like bacteria and fungi in the soil are also organic matters. About 5% of the soil is organic matter, improves soil structure and increases the nutrient and water holding capacity of the soil provides a food supply for soil biology and reduce nutrient leaching (CSIRO, 1999), organic matter is fully broken down one of the things that is left is humus. Humus has some useful qualities in that it adsorbs nutrients, adsorbs much higher quantities of water than clay can, and improves soil structure due to its low plasticity and good cohesion. (III) Water: - water accounts about 25% of the volume of the soil. (IV) Air: - different gases may enter and fill the open space in the soil; a good soil has 25% of its volume composed of air.

3.3 Soil formation

The process by which rocks are broken down into pieces called weathering, physical (mechanical) and chemical weathering. In physical weathering rocks are broken into small particles of soil and are affected by climate, type of rock, plant and animal action. Because of variation of temperature during day time and at night rocks contract and expand. The contraction and expansion make the rock layer peel-off and fall to the ground. This process is called exfoliation (onion-skin weathering). Roots of trees entering into cracks of rocks force the rocks to break down into pieces. Small creatures, such as rabbits, worms, moles etc. making holes in the soil in search of food and shelter, while doing this they break down rocks. Young rocks are softer so they can easily break down. Ex. sedimentary and igneous breaks down easily than metamorphic rocks which are old and hard. In chemical weathering there is chemical change (reaction) in soluble minerals. Such factors as heat, cold, air, water, and certain plants, acting over a long period of time, break rocks into small particles; the tiny rock particles, when mixed with water, air, and organic material, form soil, humus and the uppermost layer called topsoil normally supports plant life (Hall and Lesser, 1966).

3.4 Soil types

Different methods are used to identify the type of soil. A) Texture: - it is the size of soil particles. Soil texture is determined by the proportions of sand, (large size) silt, (medium size) and clay (small size) in the soil. When they are wet, sandy soils feel gritty, silt soils feel smooth and silky, and clay soils feel sticky and plastic, or capable of being molded. Soil texture influences many soil physical properties, such as water-holding capacity and drainage. Coarse-textured sandy soils generally have high infiltration rates but poor water holding capacity. Because of its porous, readily admits air and water, which are essential to plant growth (Hall and Lesser, 1966). Silt particles are much smaller than sand, have a greater surface area, and are generally quite fertile. They do not hold as much moisture as clay soils; however more of the moisture is plant available. Fine-textured clay soil generally has a lower infiltration rate but a good water holding capacity (Brand and Weil, 1999). The tiny, firm-packing clay particles form a nonporous soil that is difficult to till and likely to cake. Being nonporous, the soil can absorb very little water. B) Structure: - it shows the arrangement of soil particles (sand, silt and clay) and pores in the soil and to the ability of the particles to form aggregates (Braunack and Dexter, 1989). Macro-pores allows good aeration, rapid infiltration of water, easy plant root penetration, good water drainage, as well as providing good conditions for soil micro-organisms to thrive. Micro-pores hold water against gravity (capillary action) but not necessarily so tightly that plant cannot extract the water (Brand and Weil, 1999). C) Color: -it indicates the type of materials in the soil- Ex: red soil is rich in iron. Black soil is rich in humus. D) Fertility: - Soils with high nutrient content are fertile soils, if not they are infertile. E) Soil profile: - Soils have three layers from top to bottom. F) Location: - different soils are found in different parts of the world. In equatorial rain forest region soils are red and called late rites. In the temperate zone soils are black and known as chernozems. In the cold zone soils are grey and called podosols.

According to the Ministry of Agriculture about 19 soil types are identified throughout Ethiopia. The big proportion of the country's landmass is covered by lithosols/liptosols (14.7%), nitosols (13.5%), cambisols (11.1%) and regosols (12%) in order of their importance, the rest include vertisol (10.5%), fluvisols (7.9%), luvisols (5.8%), acrisol (5%), xarosols (4.8%), solonchaks (4.2%), yermosols (3.1%) phaeazems (2.9%), rendzinas (1.5%), andosols (1.2%), arenosols (0.81%), gleysols (0.47%), histosols (0.42%), solonetz (0.04%) and chernozems (0.07%). Complexes of soil forming factors have primarily influenced the distribution of the soil types (MoA, 2000). There is limited information on the fertility status of the various soils. Research showed that potassium; nitrogen; cation exchange capacity (CEC) and organic matter contents of most Ethiopian highland soils are generally high by international standards (EARO, 1998), whereas their phosphorous content is low to very low compared to the African standard most soils in the highlands of Ethiopia are fertile (FAO, 1984). Contrary to most other African soils, the majority of Ethiopian highlands soils remain relatively fertile at depth. However, most highland soils are deficient in important nutrients and require fertilizer to sustain crop yields. Research has indicated that Ethiopian soils are generally low in available nitrogen and phosphorous and cannot produce high crop yields unless these are supplied. In Ethiopia, niger is valued for its ability to thrive on waterlogged soils where other crops fail. It is usually grown on "light poor soils with coarse texture" basically on almost any soil that is not extremely heavy (Chavan, 1961). Getenet and Sharma (1996) also report that niger seed grows well at pH values between 5.2 and 7.3. Some niger seed selections are moderately salt tolerant, but flowering may be delayed by increased soil salinity (Bulcha, 2007).

According to Ashenafi Gedamu (2008) the dominant soil types of the Amhara Region include black vertisols (43%).

3.4.1 Vertisols (VR) and its key characteristics

Vertisols from Latin Verto, "turn" are clay rich soils that shrink and swell with change in moisture content. The clay minerals adsorb water and increase in volume, swell when wet and during dry periods, the soil volume shrinks, and deep wide cracks form. Surface materials fall into these cracks and are incorporated into the lower horizons when the soil becomes wet again. As this process is repeated, the soil experiences a mixing of surface materials into the subsoil that promotes a more uniform soil profile. Because they swell when wet, vertisols transmit water very slowly and have undergo little leaching. They tend to be fairly high in natural fertility. The basic property of vertisol, that endows them with high water holding capacity in their clay content, which commonly lies between 40-60% and it, may be as high as 80% (Ahmad and Marmut, 1996). The dominant clay mineral in most of the vertisols appears to be montmorillonite. The mineral montmorillonite, which belongs to the smectite family of minerals, is responsible for the general attributes of the soils and their vertic properties. Since montmorillonite has the property of swelling and shrinking, the classification concept of vertisols was based on their shrink-swell potential. This potential is a function the clay content of the soil and the relative amounts of montmorillonite in the clay fraction. Vertisols are usually very dark in color, with widely variable organic matter content (1-6%). They typically form in Ca and Mg rich materials such as limestone, basalt, or in areas of topographic depressions that collect these elements leached from uplands. Vertisols are most commonly formed in warm, sub humid or semi-arid climates, where the natural vegetation is predominantly grass, savanna, open forest, or desert shrub. Large areas of vertisols are found in Northeastern Africa, India, and Australia, with small areas scattered worldwide, make up about 2% of the world's ice-free land surface. The bulk density of Vertisols varies greatly because of their swelling and shrinking nature with changes in soil moisture content. The soils have high bulk density when these are dried and low values when in a swollen stage. The bulk density of a vertisol may vary from approximately 1 to 2 g/cm3 depending on the moisture content.

A **B**

Figure 2: Sample of vertisol (A) and thoroughly mixed sun dried vertisol (B) used for the present study. The whole soil employed for the study was collected from Ayertena Gebreal Kebele, Enemay Wereda, East Gojjam Zone, Amhara National Regional State.

3.4.1.1 Management related properties of vertisols

Soil management, the basis of all scientific agriculture, which involves six essential practices: proper tillage; maintenance of a proper supply of organic matter in the soil; maintenance of a proper nutrient supply; control of soil pollution; maintenance of the correct soil acidity; and control of erosion (Microsoft Encarta, 2009). It is important that for optimum sustainable benefits from the use of the soils, their particular properties and behavior must be understood and incorporated in management strategies. Proper use of the soil, therefore, starts with appropriate selection of crops to be grown and the adoption of practices suitable for the soils. The use of the soils is considered in three broad categories, that is, for crop production, for pasture both native and improved, and for agro forestry. For crop production on a worldwide basis, vertisols are presently used for a range of crops including cereals, small root crops, oilseeds, fiber crops and sugarcane (Ahmed, 1996). Vertisols, as a class of soils, are easily recognized because of their clayey textures, dark colors, and special attributes. These soils are very productive if well managed, but present constraints to low input agriculture. The surface micro variability of vertisols, reflected in their internal soil properties, imposes constraints on their use for agronomic research and agriculture in general. Temporal changes in physical attributes of these soils require accurate timing of agricultural practices for efficient use. As the unique mineralogy of vertisols makes these soils very susceptible to erosion, soil management practices must be geared to reduce soil loss. Although their high natural fertility and positive response to management make vertisols attractive for agriculture, some of their other properties impose critical limitations on low input agriculture. The inherent limitations of vertisols are largely a function of the moisture status of the soils and the narrow range of moisture conditions within which mechanical operations can be conducted. Farmers using traditional methods of agriculture are aware of the high risks associated with the use of these soils. Even with high input technologies, risk a version is difficult since timing of tillage and of other farming operations is critical. As a consequence, the full agricultural potential of vertisols has not yet been exploited in many parts of the world. In order to appreciate the management related properties of vertisols, it is necessary to know not only the general soil properties, but also the properties in different parts of the soil.

3.5 The effects of fertilizers on growth performance and yield of crops

Fertilizer is a substance added to soil to improve plants' growth and yield. First used by ancient farmers, fertilizer technology developed significantly as the chemical needs of growing plants were discovered. Like all living organisms, plants are made up of cells. Within these cells occur numerous metabolic chemical reactions that are responsible for growth and reproduction. Since plants do not eat food like animals, they depend on nutrients in the soil to provide the basic chemicals for these metabolic reactions. The supply of these components in soil is limited, however, and as plants are harvested, it dwindles, causing a reduction in the quality and yield of plants. Fertilizers replace the chemical components that are taken from the soil by growing plants. However, they are also designed to improve the growing potential of soil, and fertilizers can create a better growing environment than natural soil. They can also be tailored to suit the type of crop that is being grown. Typically, fertilizers are composed of nitrogen, phosphorus, and potassium compounds. They also contain trace elements that improve the growth of plants. The use of chemical fertilizers and organic compost has both positive and negative effects on plant growth and the soil. Fertilizers affect plant growth by supplementing plant nutrients which allow plants grow faster and thicker. However, this applies only if the soil is deficient in nutrients. Fertilizers do not compensate for other growth inhibiting factors such as lack of water, poor soil preparation and weeds (Maxton, 1926). Incorporating inorganic and organic fertilizers to soil would provide multiple benefits for improving the chemical and physical status of the soil to which results in improved crop yield (Basso and Ritchie, 2005). Fertilizers enhance the growth of plants. This goal is met in two ways, the traditional one being additives that provide nutrients. The second mode by which some fertilizers act is to enhance the effectiveness of the soil by modifying its water retention and aeration.

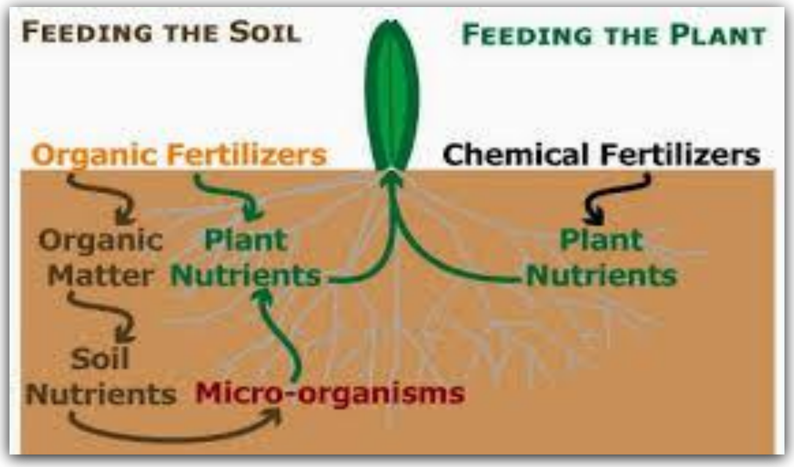


Figure 3: How does a fertilizer work (www.lovethegarden.com). Chemical fertilizers feed the plant whereas organic fertilizers feed the soil.

3.5.1 Effects of chemical fertilizers on growth performance and yield of niger

Chemical fertilizers have high nutrient contents, and are rapidly taken up by plants and significantly improve the quality and quantity of the food available today, although their long-term use is debated by environmentalists. The use of excess fertilizer can result in a number of problems, such as nutrient loss, surface and ground water contamination, soil acidification or basification, reactions in useful microbial communities, and increased sensitivity to harmful insects (Chen, 2006). The NPK chemical fertilizer decreased the soil pH and exchangeable calcium concentration, did not affect the soil concentrations of nitrogen and magnesium, and increased the concentrations of available phosphorous and exchangeable potassium. It is not worthy that a single element may not be enough to harvest good yield of crop even when other nutrients may be present in soil in sufficient amount. According to Patil and Balal (1964) individual nutrients (N:P:K) application did not give any increase in the yield of seed and straw of niger at Poona (Maharashtra), but combined application of N and P was found to be very effective in increasing the yields. Singh and Verma (1975) underlined that application of both 20 kg N + 40 kg P_2O_5/ha gave higher seed yield than application of a single nutrient or in combination of lesser dose of both fertilizers at Jabalpur (Madhya Pradesh). Singh *et al*. (1990) again added that application of 20 kg N + 20 kg P_2O_5/ha proved to be optimum dose for enhanced seed yields of winter season niger at the same locality. Thakuria and Gogoi (1991) from Jorhat (Assam) underlined that application of 40 kg N + 20 kg P_2O_5 + 1 0 kg K_2O/ha gave higher yield than other combinations of these nutrients. Agreeing to them, Upadhyay and Paradkar (1992) reported maximum seed yield of niger with the application of 40 kg N + 20 kg P_2O_5 + 20 kg K_2O/ha in vertisol of Chhindwara (Madhya Pradesh). According to Paul *et al*. (1993) application of 30 kg N + 15 kg P_2O_5 + 15 kg K_2O/ha was found to be optimum and remunerative fertilizer dose for niger under rain fed conditions in sandy loam soils at Gossaigaon (Assam). But, Sharma and Kewat (1994) emphasized that application of 40 kg N + 40 kg P_2O_5/ha without K significantly increased the seed yield of niger mainly due to improvement in yield attributing characters at Jabalpur (Madhya Pradesh). Kulmi and Soni (1995) recorded the highest seed yield of rainy season niger with the application of 30 kg N + 30 kg P_2O_5 + 15 kg K_2O/ha at Sidhi (Madhya Pradesh). With agreement to them, Agrawal *et al*. (1996) emphasized that application of 40 kg N+40 kg P_2O_5+20 kg K_2O/ha was optimum fertilizer dose for winter season niger under irrigated condition at Jabalpur (Madhya Pradesh) mainly due to improvement in number of capitulae/plant and seed/capitulum. A dose of 30 kg N + 15 kg P_2O_5 kg + 15 kg K_2O/ha proved to be economically viable to increase niger yield under rain fed condition of north bank plains agro-climatic zone of Assam (Baishya and Thakur, 1997). Paikary *et al*. (1997) found significantly higher seed yield from niger grown during pre-winter (rabi) season with the application of 40 kg N+ 40 kg P_2O_5/ha than other combinations at Semiliguda (Orissa).

Application of secondary nutrients particularly S has been reported advantageous for niger. Mamatha *et al*. (1994) underlined that the oil content in niger seeds decreased with increased nitrogen application, while it increased with phosphorus and sulphur application, but the seed and oil yield was maximum with application of 40 kg N + 80 kg P_2O_5 and 25 ppm S/ha at Bangalore (Karnataka). Application of 15 kg $ZnSO_4$ and 30 kg $MnSO_4$/ha along with recommended dose of fertilizers proved to be best for yield maximization of niger at Chhindwara (Madhya Pradesh) and Semiliguda, Orissa (DOR, 1996). Nandini Devi *et al*. (2000) emphasized that application of 60:30:30:40-N:P:K:S kg/ha proved to be the best fertilizer dose for increasing the grain and oil yields of niger in the lateritic belts of West Bengal. While summarizing the results of work done on nutrient management in niger seed at different locations of the country (DOR, 2002) balance fertilization as 30 kg N + 30 kg P_2O_5 + 15 kg K_2O + 15 kg S/ha found to be beneficial. From Maharashtra, Patil *et al*. (2006) emphasized that the application of all major nutrients (40 kg N + 40 kg P_2O_5 + 20 kg K_2O/ha) along with 20 kg S/ha proved to be optimum dose for yield maximization of Kharif niger under rainfed condition.

3.5.2 Effects of compost on growth performance and yield of niger

Organic fertilizer include compost, farm yard manure, slurry, worm castings, urine, peat, green manure, dried blood, bone meal, fish meal, and feather meal (Haynes and Naidu, 1998). Compost is a finely divided, loose material consisting of decomposed organic matter. It is primarily used as a plant nutrient and soil conditioner to stimulate crop growth. It helps the tilth quality of the soil, stabilize the pH or acidity/alkalinity, and release balanced quantities of many nutrients, and including quite a few not found in most commercial fertilizers. Compost has the added advantage of being natural. Mother Nature has been making compost for a lot longer than man has been around to enjoy the benefits. Composts are slow release organic fertilizers and excellent sources of most plant nutrients to increase crop yields (Sukhdev and Kabal, 2013). According to ANRSBA (2004) 12 tons/ha compost is recommended for niger seed production.

4. MATERIALS AND METHODS

4.1 Description of the study area

The study was conducted at Bichena town between December 2017 and April 2018. Bichena is found in West-central Ethiopia. Located in the East Gojjam Zone of the Amhara Region on the hillside overlooking the Abay River, it has a latitude and longitude of 10º27´N 38º12´E and an elevation of 2541 m. a. s. l. It is the administrative center of Enemay Wereda. The area is situated at the distance of about 265 km from Addis Ababa in the central west direction of Ethiopia (Figure 5). The area receives an average annual rain fall of 1150 mm. The minimum and maximum temperatures are 18 and 21^{0}C respectively. The soil of the study site comprises 75% vertisol, 15% reddish-brown, nitosol and 10% other soil types. The area is a mixed farming zone and is one of the most important teff (*Eragrostis tef*) growing belts of Ethiopia. Also cultivations of barely, wheat, maize, sorghum, bean, pea, chickpea, lentil, niger and vetch are common.

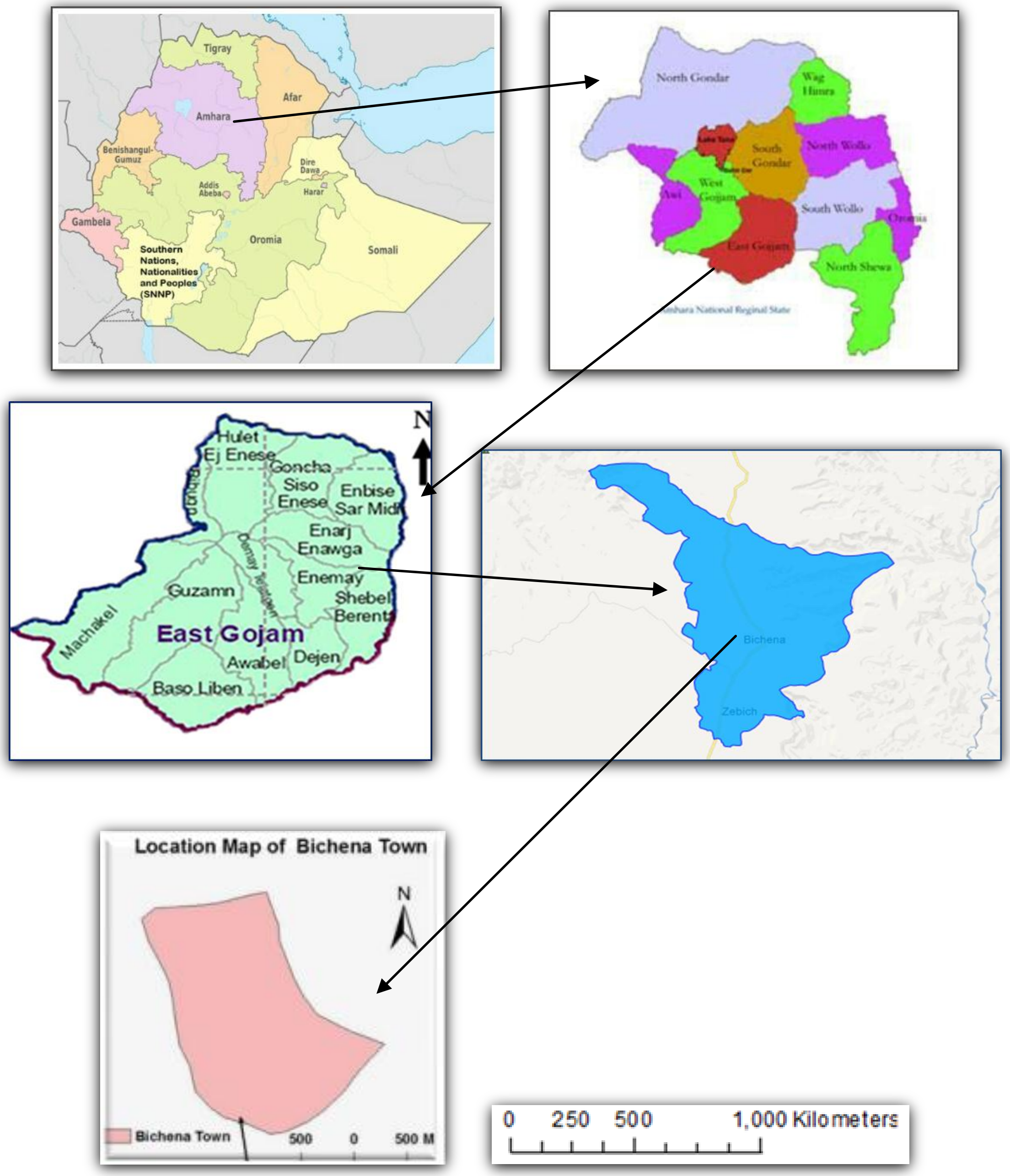


Figure 4: Map showing location of Bichena town in East Gojjam Zone of Amhara National Regional State.

4.2 Seed procurement

Seeds of *Guizotia abyssinica* were purchased during the 4^{th} week of October 2017 from the local market of Bichena town. Seeds were sieved to remove any debris materials and were stored at room temperature in paper bags until required.

Figure 5: Seeds of *G. abyssinica* used for planting in plastic bags. The seeds were purchased from the local market of Bichena town in October 2017.

4.3 Nursery bed preparation

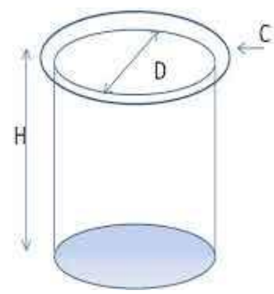
Before starting the actual plastic bag experiment, a rectangular nursery bed of 250 cm x 650 cm was prepared, which was enough to accommodate the 150 bags. The nursery was fenced wooden materials such that the niger plants were protected from wind and domestic animals. The fence has a suitable entrance fitted with appropriate protection so as to ward off animals. Dried grass stalks were used to cover the bags for conserving moisture, but the cover was removed at the onset of germination as the continued presence of the grass stalk forced bending of the emerging seedlings.

4.4 Soil sampling and analysis

Soil samples were collected from the same site of bare field. Samples were randomly removed to the end of the vertisols horizon with the help of pick axe. Sampling from plots under crop cultivation was intentionally avoided. Since farmers in the locality used commercial fertilizers and this may add chemical residues to the soil and influence niger plant growth. A large composite soil sample was then prepared by drying the vertisol in sun, powdering this and thoroughly so as to ensure sample homogeneity as much as possible. Composite soil sub sample was made from the powdered soil and was then subjected to various analyses in the Debre Markos Soil Testing and Fertility Improvement Center Laboratory.

4.5 Fertilizer amount and application

The research outputs conducted by Amhara National Regional State Bureau of Agriculture (ANRSBA, 2004) proved that for niger 50 and 30 kg/ha DAP and Urea respectively as well as 12 tons/ha compost were recommended. Circular plastic bags were used for the present study (depth 20 cm, diameter 10 cm).



$A = \pi r^2$ Where, r is the radius of a circle (r = diameter (D)/2)

Pi (π) = 3.14

A = 3.14 × (5 cm)^2 = 3.14 × 25 cm^2 = 78.5 cm^2

1m = 100 cm (1m^2 = 10,000 cm^2) ⇒ 78.5 cm^2 = 0.008 m^2

1 ha = 100 m × 100 m = 10,000 m^2

For DAP application

10,000 m^2 = 50 kg

0.008 m^2 = ? ⇒ 4 × 10^{-5} kg = 0.04 gm = 40 mg

For Urea application

10,000 m^2 = 30 kg

0.008 m^2 = ? ⇒ 2.4 × 10^{-5} kg = 0.024 gm = 24 mg

For compost application

10,000 m^2 = 12 ton, 12 ton = 12000 kg (1 ton = 1000 kg)

10,000 m^2 = 12000 kg

0.008 m^2 = ? ⇒ 0.0096 kg = 9.6 g

The required quantity of all organic sources of nutrients, composts were weighted as per treatments using digital balance SF-400 and mixed with the soil one day before the time of planting (9.6 g compost per pot was applied) while nutrients from chemical sources were applied in split dose, half at the time of planting (12 mg) and the remaining half (12 mg) applied at 30 days after planting in case of urea but full dose of phosphorous (as DAP, 40 mg) was applied (Rai, 1986) once at planting per bag using TANITA 1479X. In control treatments no additional nutrients were added.

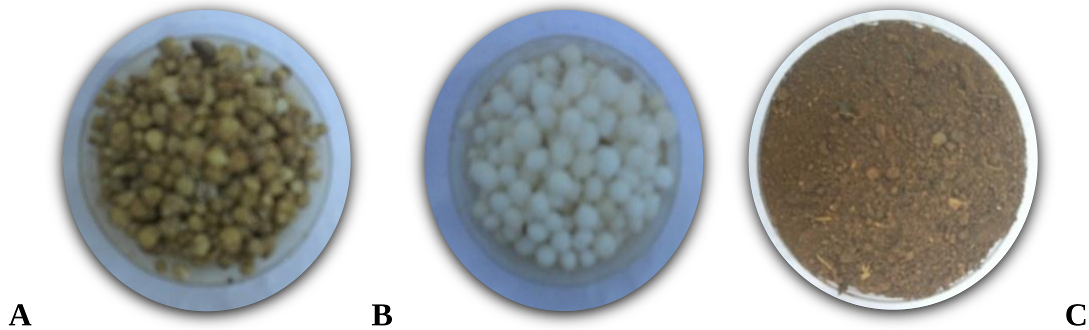


Figure 6: Samples chemical fertilizers and compost used for the present study: (A) DAP, (B) Urea and (C) Compost. The chemical fertilizers were purchased from the local market of Bichena town, and the compost was obtained from Enemay Wereda Rural Development Agricultural Office and Tree Planting Center.

4.5.1 Raw materials used for composting and the manufacturing processes

For the present study 2 m depth and 5 m width pit was prepared then raw materials, leaves, dung, nitosol and ash were mixed together during the mid of August, 2017. Rain keeps the raw materials wet and aided the decomposition process, producing rich compost. The mixture of different raw materials were turned and mixed once every 15 days for about three months.

4.6 Planting of seeds of *G. abyssinica* and planting method under nursery bed conditions

One hundred fifty plastic bags (depth 20 cm, diameter 10 cm) were filled with 1kg of vertisol, among which 50 bags contained only vertisol, 50 bags contained soils mixed with chemical fertilizers (DAP and urea) and the rest 50 bags contained soils mixed with compost (Figure 8: A). Each plastic bag were picked up by using sharp nail of 3 cm size at the bottom 7 narrow holes, and a total of 14 narrow side holes . The bags were labeled and randomly arranged on the prepared nursery bed. Lottery methods are used to randomize the placement of plastic bags.

Seven hundred fifty seeds were planted on December 23, 2017 by hand in planting plastic bags. Before planting the seeds, the soil was watered so as to ensure enough moisture for the seeds. Five healthy looking and big seeds of niger were planted in the middle of each of the 150 moisten pots at the depth of 2 cm (Bulcha, 2007). This was because correct planting depth gives good germination. Just after the planting, the seeds were well covered in the soil, a light watering was given for germination of seeds and bird watching was done till the germinating seedlings got well established. Each bag containing the planted seeds was watered the same amount of tap water twice a day (200 ml morning, 200 ml late evening) initially, from December 23-31, 2017 and was provided with a daily dose of 200 ml thereafter using a watering can and were allowed to grow for four months and a week under nursery bed conditions, where the mean minimum and maximum temperatures during the study period were 22.3 $\pm$ 24.1 ^{0}C noon and 16.7 $\pm$ 20.2 ^{0}C nights respectively.

Figure 7: Measuring 1 kg thoroughly mixed sun dried vertisols collected from Ayertena Gebreal Kebele, Enemay Wereda, East Gojjam Zone, Amhara National Regional State used to fill plastic sleeves for the present study.

A

B

Figure 8: One hundred fifty labeled and randomly arranged plastic bags (depth 20 cm, diameter 10 cm) under nursery bed conditions (A). Each plastic bag was watered equal amount of tap water (B), twice a day (200 ml morning and 200 ml late evening) initially for about a week and was provided a daily dose of 200 ml thereafter using a watering can.

4.7 Harvesting

Crop was harvested when majority of leaves (nearly 80%) in plants senescened and capitulae turned into brownish in color. Harvesting was done on 127, 113 and 120 days in vertisol only, VR + CF and VR + Comp after germination respectively for biomass determination. The roots of harvested seedling were watered too much to minimize the detachment of fine roots, the detached parts were tied on the corresponding part. The shoot and root of the fresh seedlings were carefully separated by cutting with dissecting knife. The respective shoot and root of seedlings were labeled and arranged. Dry matter data has been recorded for three consecutive measurements after drying the seedling in the sun for four days so as to attain constant dry weight. The dried shoot and root of each seedling were measured separately to determine shoot and root weight and together to get total dry weight by using a digital balance SF-400. The ripen capitulae (head) of each treatments were collected using scissor and stored in plastic bags separately. The collected capitulae were sun dried separately for the determination of seed yields per plant. Threshing was done on winnowing and the chaffs were separated so as to keep seeds clean. The seeds were weighted on TANITA 1479X and stored in plastic bags.

A B

Figure 9: The capitulae (A), roots and shoots (B) of *G. abyssinica* seedlings

A B C

D

Figure 10: Sun dried capitulae of *G. abyssinica* obtained from control (A), chemical fertilizers (B) and compost (C). Threshing was done on winnowing (D) to separate seeds from the chaffs for the determination of seed yields.

4.8 Data collection and statistical analysis

Data on seed germination response were collected every two days, after the first day of germination, for about 15 consecutive counts. Seeds were considered germinated at the time when protrusion of radicle. The final germination was recorded, and expressed in terms of germination parameters such as germination percentages (GP) mean germination time (MGT), and germination vigor (GV) were calculated according to Lbourian and Agudo (1987), as follows.

1. Determination of germination days: The duration of seed germination was recorded.
2. Determination of Germination percentage. It is the proportion of the seeds that germinate from all seeds subjected to the right conditions for growth. Germination percentage (GP) = $(n/N) \times 100$; where: $n =$ total number of germinated seeds in plastic sleeves. $N =$ Total number of seeds.
3. Mean germination time: $MGT = (\sum niti) \ / $ n where: $ni =$ percentage of seeds germinated between consecutive counts.

   $ti =$ Time (in day) taken since germination experiment started.

   $n =$ Total number of seed germinated.

4. Germination vigor: $GV = \sum (Gi/ti) \times 100/N$

   Where: Gi = number of seeds germinated up to the day under consideration.

   ti = Time taken for all germination.

   N = Total number of seeds used.

After germination had occurred and the seedlings had grown to a height of 5 to 7 cm, only one of the most vigorous and looked health seedlings was kept as judged by eye and the others were removed. From each treatments totally 20 plastic bags were selected by simple random sampling technique. Plant height, intermodal length, number of leaves, leaf area, number of branches per plant and RCD were considered as an important growth parameters of the present study. Similarly, number of capitulae/plant, number of seeds/plant, seeds weight, 1000 seeds weight, chaff dry weight and total dry weight were also considered as yield parameters. To compare growth responses of seedlings under nursery bed conditions, height (cm) increment measurements were taken every 5 days for the first 30 days and every 7 days until anthesis each from the ground to the tip of the apex. Likewise, intermodal length (cm), number of leaves and leaf area (mm^2) were measured periodically at 15, 30, 45, 60, 75, 90 days after germination and number of capitulate (heads) per plant, number of branches per plant, total dry weight (g), chaff dry weight (g), RCD, seed yield (g) and 1000 seeds weight (g) were recorded at harvest. Because the feature to be measured, leaf area has an irregular shape, its area cannot be directly calculated by using mathematical formula. Therefore, to found the area of the leaves (three leaves from each sampled plant) was spread over millimeter graph paper, a uniform interval 1mm and the outline of leaves were drawn while still attached to the plant. Then the number of grid squares was counted within the leaves (number of full squares, ¾, ½ and ¼ squares) and the number of grid squares was added to get the total number of squares. The approximate areas of the leaves were calculated using area $= S^2$.

The data of plant parameters were analyzed and their means were computed. The Analysis of variance (ANOVA) was carried out for germination, growth and yield parameters of the study using SPSS version 20. Duncan's post hoc test ($p \leq 0.05$) was used to determine the homogeneity subsets whenever significant differences existed among mean values presented in the appendices and excel program, excel 2007 to illustrate and compare data on Figures.

5. RESULTS

5.1 Germination parameters of niger as influenced by chemical fertilizers and compost under nursery bed conditions

5.1.1 Germination percentage

Results on percentage germination of *Guizotia abyssinica* obtained from plants treated within chemical fertilizers, compost or a combination of both, as well as the control are provided in Figure 11. Seed germination began within five days in all treatments under nursery conditions. Maximum germination percentage was observed in VR + CF treatments, which were 66% compared to compost (62.8%) and control treatments (50.4%). However, there was no significant difference among the various treatments ($p \leq 0.05$).

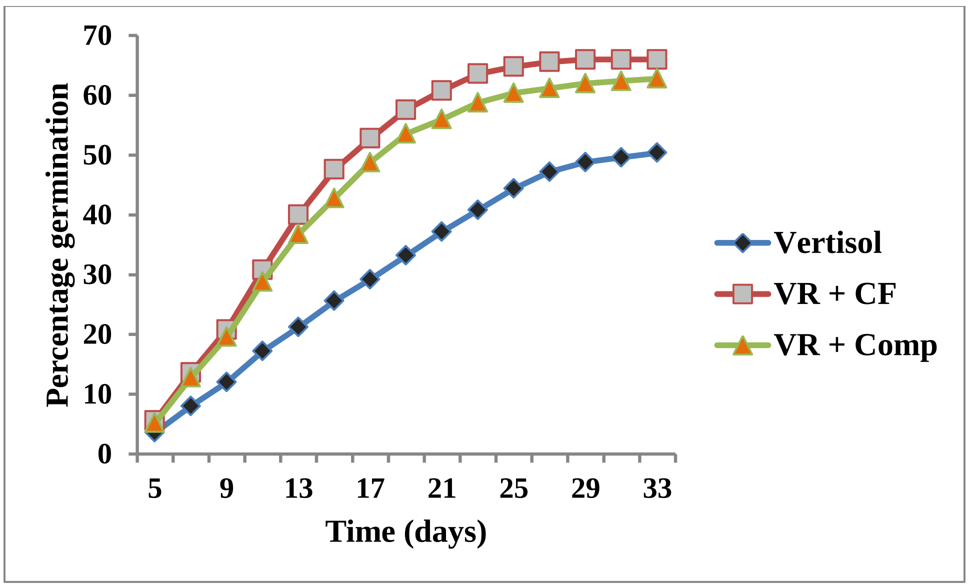


Figure 11: Germination percentage of *G. abyssinica* seeds planted in plastic bags filled with vertisol only, VR + CF and VR + Compost. Data points represent mean percentage germination on the respective days.

5.1.2 Mean germination time

The effects of application of chemical fertilizers and compost on mean germination time are shown in Figure 12. Maximum mean germination time was obtained from seeds planted with control treatments (11.7%) compared to compost (10.6%) and chemical fertilizer treatments (10.4%). Minimum mean germination time was obtained from chemical fertilizer treatments. However, there was no significant difference among the various treatments ($p \leq 0.05$).

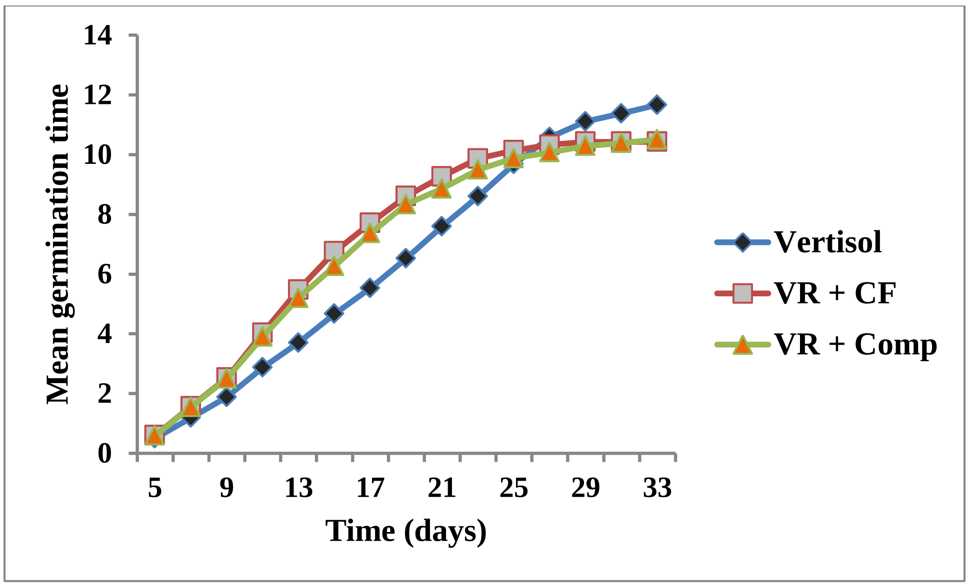


Figure 12: Mean germination time of *G. abyssinica* seeds planted in plastic bags filled with vertisol only, VR + CF and VR + Compost. Data points represent mean germination time on the respective days.

5.1.3 Germination vigor

Germination vigor percentage of vertisol only, VR + CF and VR + Comp seeds planted in plastic bags under nursery conditions were calculated. There was no significant difference among the various treatments ($p \leq 0.05$). However, maximum germination vigor percentage was obtained in chemical fertilizer treatments (2.6%) compared to compost (2.4%) and control treatments (1.8%) as shown in Figure 13 below.

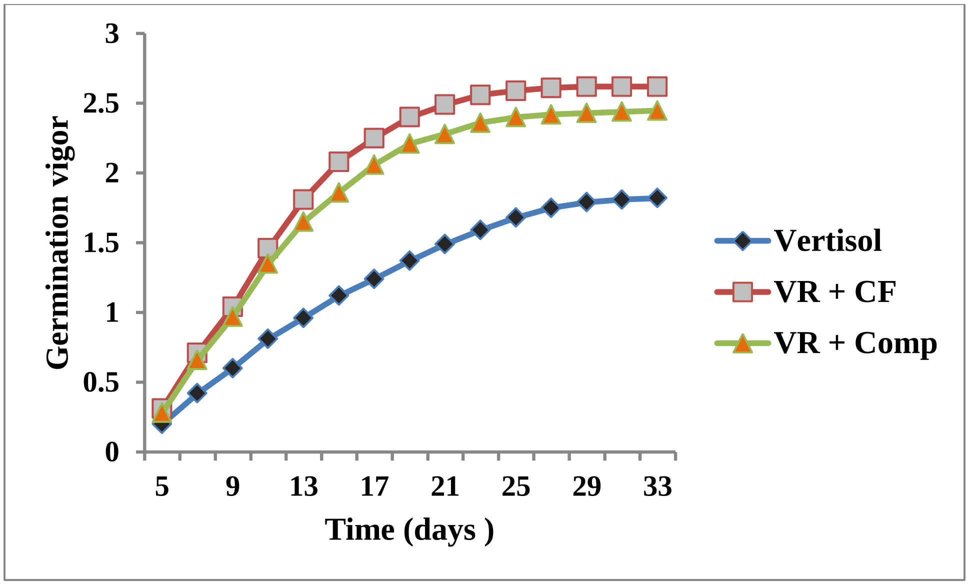


Figure 13: Germination vigor of *G. abyssinica* seeds planted in plastic bags filled with vertisol only, VR + CF and VR + Compost. Data points represent germination vigor on the respective days.

5.2 Flowering and maturity of niger as influenced by chemical fertilizers and compost under nursery bed conditions

As shown in Table 1 application of fertilizers fasten flowering and maturity. The start of flowering, 50% and complete flowering and maturity in VR + CF groups were 12, 7, 13, and 14 days respectively earlier compared to the control. The corresponding days in the VR + Comp treatments were 7, 1, 6 and 7 respectively.

Table 1: Treatment employed, planting date, flowering and days of maturation. Seedlings grown in VR + CF showed earlier start of flowering, 50% and complete flowering as well as days of maturation.

Treatments	Planting date	Start of germination	Start of flowering	50% flowering	Complete flowering	Days of maturation
Vertisol only	December 23/2017	December 27/2017	79 DAG	89 DAG	101 DAG	127 DAG
VR + CF	December 23/2017	December 27/2017	67 DAG	82 DAG	88 DAG	113DAG
VR + Comp	December 23/2017	December 27/2017	72 DAG	88 DAG	95 DAG	120 DAG

5.3 Growth parameters of niger as influenced by chemical fertilizers and compost under nursery bed conditions

5.3.1 Plant height increment

Seedlings grown in vertisol only, VR + CF and VR + Comp have shown significant differences in their mean height. However in the 1st, 2nd, 3rd, 4th, 5th, 6th, 7th, 8th, and 9th weeks $i.e.$ 5, 10, 15, 20, 25, 30, 37, 44, and 51 days there was no significant differences. Seedlings grown in the control resulted with mean height of 0.7, 1.6, 2.5, 3.2, 3.9, 4.3, 4.6, 4.9, and 5.3 cm respectively. The mean height were 1.1, 2.3, 3.3, 4.5, 5.6, 6.4, 7.4, 8.5, and 9.5 cm respectively for plants grown in VR + CF. The corresponding mean height for plants grown in VR + Comp were 0.9, 1.9, 2.7, 3.8, 4.7, 5.1, 5.5, 5.9, and 6.4 cm respectively. After 10th, 11th, 12th, 13th, 14th, and 15th weeks $i.e.$ 58, 65, 72, 79, 86, and 93 days plants grown in VR + CF showed better significant growth ($p \leq 0.01$) with mean height of 14.2, 26.6, 41.4, 51.4, 63.3, and 73.8 cm respectively. The control plants resulted in mean height of 5.6, 6.5, 8.8, 12.5, 16.7, and 25 cm respectively. The corresponding values for plants grown in VR + Comp were 7.3, 10.4, 15.5, 22.5, 30.5, and 41.5 cm respectively as shown in Figure 14. In general application of DAP and urea at rates of 50 and 30 kg/ha respectively improved the vegetative growth by 195% compared to the control.

Similarly, application of compost at rates of 12 tons/ha improved the vegetative growth by 66%.

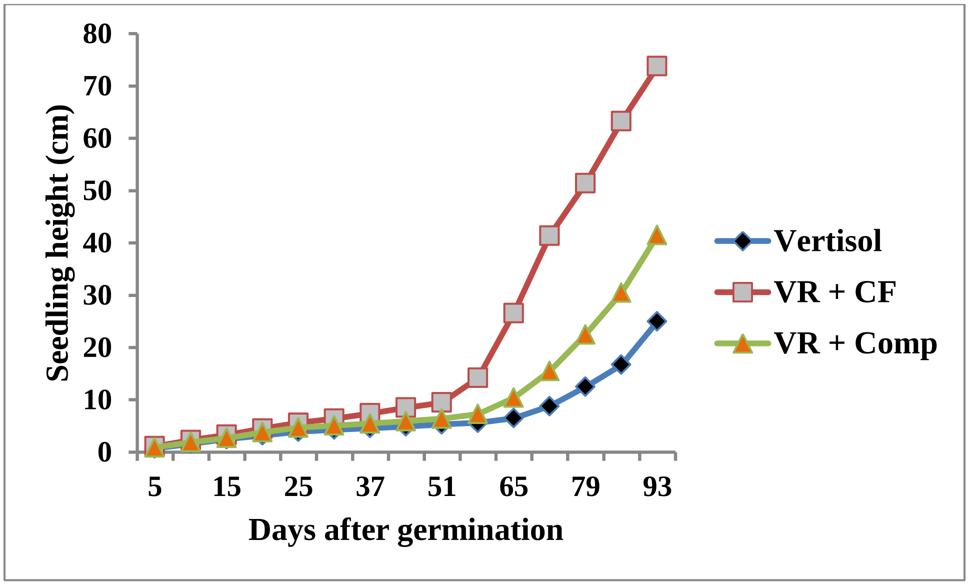


Figure 14: Mean height (cm) of *G. abyssinica* seedlings grown in vertisol only, VR + CF, and VR + Compost. Data points represent the mean height increment on the respective days.

5.3.2 Internodal length

The mean internodal length of seedlings grown in vertisol only, VR + CF and VR + Comp are shown in Figure 15. Plants grown in VR + CF showed better significant internodal length ($p \leq 0.01$). The highest internodal length difference was observed in the 10th and 12th weeks i.e. 75 and 90 days with mean internodal length of the control were 2.8 & 5.3 cm, VR + CF 23.6 & 39.6 cm and VR + Comp 6.7 & 11.9 cm respectively. In 2nd, 4th, 6th and 8th weeks there were no big mean internodal length differences. The mean internodal length of the control groups were 0.7, 0.9, 1.1 & 1.5 cm respectively. The corresponding values in VR + CF treatments were 2.9, 4.2, 6 & 10.6 cm respectively. The VR + Comp groups resulted in 1.4, 1.8, 2.5 & 3.4 cm respectively.

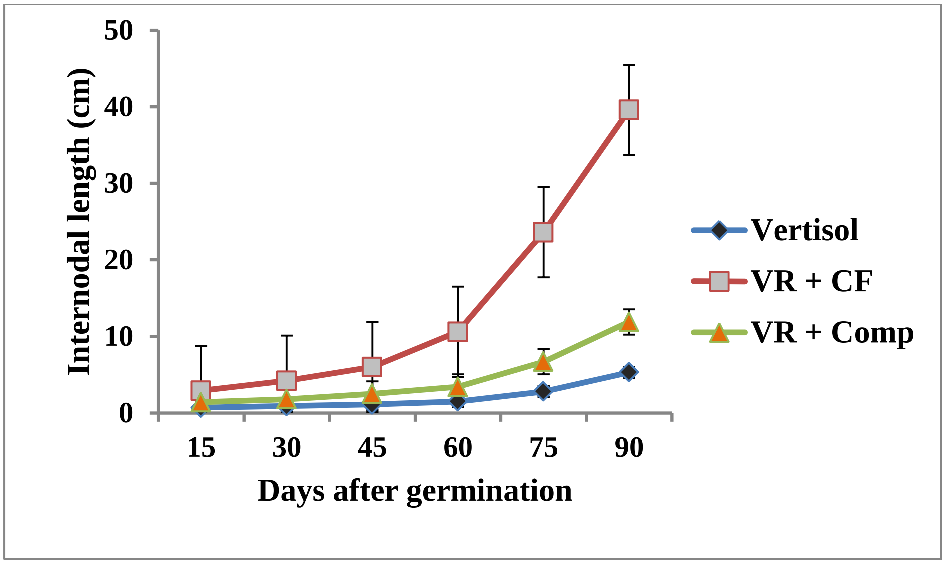


Figure 15: Mean internodal length (cm) of *G. abyssinica* seedlings grown in vertisol only,VR + CF and VR + Compost. Error bars indicate ± SE.

5.3.3 Number of branches/plant

Maximum mean number of branches was registered in VR + CF treatments (18) compared to VR + Comp (7) and the control treatments (3). The control treatments had significantly lowest number of branches/plant among the treatments ($p \leq 0.01$) as shown in Figure 16.

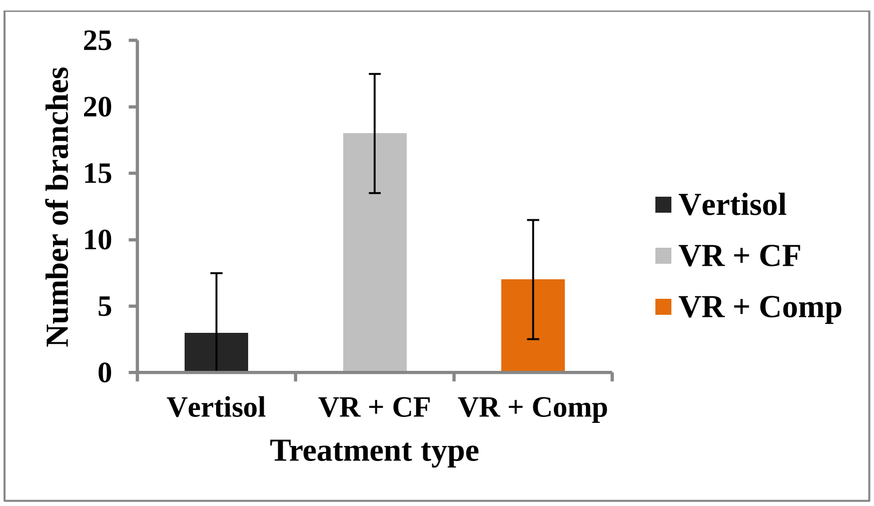


Figure 16: Mean number of branches of *G. abyssinica* seedlings grown in vertisol only, VR + CF and VR + Compost. Vertical bars indicate ± SE.

5.3.4 Leaf number

The mean number of leaves produced per plant was highly significant ($p \leq 0.01$) for seedlings grown in VR + CF (50) compared to those grown in vertisol only (19) and VR + Comp (26) as provided in Figure 17.

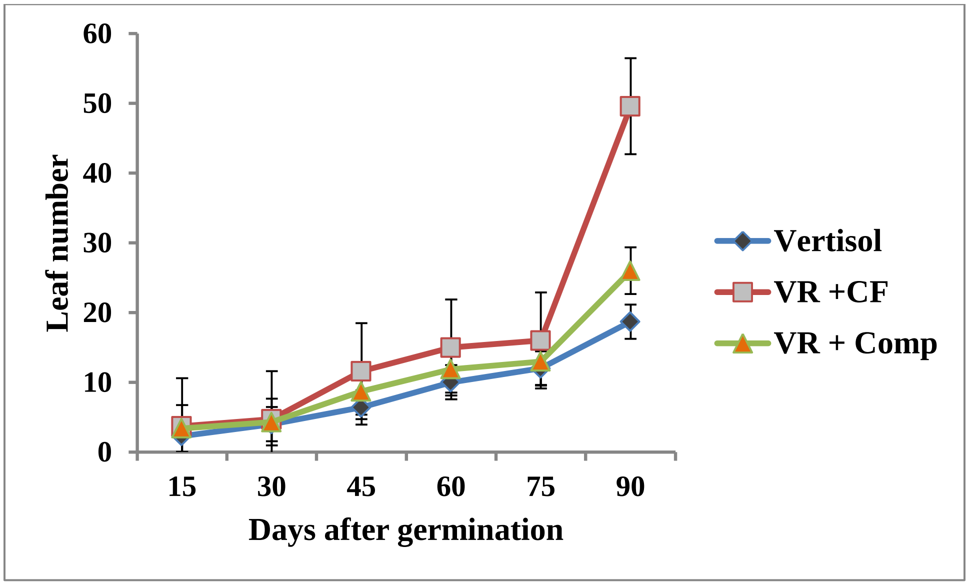


Figure 17: Mean leaf number of *G. abyssinica* seedlings grown in vertisol only, VR + CF and VR + Compost. Vertical bars indicate ± SE.

5.3.5 Leaf area

Seedlings grown in VR + CF showed highly significant ($p \leq 0.01$), maximum mean leaf area value of 136 mm^2 compared to those grown in vertisol only (26.2 mm^2) and VR + Comp (43.2 mm^2) as shown in Figure 18 below.

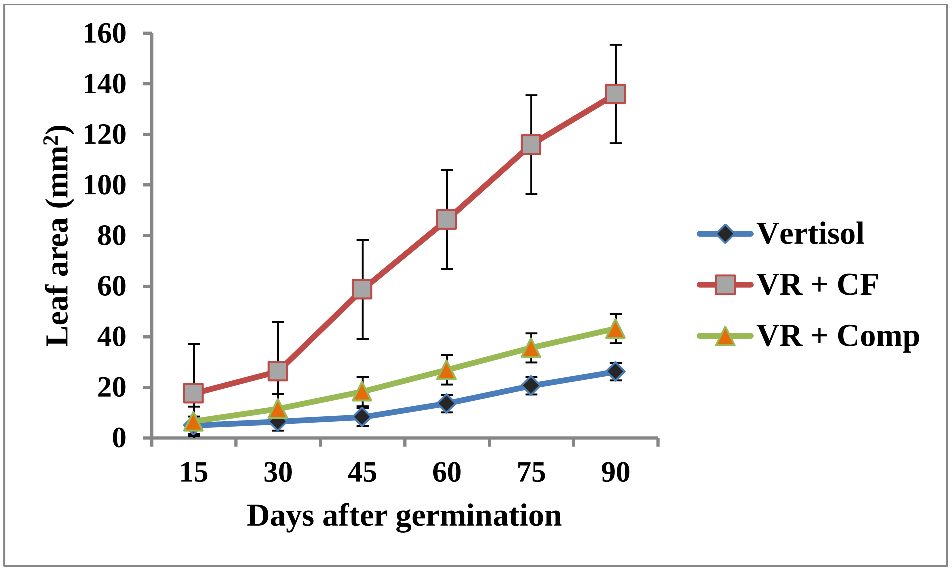


Figure 18: Mean leaf area (mm^2) of *G. abyssinica* seedlings grown in vertisol, VR + CF and VR + Compost. Vertical bars indicate ± SE.

5.3.6 Root collar diameter (RCD)

Significantly maximum RCD ($p \leq 0.01$) was obtained in the chemical fertilizer treatments (1.8 cm) compared to compost (1.3 cm) and control treatments (1.2 cm) as shown below in Figure 19.

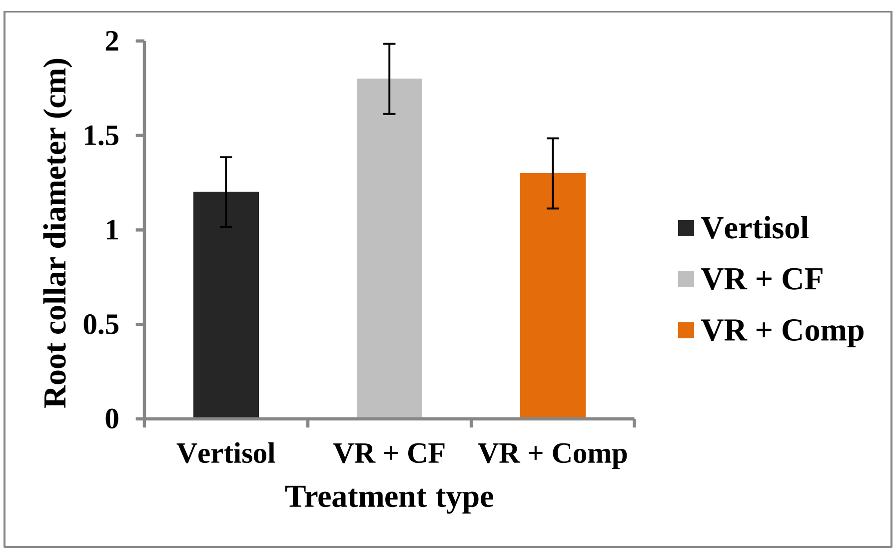


Figure 19: Mean root collar diameter (cm) of *G. abyssinica* seedlings grown in vertisol only, VR + CF and VR + Compost. Vertical bars indicate ± SE.

5.4 Yield parameters of niger as influenced by chemical fertilizers and compost under nursery bed conditions

5.4.1 Number of capitulae per plant

Significantly highest number of capitulae /plant was recorded ($p \leq 0.01$) in VR + CF treatments (19) compared to VR + Comp (8) and the control treatments (4). The control treatments had the lowest number of capitulae/plant among the treatments as shown in Figure 20.

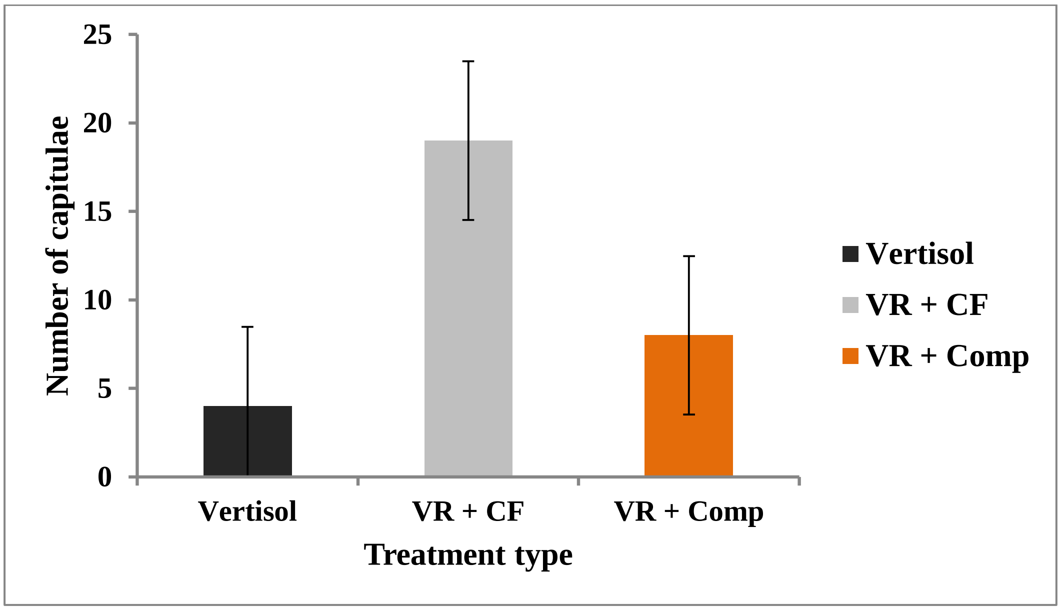


Figure 20: Mean number of capitulae per plant of *G. abyssinica* seedlings grown in vertisol only, VR + CF and VR + Compost. Vertical bars indicate ± SE.

5.4.2 Number of seeds per plant

Plants grown in VR + CF had significantly ($p \leq 0.01$) highest value of mean number of seeds/plant (355) compared to VR + Comp (164) and the control treatments (90). Application of DAP and urea at rates of 50 and 30 kg/ha respectively increased the yield by 294% compared to the control. Similarly, application of compost at rates of 12 tons/ha increased the yield by 82% as shown in Figure 21 below.

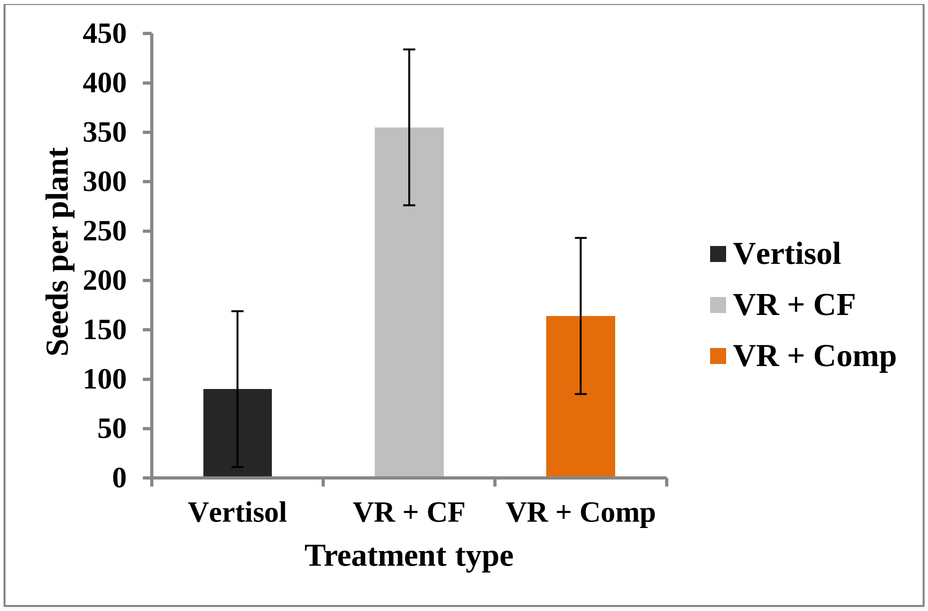


Figure 21: Mean number of seeds /plant of *G. abyssinica* seedlings grown in vertisol only, VR + CF and VR + Compost. Vertical bars indicate $\pm$ SE.

5.4.3 Seeds weight per plant (g)

Mean seeds weight had significantly ($p \leq 0.01$) maximum in VR + CF treatments with the value of 0.9 g compared to VR + Comp (0.5 g) and the control treatments (0.3 g) as shown below in Figure 22.

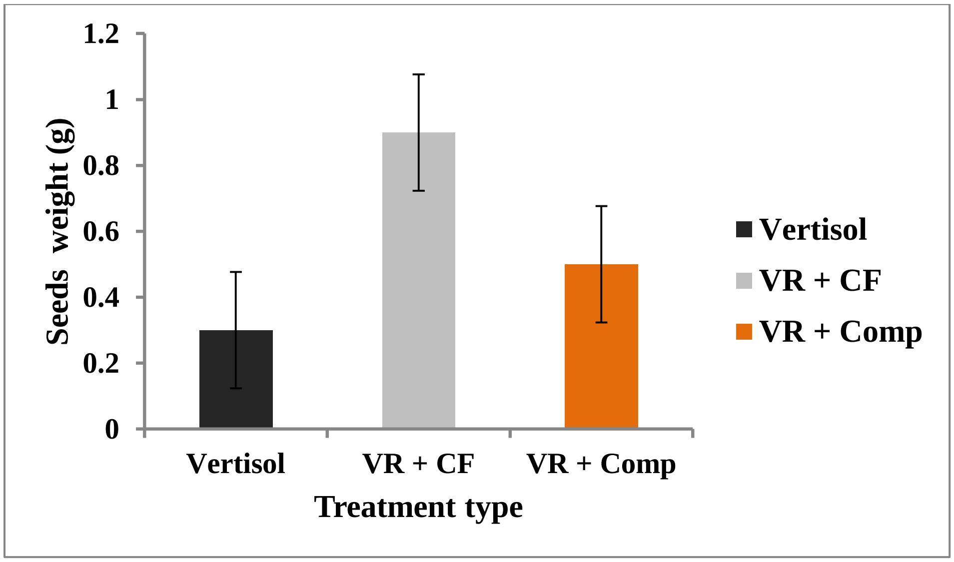


Figure 22: Mean seeds weight (g) per plant of *G. abyssinica* seedlings grown in vertisol only, VR + CF and VR + Compost. Vertical bars indicate $\pm$ SE.

5.4.4 Thousand seeds weight (g)

One thousand seeds were taken randomly from the sampled plants of each treatments then weighed in TANITA 1479X to determine 1000 seeds weight from each treatments. Though slight differences of 1000 seeds weight was recorded between VR + CF and VR + Comp, maximum 1000 seeds weight was recorded in VR + CF treatments (2.3 g). 2.2 g and 1.8 g of 1000 seeds weight was recorded in VR + Comp and control treatments respectively (Figure 23).

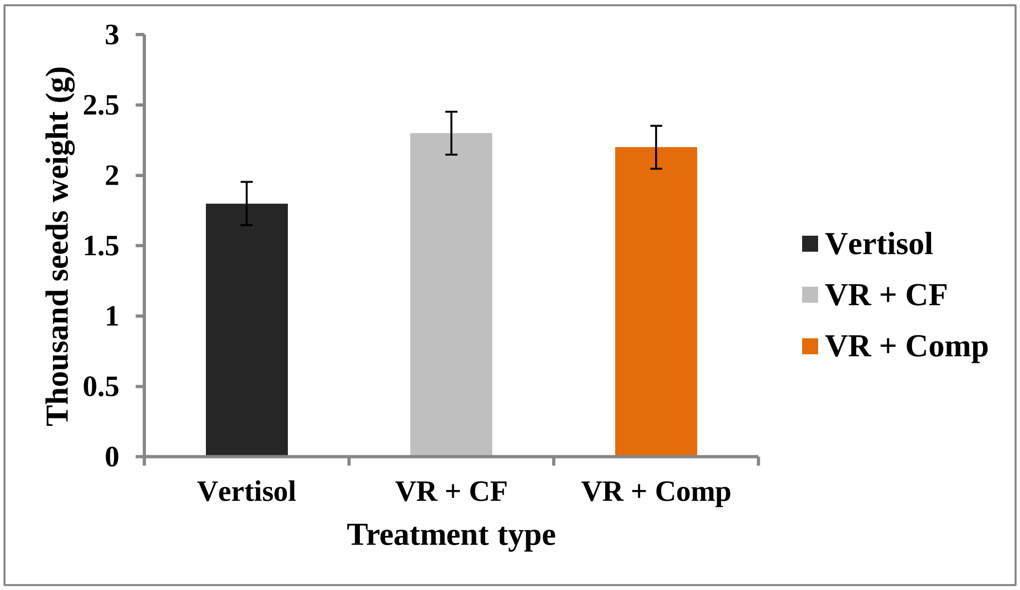


Figure 23: Thousand seeds weight (g) of *G. abyssinica* seedlings grown in vertisol only, VR + CF and VR + Compost. Vertical bars indicate $\pm$ SE.

5.4.5 Biomass production

The VR + CF treatments had highest biomass production of 5.5 g compared to VR + Comp (1.9 g) and control treatments (1.2 g). The highest mean shoot, root and total dry weight (g) was recorded in VR + CF treatments as shown below in Figure 24, 25 and 26 respectively. Plants grown in VR + CF also exhibited the highest chaff dry weight (1.2 g) compare to those grown in VR + Comp (0.5 g) and control treatments (0.3 g) (Figure 28). However, the highest mean shoot to root dry weight (g) ratio was recorded in control treatments (4.7) compared to the VR + CF (3.8) and VR + Comp treatments (4.4) as shown in Figure 27.

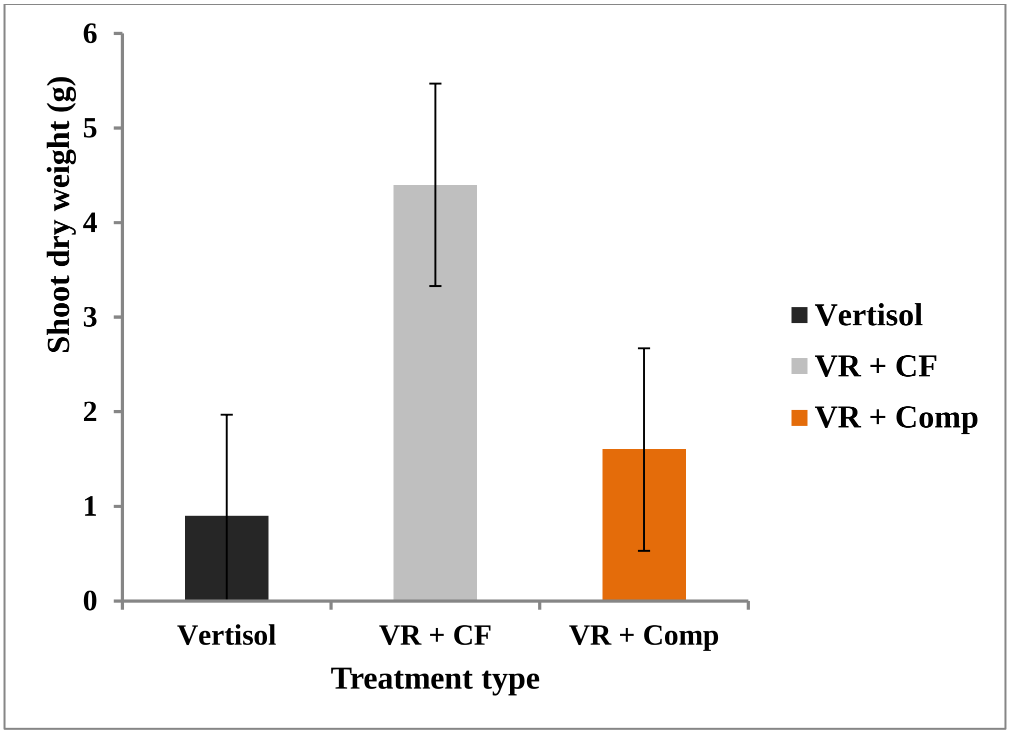


Figure 24: Mean shoot dry weight (g) of *G. abyssinica* seedlings grown in three treatments. Seedlings grown in VR + CF showed the maximum value compared to the vertisol only and compost. Error bars represent ± S.E.

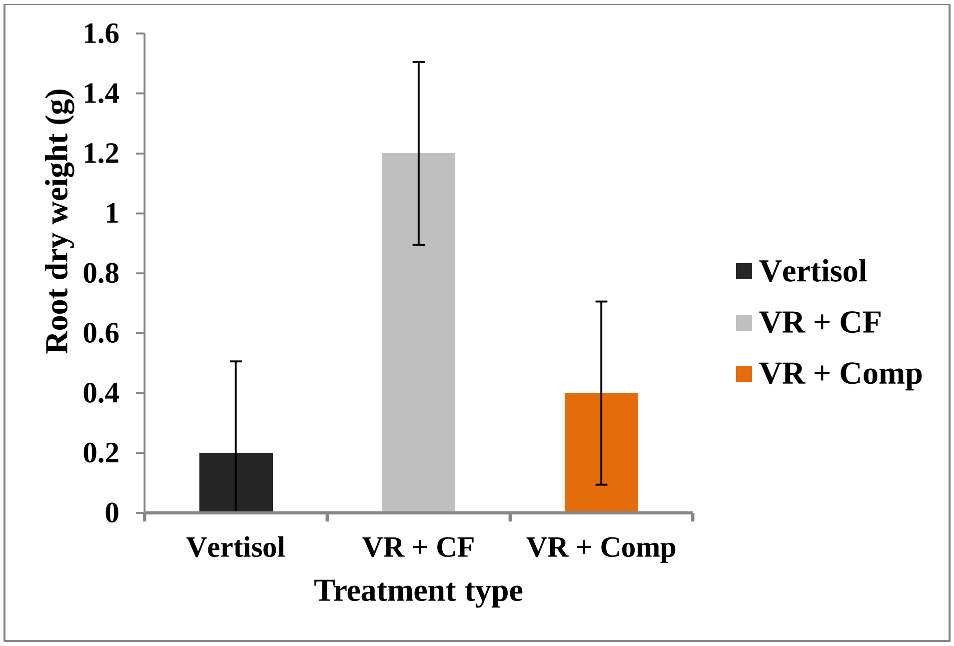


Figure 25: Mean root dry weight (g) of *G. abyssinica* seedlings grown in three treatments. Seedlings grown in VR + CF showed the maximum value compared to the vertisol only and compost. Error bars represent ± S.E.

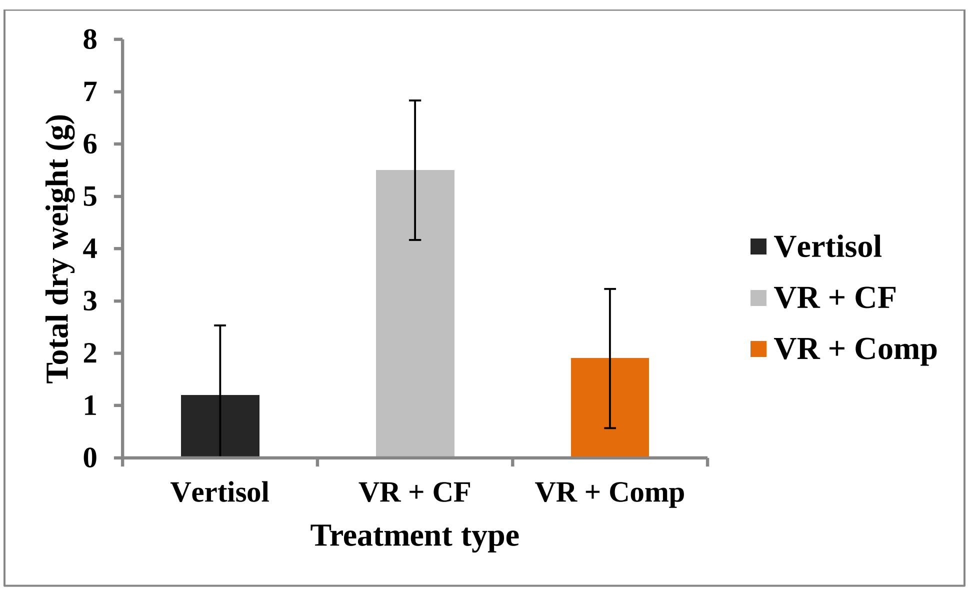


Figure 26: Mean total dry weight (g) of *G. abyssinica* seedlings grown in three treatments. Seedlings grown in VR + CF exhibited the highest dry weights compared to those located in Vertisol only and VR + Compost. Error bars represent ± S.E.

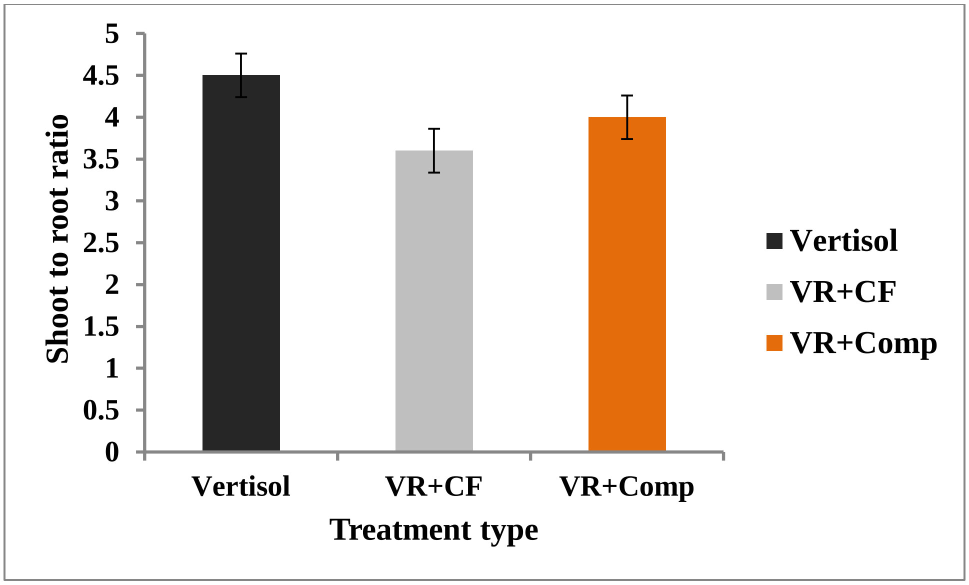


Figure 27: Mean shoot to root dry weight (g) ratio of *G. abyssinica* seedlings grown in three treatments. Seedlings grown in the control treatments exhibited the highest shoot to root ratio compared to those located in VR + CF and VR + Compost. Error bars represent ± S.E.

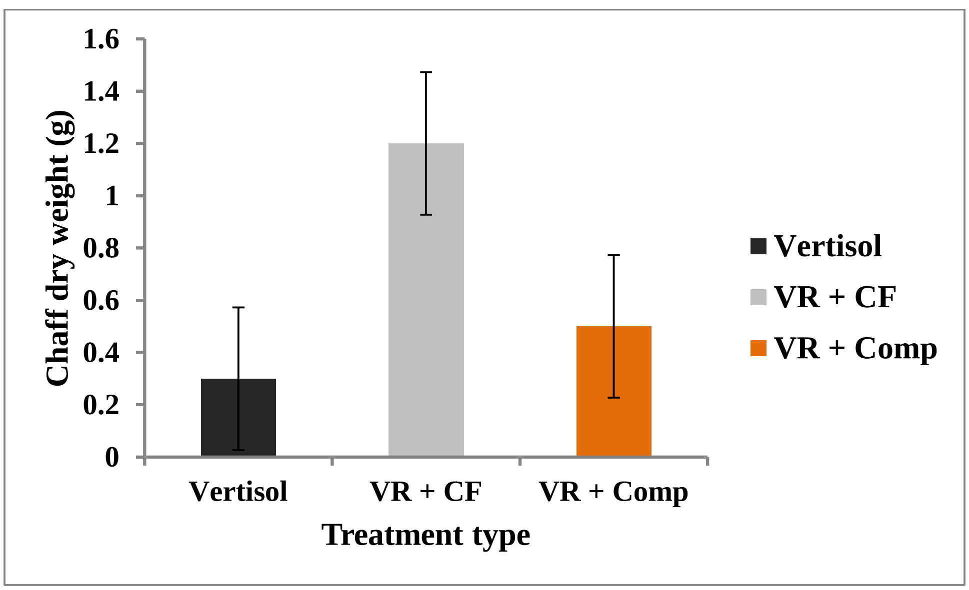


Figure 28: Mean chaff dry weight (g) of *G. abyssinica* seedlings grown in three treatments. Seedlings grown in VR + CF exhibited the highest chaff dry weight compared to those located in Vertisol only and VR + Compost. Error bars represent ± S.E.

5.5 Results of soil analysis

The results of vertisol analyzed for texture, pH, OC, TN, Av. P, and Av. K are presented in Table 2. The results indicated that the vertisol used for the present study was below the standard in terms of organic carbon (1.17% compared to the standard average value of 4-10%), total N (0.101% compared to the standard average value of 0.125-0.225%) and available P (2 ppm compared to the standard average value of 8-12 ppm). However, the vertisol used contained high available K (267 kg/ha compared to the standard average value of 100-250 kg/ha) (Frank, 1990).

Table 2: The results of physico-chemical properties of vertisols analyzed in Debre Markos Soil Testing and Fertility Improvement Center Laboratory used for the present study

S. No.	**Constituent**	**Analytical value**	**Interpretation**	**Method of determination**
A	Physical properties			
	Texture		Clay soil class	Hydrometer method
1	Sand (%)	8		
2	Silt (%)	16		
3	Clay (%)	76		
B	Chemical properties			
1	Soil pH	6.85	Slightly acidic	Water method
2	Organic Carbon (OC %)	1.17	Very low	Walkely & Black method
3	Total Nitrogen (TN %)	0.10	Low	Kjieldhal method
4	Av. P (ppm)	2	Very low	Olsen method
5	Av. K (kg/ha)	267	High	Ammonium acetate method

5.6 Plant materials used for compost manufacture

The compost used for the present study was manufactured from dung, nitosol, ash and different plant materials. The plant materials were used in their vegetative stages (Table 3).

Table 3: List of plants used for compost manufacture for the present study. The plant materials were used at their vegetative stages (data obtained from agricultural extension workers of Enemay Woreda through interview).

S. No.	Local Amharic name	English name	Scientific name
1	Sensel/Semiza	Poison arrow tree	*Justica shimperiana*
2	Gerawa	Bitter leaf	*Vernonia amygdalina*
3	Yekura hareg	Corton	*Cucumis dipsaceus*
4	Astenager	Jimsonweed	*Datura stramonium*
5	Sesbania	Sesbania	*Sesbania sesban*
6	Yeferenge tid	Mexican cypress	*Cupress lusitanica*
7	Serdo	Bermuda grass	*Cynodon dactylon*
8	Muja	Snowdenia	*Snowdenia polystachya*
9	Telenje	Chaff flower	*Achyranthes aspera*
10	Yahiya eshoh	Milk thistle	*Silybum marianum*
11	Chakema/Gullo	Caster bean	*Ricinus communis*
12	Lite	Cheeseweed	*Malva parviflora*
13	Bisana	Corton	*Corton macrostachyus*

6. DISCUSSIONS

6.1 Germination parameters of niger as influenced by chemical fertilizers and compost under nursery bed conditions

6.1.1 Seed germination

Not all the seeds planted in the plastic sleeves germinated. However, greater than 50% seed germination was achieved in this study. Some of the seeds did not germinate may be due to seed dormancy mechanisms that are specific to the species. That plants develop diverse dormancy mechanisms so as to avoid unfavorable environmental conditions is well established (Bewley and Black, 1994; Bradbeer, 1988; Legesse Negash, 1995; 2010). Maximum germination percentage was recorded in VR + CF (66%). This may be due to nitrogen, the most effective in breaking dormancy and stimulating germination and emergence (Agenbag and Villiers, 1989). The potential role of nitrogen, and especially nitrate, as a stimulator of seed germination is known (Bewley and Black, 1982; Hilhorst and Karssen, 1992; Baskin and Baskin, 1998). However there was no significant difference among the treatments at $p \leq 0.05$.

6.2 Flowering and maturity of niger as influenced by chemical fertilizers and compost under nursery bed conditions

A significant variation was noted among the treatments in relation to days for flowering and maturity. The minimum days for start of flowering, 50% and complete flowering and maturity was recorded in VR + CF. Similar result was obtained by Jirali *et al*. (1988), they opined that niger produced maximum number of flowers on 75th day after sowing and produced maximum yield. Salim and Saena (1993) noted that early flowering was associated with high harvest index, large number of capitulae and high seed mass.

6.3 Growth parameters of niger as influenced by chemical fertilizers and compost under nursery bed conditions

6.3.1 Height increment

Plant height is a simple measurement of plant growth and it depends on number of nodes and length of effective nodes. In this study a significant effects of application of chemical fertilizers and compost on plant height was obtained. Maximum plant height was noted in chemical fertilizer treatments (73.8 cm), while minimum plant height was in the control treatments (25 cm). Plants were shorter in the control groups, probably because no fertilizer was applied. An increase of plant height in VR + CF treatments would likely to be associated with nitrogen and phosphorus vegetative growth promoting effect, which increased the seedling height by 21% (Taiz and Zeiger, 2006).

6.3.2 Branches per plant

Application of DAP and urea at rates of 50 and 30 kg/ha respectively and compost at rates of 12 tons/ha exerted their marked influence on production of branches/plant at maturity. The VR + CF treatments produced maximum number of branches/plant (18) compared to VR + Comp (7) and the control (3). The lowest number of branches/plant in the control treatments was probably because no fertilizers were applied (Mondal *et al*., 1992). In this study, VR + CF caused to increase the number of branches/plant of niger. This increased number of branches/plant in VR + CF might be due to the vegetative growth promoting effect of nitrogen as well as branch development effect of phosphorus (ICAR, 1992). Mohan (2008) reported that number of branches/plant significantly increased with application of NP fertilizers.

6.3.3 Leaf number

Application of chemical fertilizers and compost significantly increased the number of leaves. Maximum number of leaves was registered in VR + CF (50). This might be due to favorable effect of high nutrient availability. Nitrogen is a chlorophyll component, and it promotes vegetative growth and green foliage (Jones, 1983). The control treatments produced significantly minimum mean number of leaves (19).

6.3.4 Leaf area

Leaf area fairly gives a good idea of photosynthetic capacity of the plant. It is an important variable for most eco physiological studies in terrestrial ecosystem concerning light interception, evapo-transpiration, photosynthetic efficiency, fertilizers, and irrigation response and plant growth (Blanco and Folegatti, 2005). It is also valuable in studies of plant nutrition, plant competition, plant-soil-water relations, plant protection measurement and heat transfer in plants (Mohsenin, 1986) and thus it is an important parameter in understanding photosynthesis, light interception, water and nutrient use and crop growth and yield potential (Smart, 1974; Williams, 1987). It has been observed in the present study that the effect of chemical fertilizers and compost had profound influence on leaf area of niger at different crop growth stages. Maximum leaf area was noted in VR + CF (136 mm^2). This might be due to the fact that 50 and 30 kg/ha DAP and urea respectively provide better nutritional environment. A high leaf area is desired for high productivity. Further increase in leaf area beyond optimum level causes lodging and reduction in yield (Nichiporovich, 1970). However, optimum leaf area reaches well before anthesis and fell progressively as water stress increases (Fisher and Khan, 1996).

6.3.5 Root collar diameter

The RCD is defined as the diameter of the main stem measured at or within a specified distance from the root collar. The highest mean RCD was obtained in VR + CF groups (1.8 cm). Fertilization treatments increased the seedling root collar diameter by 29% (Taiz and Zeiger, 2006). Nitrogen and phosphorus are critical determinants of plant growth and productivity, and both plant growth and root morphology are important parameters for evaluating the effects of supplied nutrient (Razaq *et al*., 2017).

6.4 Yield parameters of niger as influenced by chemical fertilizers and compost under nursery bed conditions

6.4.1 Capitulae per plant

The VR + CF treatments had significantly highest number of capitulate/plant (19) compared to VR + Comp (8) and the control (4). This was due to the production of highest plant height and number of branches, correspondingly increased number of capitulae/plant (Cheema, *et al*., 2001 and Sharma, *et al*., 1994). The poor vegetative growth (height, branches and foliage) of plants in control groups were due to less accumulation of food materials and photosynthates by the plants resulted into production of minimum number of capitulate/plant (Venkatakrishanan and Ravichandran, 1998).

6.4.2 Number of seeds/plant

Application of DAP and urea as well as compost at rates of 50 and 30 kg/ha and 12 tons/ha respectively had a marked effects on seed of niger under nursery bed conditions. Because of superiority in growth parameters due to efficient accumulation of desired food materials and photosynthates in VR + CF the number of seeds/plant increased over other treatments. Plant height possessed the positive association with grain yield (Lic and Chin, 1980). The decreased seed yield of niger in the control groups might be due to a decrease in plant height and number of branches and there by leading to reduced number of capitulae/plant and number of seeds/capitulum. Sharma *et al*. (1994) reported that improvements in seed yield attributed to increments in yield components and associated with better nutrition, plant growth and increased nutrient uptake (Sharma, 1990a). Moreover, the lower organic matter, lower total nitrogen and phosphorus contents observed on the vertisols analyzed had also positively influenced crop yield and increased niger seed yield at VR + CF.

6.4.3 Seed weight

The highest seeds weight and 1000 seeds weight was recorded in VR + CF groups; which was 0.9 & 2.3 g respectively. The minimum value was registered in control groups about 0.3 & 1.8 g respectively. One thousand seeds (achenes) weight is from 2 to 5 g (Weiss, 2000), with about 40 seeds per head. Such significance in the productivity of niger was very low which may be enhanced by adequate supply of nutrients especially phosphorus, because being oil crop niger respond well to phosphorus (Nambaiar and abrol, 1989).

6.4.4 Biomass production

The VR + CF groups had highest biomass production of 5.5 g compared to VR + Comp (1.9 g) and the control (1.2 g). This was due to VR+CF treatments received supply of more N and P resulted into more utilization of food nutrients as well as more accumulation of photosynthates than other treatments. Fertilization treatments increased the seedling mean dry weight of the stems and leaves by 72% and 123%, respectively (Taiz and Zeiger, 2006). The niger seeds which are small and shiny black contain 30 to 40% good quality edible oil. It is mainly grown in tribal pockets with the use of minimum agro inputs, particularly fertilizers leading to very low productivity (Sharma, 1993). Mondal *et al*. (1992) and Ramamurthy and Shivshankar (1996) have reported higher dry matter accumulation by plants due to balanced supply of essential elements to the crop.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Application of DAP and urea at rates of 50 and 30 kg/ha respectively improved vegetative growth by 195% compared to the control. Similarly yield increased by 294%. On the other hand niger plants grown in soils mixed with compost at rates of 12 tons/ha improved the vegetative growth by 66% and yield increased by 82%. This was because fertilizers are sources of mineral elements, which plants require for effective growth and development. However VR + CF treatments showed better growth performance and yield components compared to VR + Comp treatments.

7.2 Recommendations

Application of DAP and urea at rates of 50 and 30 kg/ha respectively and compost at rates of 12 tons/ha should be recommended in niger seed production of similar climatic and soil conditions. Moreover, fertilizer applications on niger seed production should consider soil related factors that affect the availability and evolution of nutrients in soils as integral parts of efforts to improve niger seed production and soil fertility. Thus, a further research work should be undertaken to determine the effectiveness of integrated use of nutrients from chemical fertilizers and compost. It may be said that neither organic nor inorganic chemical fertilizers alone can supply desired nutrients to crop plants and there by the high yield whereas; the combination of both can achieve the expected result. The investigation required to be conducted with more number of treatments under various agro climatic zones.

8. REFERENCES

Adefris Teklewold and Adugna Wakjira (2004). Seed filling and oil accumulation in noug (*Guizotia abyssinica* L. f. Cass.). *SINET Ethiopian Journal of Science.* 27(1): 25–32.

Agenbag, G.A. and Villiers, O.T. (1989). The effect of nitrogen fertilizers on the germination and seedling emergence of wild oat (*A. fatua* L.) seed in different soil types. *Weed Research*. Vol. 29.

Agrawal, K.K., Jain, K.K., Sharma, R.S. and Kashyap, M.L. (1996). Response of winter Niger (*Guizotia abyssinica*) to time of sowing and fertility levels. *Journal of Oilseeds Research* 13 (1): 122–123.

Ahmad, N. and Marmut, A. (1996). *Vertisols and Technologies for their management*. Elsevier, Amsterdam.

Ahmed, N. (1996). Science Direct. *Developments in Soil Sciences.* Vol. 24. pp. 363–428.

Amare Aleminew (2012). *Response of noug (Guizotia abyssinica Cass.) to NP Fertilizers Application and Seeding Rates on Yield and Yield Components* at Ebinat District, in Amhara Region, Ethiopia, MSc. Thesis, Bahir Dar University, Ethiopia. 107 pp.

ANRSBA (2004). *Crop Management & Protection Package under semi-arid conditions.* Vol. 2. pp. 132–135.

Ashenafi Gedamu (20080. *Food supply, Triticale production in Ethiopia: It's Impact on Food security and poverty*. 98 pp.

Baagøe, J. (1974). The genus Guizotia (Compositae). *A taxonomic revision*. Botanisk Tidsskrift 69(1): 1–39.

Baishya, A. and Thakur, A.C. (1997). *Effect of graded levels of NPK fertilizers on the yield of niger under rainfed condition of north bank plain zone of Assam agriculture Science Society of North East India*. 10 (1): 116–117.

Barroco, R.M., Van, P.K., Bergervoet, J.H., De V.L., Groot S.P., Inez D., Engler, G. (2005). The role of the cell cycle machinery in resumption of post embryonic development. *Plant Physiology*. 1376 (1): 127–140.

Baskin, C.C. and Baskin, J.M. (1998). *Seeds. Ecology, biogeography, and evolution of dormancy and germination*. London: Academic Press.

Basso, B. and Ritchie, J.T. (2005). *Impact of compost, manure and inorganic fertilizer on nitrate leaching and yield for a 6-year maize-alfalfa rotation in Michigan, Agriculture, Ecosystems and Environment,* Vol. 108 no. 4. pp. 309–341.

Bewley, J. D. (1997). Seed Germination and Dormancy. *Plant Cell* 9: 1055 – 1066.

Bewley, J. D. and Black, M. (1994). *Seeds: Physiology of Development and Germination. 2nd Ed.* Plenum Press, New York and London, 445 pp.

Bewley, J.D. and Black, M. (1982). *Physiology and Biochemistry of seeds.* Vol. 2*:* Viability, dormancy and environmental control. Berlin: Springer-Verlag.

Bhardwaj, S.P. and Gupta, R.K. (1977). Tilangi, a potential rich yielding oilseed crop. *Indian Farming* 27 (6): 18–19.

Bisen, R., Pandey, A.K., Jain, S., Sahu, R., Sharma, S. and Ranganatha, ARG. (2015). *Genetic analysis using variability, correlation and path analysis in niger (Guizotia abyssinica Cass*.) *In:* IOSR extended summaries: National Seminar on strategic intervention to enhance oilseeds production in India. Hydrabad, Bharatpur. pp. 123–125.

Blanco, F.F. and Folegatti, M.V. (2005). *Estimation of leaf area for greenhouse cucumber by linear measurements under salinity and grafting, Agricultural Science,* Vol. 62, no. 4. pp. 305–309.

Bradbeer, J.W. (1988). *Seed Dormancy and Germination*. Blackie Academic & Professional, London, 146 pp.

Brady, N. and Weil, R. (1999). *The nature and properties of soils*. 12th Ed, Prentice-Hall In: Sydney.

Braunack and Dexter (1989). Soil aggregation in the seed bed: A review II. Effect of aggregates and beds of aggregates*. Soil and Tillage Research* Vol. 15. pp. 259–279.

Bulcha Weyessa (2007). *Guizotia abyssinica* (L. f.) Cass. *PROTA (Plant Resources of Tropical Africa: Resources vegetables de l'Afrique tropical*. Wageningen, Netherlands. http://www.prota4u.org/search.asp. Accessed 14 November 2017.

Chachalis, D. and Reddy, K.N. (2000). Factors affecting Campsis radicans seed germination and seedling emergence. *Weed Science,* 48: 212–216.

Chavan, V.M. (1961). *Niger and Safflower*. Indian Central Oilseeds Committee, Hyderabad. India.

Cheema, M.A., Malik, M.A. and Hussain, A. (2001). Effects of time and rate of nitrogen and phosphorus application on the growth and seed and oil yield of canola (*Brassica napus* L.). *J. Agron. Crop Sci.*, 186: 103–110.

Chong-Ho Wang, Yu-Wen Lin, Wei-Ten Huang, and Li-Rongchiu (2005). *The various raw materials for composting, their benefits and drawbacks and the techniques of composting, mixing together different raw materials to achieve a better balance*.

Chopera, R.N., Nayar, S.L. and Chopra, I.C. (1986). *Glossary of Indian medicinal plants (including the supplement*). Council of Scientific and Industrial Research, New Delhi.

Chude V.O., Malgwi W.B., Amapu I. V., and Ano O.A. (2004). *Manual on soil Fertility Assessment*. Federal Fertilizer Department (FFD) in collaboration with FAO/National special programme for Food security, Abuja, Nigeria.

CSA (2008). *Agricultural sample survey: Report on area and production of crops.* Vol. 1. Statistical Bulletin, Addis Ababa, Ethiopia.

CSA (2011). *Agricultural survey 2010/2011* Vol. I. Report on area and production of major crops. Statistical Bulletin.

CSA (2016). *The Federal Democratic Republic of Ethiopia Central Statistical Agency report on area and production of major crops*, Addis Ababa, Ethiopia.

CSIRO (1999). *Organic Matter and Soils, Discovering Soils Booklets, Division of Soils*, common wealth Scientific and Industrial Research Organization.

Dempewolf, H., Rieseberg, L.H. and Cronk, Q.C.B. (2008). *Crop domestication in the compositae: a family-wide trait assessment*. Genetic Resources and Crop Evaluation, 55: 1141–1157.

Dempewolf, H., Tesfaye, M., Teshom, A., Bjorkman, A.D., Andrew, R.L., Scascitelli, M., Black, S., Bekele, E., Engels, J.M., Cronk, Q.C. and Rieseberg, L.H. (2015). Patterns of domestication in the Ethiopian oilseed crop noug *(Guizotia abyssinica). Evolutionary Applications*. 8(5): 464–475.

Doggett, H. (1987). *Niger/Noug Research Methodology*. *In* Oil Crops: Niger and Rapeseed/Mustard. Proceedings of the Third Oil Crops Network Workshop held in Addis Ababa, Ethiopia, 6-10 October (A. Omran, Ed.). IDRC-MR153e. pp. 210-219.

DOR (1996). *Annual Report*, 1995-96. Niger, Directorate of Oilseeds Research, Hyderabad (AP). 38 pp.

DOR (2002). *"Integrated Nutrient Management for Oilseed Crops" Bulletin* Compiled by B.N. Reddy and Sudhakara Babu: Edited by D.M. Hegde, DOR, Hyderabad, Directorate of Oilseeds Research, 10 pp.

Duke, J.A. (1983). *Guizotia abyssinica (*L. f.*) Cass. In:* Handbook of energy crops.

EARO (1998). *Annual Report of soil Department*. Addis Ababa, Ethiopia.

FAO (1984). *Land use and production system*: *Assistance to Land use planning, Ethiopia Technical Report* 4, AG: DP/ETH/ 781003, Rome.

Fessehaie, R. (1992). *Weed science research on Niger, linseed and rapeseed*. *In* Oilseed Research and Development in Ethiopia. Proceedings of the First National Oilseed Workshop, 3-5 December 1991, Addis Ababa. pp. 136-151

Finch-Savage WE, Leubner-Metzger G. (2006). Seed dormancy and the control of germination*: New Phytologist* 171, pp. 501–523.

Fisher, R.A. and Khan, G.D. (1996). The relationship of grain yield to vegetative growth and post flowering leaf area in the wheat crop under condition of limited soil moisture. *Australian Journal of Agricultural Research* 17: 281-295.

Frank, B. (1990). *Agricultural compendium*; FAO and Booker (MTS).

Getinet Alemaw and Adefris Teklewold (1995). An agronomic and seed quality evaluation of noug (*Guizotia abyssinica* Cass.) germplasm in Ethiopia. *Plant breeding* 114: 375-376.

Getinet Alemaw and Nigussie Alemayehu (1997). *Highland oil crops: a two decade research experience in Ethiopia*, *Research report* No. 30. Institute of Agricultural research, Addis Ababa, Ethiopia.

Getinet Alemaw and Sharma, S. M. (1996). Niger *Guizotia abyssinica (*L. f.) Cass. *Promoting the conservation and use of underutilized and neglected crops* 5. Institute of plant Genetics and Crop plant Research, Gatersleben/International plant Genetic Resources Institute. Rome, Italy. 50 pp.

Hall, M.A. and Lesser, M.S. (1966). *Review Text in Biology*. How soil depletion can be prevented. AMSCO School publications, Inc. New York, 10013. 418 pp.

Hartmann and Kester (1975). *Plant propagation: principles and practices*. 3rd Ed. Prentice Hall, Inc. 662 pp.

Hartmann, H. T., Kester, D. E., Davis, F. T. and Geneva, R. L. (2004). *Plant Propagation.*

Haynes, R.J. and Naidu, R. (1998). Influence of lime, fertilizer and manure applications on soil organic matter content and soil physical conditions: *A review on Nutrient cycling in Agro ecosystems*, Vol. 51, no. 2. pp. 123–137.

Hilhorst, H.W.M. and Karssen, C.M. (1992). *Effect of chemical environment on seed germination*. *In*: Fenuer M, ed. Seeds: the ecology of regeneration in plant communities. Wallingford: CAB International, pp. 327–348.

Hiremath, S.C. and H.N. Murthy (1986). The structure, stability and meiotic behavior of B-chromosomes in *Guizotia scabra* (Vis.) Chiov. Subsp. scabra (Compositae). *Caryologia* 39: 397-402.

Hiremath, S.C. and Murthy, H.N (1992). Cytological studies in Guizotia (Asteraceae). *Caryologia* 45: 69-82.

Hiruy Belayneh (1987). Determination of the optimum harvesting stage for niger (*Guizotia abyssinica* Cass). *Ethiop. J. Agric. Sci*. 9: 83-94.

Hiruy Belayneh (1991). *Oil crop germplasm: A vital resource for a plant breeder*. *In* Plant genetic resources of Ethiopia. pp. 344 - 354, (Engels, J.M.M., Hawkes, J.G. and Woreda, M. Eds). Cambridge University Press, Cambridge.

Hong, T.D., S. Linington and R.H. Ellis (1996). *Seed storage behavior: a compendium. Handbooks for Gene banks:* No. 4. International Plant Genetic Resources Institute, Rome.

Https://www.lovethegarden. com/community/fun-facts/how-dose-a fertilizer work. 27/04/2017.

Indian Council of Agricultural Research (ICAR) (1992). Niger: Package of practices for increasing production. *Extension Bulletin* No. VII. Directorate of Oilseeds Research, ICAR.

Jirali, D.I., Panchal, Y.C., Janardhan, K.V., Janagoudar, B.S. and Patil, B.C. (1988). Studies on flowering pattern and yield of chickpea (*Cicer arietinum L*.) under receding soil moisture condition. *Indian Journal of Plant Physiology* 31 (3): 293–296.

Johnson, D.G. (1975). World Agriculture, Commodity Policy, and Price variability. *American Journal of agricultural Economics.* Vol. 57, No. 5. pp. 823–828.

Jones, J.B. (1983). *A guide for Hydroponic and soil-less culture Grower*, Timber press, Beaverton, Ore, USA.

Kifle Dagne (1994b). *Cytology, Phylogeny and Oil quality of Guizotia* Cass. *(Compositae)*. Ph.D. Dissertation, Addis Ababa University, Ethiopia.

Koller, D. and Hadas, A. (1982). *Water relations in the germination of se Eds. In:* Encyclopedia of Plant Physiology, Vol. 12B. PP. 401 - 431 (Lange, O. L., Nobel, P. S., Osmond, C. B., and Ziegler, H. Eds), Berlin.

Konging, R.E. (1994). A critical Analysis of Artificial Fruit Ripening: Scientific, Legislative and Socio-Economic Aspects. *Plant physiology*. https://www. Researchgate. net > publication.

Krock, B., Schmidt, S., Hertweck, C. and Baldwin, I. T. (2002). Vegetation derived abscisic acid and four terpenes enforce dormancy in se Eds of the post-fire annual, *Nicotiana attenuata*. *Seed Sci. Res.* 12: 239-252.

Kulmi, GS and Soni, SN. (1995). Responses of Niger *(Guizotia abyssinica* L. f. Cass.) Cultivars to different fertility levels under rainfed conditions. *Crop Research* 10 (2): 141-144.

Lbourian, L.G and Agudo, M. (1987). The physiology of seed germination in *Salvia hispanica* L. *Anais da Academia Brasileira de Ciências*. 59: 37-56.

Legesse Negash (1995). *Indigenous Trees of Ethiopia: Biology, Uses and Propagation Techniques.* Printed by SLU Reprocentralen, Umea, Sweden. ISBN 91-7191-105-7. 285 pp.

Legesse Negash (2010). *A Selection of Ethiopian's Indigenous Trees: Biology, Uses and Propagation Techniques*. ISBN 978-99944-52-27-9.

Legesse Negash. (1993). Investigations on the germination behavior of wild olive se Eds and the nursery establishment of the germinates. *SINET: Ethiop. J. Sci.*, 16: 71–81.

Legesse Negash. (2002a). Review of research advances in some selected African trees with special reference to Ethiopia. Review article. *Ethiop. J. Biol. Sci*. 1: 81-126.

Lic C. P. and Chin C. (1980). The correlation and path analysis of agronomic character in triticale and wheat. *Journal of Agriculture Association*, China 111: 24–37.

Lin, Edo (2005). *Production and Processing of Small Seeds for Birds.* Agricultural and Food Engineering Technical Report 1. Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/docrep/008/y5831e/y5831e00.htm#Contents.

Liu, P. P., Koizuka, N., Homrichhausen, T. M., Hewitt, J. R., Martin, R. C. and Nonogaki, H. (2005). Large-scale screening of Arabidopsis enhancer-trap lines for seed germination-associated genes. *Plant J.*41: 936-944.

Mamatha, B.R., Shivaraj, B. and Gowda, A. (1994). *E*ffect of N, P, K and S on seed and oil yield on Niger. *Current Research,* 3(9*)*: 108-110.

Manandhar.N.P, N.P. (2002). *Plants and people of Nepal* Timber press Oregon ISBN 0–88192–527–6.

Manzano, P., Malo, J.E. and Peco, B. (2005). Sheep gut passage and survival of Meditrranean shrub seeds. *Seed Science Research* 15: 21–28.

Maxton, J.L. (1926). *A study of the effects of fertilizers on the germination of seeds when placed in contact for varying periods of time*. Virginia Polytechnic Institute.

McConnachie, A.J. (2015). *BioControl* 60: 715. https://doi.org/10.1007/s10526-015-9675-2

Michael, M. C. (2005). *Determining the Effects of Water temperature and exposure terms on Seed Germination*. California State Science Fair.

Microsoft Encarta (2009*)*. © 1993-2008 Microsoft Corporation.

MOA (2000). *Agro-ecological Zonations of Ethiopia*. Addis Ababa, Ethiopia.

Mohan, K. (2008). *Studies on maximizing seed yield and quality in niger (Guizotia abyssinica* Cass.*)*. Dharwad in seed Science and Technology College of Agriculture, Dharwad university of Agricultural Sciences, Dharwad.

Mohsenin, N.N. (1986). *Physical properties of plant and Animal materials*. Gordon and Breach Science publishers, New York, NY, USA.

Mondal S. S, Verma D. and Kulia S. (1992). Effect of organic and inorganic sources of nutrients on growth and seed yield of sesame (*Sesamum indicum L*). *Indian Journal of Agricultural Science* 62 (4): 258–262.

Murthy, H.N., Hiremath S.C. and Pyati, A.N. (1995). Genome classification in Guizotia (Asteraceae*)*. *Cytologia*. 60: 67-73.

Murthy, H.N., S.C. Hiremath and S.S. Salimath (1993). Origin, evolution and genome differentiation in *Guizotia abyssinica* and its wild species. *Theor. Appl. Genet*. 87:587-592.

Nambiar, KKM. And Abrol, LP. (1989). *Impact of integrated plant nutrients on yield and quality of seeds*. https://www. republication. Com

Nandini Devi K, Ghosh RK, Bhowmick MK and Sounda G. (2000). *Effect of different levels on NPK and S on growth, yield and oil content of Niger in Alfisols of West Bengal*. *In*: National Seminar on "Oilseed and Oils Research and Development Needs in the Millennium" Extended Summaries. pp. 184-185.

Nasirullah, K., T., Mallika, S. Rajalakshmi, K.S., Pashupathi, K.N., Ankaiah, S. Vibhakar, M.N., Krishnamurthy, K.V., Nagaraja and Kapur, O.P. (1982). Studies on Niger seed oil (*Guizotia abyssinica*). *J. Food Sci. and Technol*. 19: 147-149.

Neff, M. N., Sanderson, L., and Tedor, D. (2009). Light-mediated germination in lettuce Se Eds: Resurrection of a classic plant physiology lab exercise. *American Biology Teacher* 71(6): 367-370.

Nichiporovich, AA. (1970). Great achievements of biological science in raising the production of plants. *Soviet Journal of Ecology* 1: 1-5.

Paikaray, RK., Mishra, KN., Khanda, CM. and Garnayak, LM. (1997). Effect of nitrogen, phosphorous and plant density on yield and nutrient uptake in late sown niger (*Guizotia abyssinica* L. f. Cass.). *Indian Journal Agronomy* 40 (3): 520–523.

Patil CB (1979). Yield and yield attributes of niger as affected by different agro-techniques. *Indian J Agril Sci* 49(8): 633-636.

Patil, S.S. and Ballal, K.K. (1964). Effects of N, P and K on yield of niger. *Indian Oilseeds Journal*, (Telhan Patrika). 8 (4): 313–318.

Patil, S.S.; Dabke, D.J., Dongale, J.H. and Chavan, R.N. (2006). Effects of nitrogen and sulphur levels on yield, quality and nutrient uptake by niger (*Guizotia abyssinica* Cass.) in lateritic soils of Kokan. *J. Maharashtra agric. Univ*. 31(1*)*: 1-4.

Paul, S.K., Suhrawardy, J. and Gupta, B. (1993). Responses of Niger to NPK fertilization under rainfed condition in Assam. *Madras Agricultural Journal*, 80 (5): 289–290.

Prinz, K.D. (1976). *Unterschungen Zur Okophysiologie von Nigersaat (Guizotia abyssinica* Cass.*) athiopischer und indischer Herkunft. PhD thesis*. University of Gottingen, Germany.

Protabase- Plant Resources of Tropical Africa. http://www. Prota.org. Accessed 02/10/2017.

Rai (1986). *Plant-soil interactions at low pH*: RAMAN RAI Department of microbiology, N.D. University of Agriculture and Technology, N_2-fixing Azospirillum species.

Ramachandran, T.K. and Menon, P. (1979). Pollination mechanisms and inbreeding depression in niger (*Guizotia abyssinica* Cass.). *Madras Agric. J.* 66: 449-454.

Ramamurthy, V. and Shivashankar, K. (1996). Effects of organic matter and Phosphorus on growth and yield of soybean (*Glycine max*). *Indian Journal of Agronomy* 41 (1*)*:65–68.

Raven, P.H., Ray, Evert, F., Susan, E. and Eichhorn (2005). *Biology of Plants,* 7th Ed. New York: W.H. Freeman and Company Publishers. pp. 504–508 ISBN.

Razaq, M., Zhang, P., Shen, H-L, Salahuddin (2017). Influences of nitrogen and phosphorus on the growth and root morphology of Acernmono. *PLOS ONE* 12(2): e 0171321.

Riley, K.W. and Hiruy Belayneh (1989). *Niger. In:* oil Crops of the World: their breeding and their breeding and utilization. Robbenelen, G., Downey, R.K. and Ashari A. eds. McGraw-hill, New York. pp. 394-403.

Salim, S.N and Saxsena, M.C. (1993). Adoption of spring sowed chickpea to Mediterranean basin. II. Factors influencing drought. *Field crop Research* 34 (2): 137–146.

Seegeler, C.J.P. (1983). *Oil plants in Ethiopia: Their taxonomy and agricultural significance*. Centre for Agricultural Publication and Documentation, PUDOC, Wageningen. pp. 122-146.

Sem-Partners (2006). *Niger Aso-Fix. Coupez les rotations cerealieres a bas Couts*. Sem-Partners, la nouvelle dynamique des semences.

Sharma, R.S. And Kewat, M.L. (1994). Effect of sowing date and fertilizer on yield attributes and seed yield of niger (*Guizotia abyssinica* L. f. Cass.) under rainfed condition. *Indian Journal of Agronomy* 39 (1): 148 – 150.

Sharma, S.M. (1990A). *Niger seed in India: present status of cultivation, research achievements and strategies. In:* proceedings of the three meetings held at Pantnagar and Hyderabad India, 4–7 January 1989, pp. 159–165.

Sharma, S.M. (1993). *Status and strategies of sesame and niger research in India*. National seminar on Oilseed Research and Development in India, Hyderabad. pp. 60–69.

Sharma, S.M. and Sengar, RBS. (1989). Control of diseases of niger. *Indian Farming* 29: 13-14.

Sharma, S.M., Nageraj, G. and Balakrishnan, R. (1994). *Niger genetic resources: Evaluation and analysis*. Directorate of oilseeds Research (ICAR), Rajendrangar, Hyderabad.

Simmonds, N.W. (1976). *Evaluation of crop plants*. Longman Group Ltd., London.

Singh, P.P. and Verma, SNP. (1975). Yield potential of niger (*Guizotia abyssinica* Cass.). *Mysore J. agric. Sci.,* 9(4): 644-648.

Singh, P.P.; Singh, R.V.; Singh, S., Singh, M.P., Jain, A. and Kahandait, S.L. (1990). Effects of sowing date, fertility levels and plant densities on the growth and seed yield of winter niger (*Guizotia abyssinica* Cass.). *Indian J. Applied & Pure Biology*, 5(2): 89-92.

Smart, R.E. (1974). Photosynthesis by grapevine canopies. *Journal of Applied Ecology*, Vol. 11, no. 3. pp. 997–1006.

Sujatha, M. (1993). Pollen-pistil interactions and the control of self-incompatibility in niger *(Guizotia abyssinica* Cass). *J. Oilseeds Res. 10*: 334-336.

Sukhdev, S.M. and Kabal, S.G. (2013). *Potential of Management Practices and Amendments for Preventing Nutrient Deficiencies in field under organic cropping system*.

Taiz, L. and Zeiger, E. (2006). *Plant Physiology*. 4th Ed., Sinauer Associates, Inc., Sunderland.

Thakuria, K. and Gogoi, P.K. (1991). Nutrient requirement of niger (*Guizotia abyssinica* L. f. Cass.) under rainfed condition. *Indian Journal of Agronomy* 37 (3): 608–610.

Thomas, R. and Balakrishinan, M. (1999). Depletion of Biodiversity in Acacia auriculiformis Introduced Habitat. *Int. J. Ecol. Envir. Sci*. 25: 127-141.

Tosh, G.C. and Patro, G.K. (1975). Control of dodder (Cuscuta chinensis Damk) in niger (Guizotia abyssinica L. f. Cass.) with Chlorpropham. *Weed Research* 15: 207-209.

Tosh, G.C., G.K. Patro and A. Misra (1977). Effects of Pronamide and Chlorpropham on cuscuta in niger. *Weed Abstracts* 1978. Abstract No. 4024.

Tosh, G.C., Patro, G.K. and Misra, A. (1978). Control of cuscuta in niger seed. *Weed Abstracts* 1979. Abstract No. 1202.

Turner and Powell (1962). Chromosome numbers in Nigerian compositae. *Botanical Journal of Linnean Society*, Vol. 68. pp. 329–335.

Upadhyaya, P.C. and Parakdar, V.K. (1992). *Influence of sowing dates and fertility levels on performance of niger cultivar*. *In* Natl.Symp on "Response Management for Sustained crop production' held at Bikaner (Rajasthan), February 25–28, 1992 p. 38.

USDA FAS (2010). *Oilseeds: World Markets and Trade, Current world production, Market and Trade Reports*, http://www.fas.usda.gov/oilseeds/current.

Van Staden, J, Brown, N.A.C., Jager, A.K. and Johnson, T.A. (2000). Smoke as a germination cue. *Plant Species Biology* 15: 167-178.

Vaughan, J. G. (1970). *The structure and utilization of oil seeds*. Chapman and Hall, London, pp. 41-43.

Venkatakrishnan, A.S. and Ravichandran (1998). Effects of dry land technologies on yield of sesame (*Sesamum indicum*) under rainfed condition. *Indian Journal Agronomy* 43 (1): 154–157.

Washa, B. W. and Nyomora, AMS. (2012). The effect of moisture and seed treatment on the In-situ and ex-situ regeneration of *Dabergiamel anoxylon* (African Blackwood) in: Pugu Forest reserve. *HURIA Journal,* 10: 56-70.

Weiss, E.A. (1983). *Oil seed crops*. Tropical Agriculture Series. Longman. London.

Weiss, E.A. (2000). *Oil seed crops* 2nd ed. Blackwell Science, Oxford, UK. pp. 259-273.

Williams, L.E. (1987). Growth of Thompson seedless grapevines: I. Leaf area development and dry weight distribution. *Journal of American Society and Horticultural Science,* Vol. 112, no. 2. pp. 325–330.

Yitbarek Semeane and Tiruwork Amogne (1992). Field evaluation of fungicides on niger for the control of shot hole (Septoria sp.). *Oil Crops News* l. 9: 26-29.

Yonas Abiye (2015). *Ethiopian Major Staple Crops*. http://allafrica. Com/stories/2015.

Zemedie Asfaw and Abebe Getahun (2001). *Biology Student Textbook Grade 11*. Mega publishing Enterprise, Addis Ababa. 265 pp.

9. APPENDICES

Appendix 1: Germination percentage, Mean germination time and germination vigor of Guizotia abyssinica seedlings grown in Vertisol only, VR+CF and VR+Comp

A. Germination percentage

Days	Vertisol	VR+CF	VR+Comp
5	3.6	5.6	5.2
7	4.4	8	7.6
9	4	7.2	6.8
11	5.2	10	9.2
13	4	9.2	8
15	4.4	7.6	6
17	3.6	5.2	6
19	4	4.8	4.8
21	4	3.2	2.4
23	3.6	2.8	2.8
25	3.6	1.2	1.6
27	2.8	0.8	0.8
29	1.6	0.4	0.8
31	0.8	0	0.4
33	0.8	0	0.4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Vertisol	15	50.4	3.36	1.709714
VR+CF	15	66	4.4	12.11429
VR+Comp	15	62.8	4.186667	9.254095

ANOVA

Source of Vari	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between (	9.052444	2	4.526222	0.588379	0.559738	3.219942
Within Gr	323.0933	42	7.692698			
Total	332.1458	44				

B. Mean germination time

Days	Vertisol	VR+CF	VR+Comp
5	0.5	0.6	0.59
7	0.69	0.97	0.96
9	0.69	0.96	0.95
11	0.99	1.5	1.4
13	0.83	1.45	1.3
15	0.97	1.28	1.07
17	0.86	0.95	1.1
19	1	0.9	0.97
21	1.07	0.66	0.52
23	1	0.6	0.64
25	1.08	0.27	0.38
27	0.9	0.19	0.2
29	0.53	0.1	0.21
31	0.27	0	0.1
33	0.29	0	0.12

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Vertisol	15	11.67	0.778	0.07369
VR+CF	15	10.43	0.69533	0.2563
VR+Com	15	10.51	0.70067	0.19192

ANOVA

Source of Vari	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between (	0.06421	2	0.03211	0.18455	0.83215	3.21994
Within Gr	7.30671	42	0.17397			
Total	7.37092	44				

C. Germination vigor

Days	Vertisol	VR+CF	VR+Comp
5	0.2	0.31	0.28
7	0.22	0.4	0.38
9	0.18	0.33	0.31
11	0.21	0.42	0.38
13	0.15	0.35	0.3
15	0.16	0.27	0.21
17	0.12	0.17	0.2
19	0.13	0.15	0.15
21	0.12	0.09	0.07
23	0.1	0.07	0.08
25	0.09	0.03	0.04
27	0.07	0.02	0.02
29	0.04	0.009	0.01
31	0.02	0	0.009
33	0.01	0	0.008

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Vertisol	15	1.82	0.12133	0.0045
VR+CF	15	2.619	0.1746	0.02466
VR+Com	15	2.447	0.16313	0.01959

ANOVA

Source of Vari	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between (	0.02358	2	0.01179	0.72551	0.49004	3.21994
Within Gr	0.68253	42	0.01625			
Total	0.70611	44				

Appendix 2: Mean height (cm) of *Guizotia abyssinica* seedlings grown in Vertisol only, VR+CF and VR+Comp (93 DAG)

sample	Vertisol	VR+CF	VR+Comp
1	29.6	68	29
2	21.5	69.2	23.3
3	26.7	88.5	37.5
4	25.5	92	34
5	26.6	69	40
6	28.1	99.2	34.6
7	37.5	65	62
8	28	78	42.2
9	18	88.5	32.2
10	29.5	98.5	51
11	22.5	86	50
12	22	48.5	51.5
13	26.5	82	45
14	25	36	42.6
15	29.6	50	45
16	27.2	76	46.4
17	19	78.8	44
18	22	62.5	39
19	12	71	37.4
20	23.6	70	43

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Vertisol	20	500.4	25.02	28.56168
VR+CF	20	1476.7	73.835	274.8856
VR+Comp	20	829.7	41.485	76.87397

ANOVA

Source of Vari	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between (	24670.15	2	12335.08	97.29994	4.19E-19	3.158843
Within Gro	7226.103	57	126.7737			
Total	31896.26	59				

Appendix 3: Mean internodal length (cm) of *Guizotia abyssinica* seedlings grown in Vertisol only, VR+CF and VR+Comp (90 DAG)

Sample	Vertisol	VR+CF	VR+Comp
1	6.6	30.9	8.4
2	3.9	33.2	3.7
3	6.7	37.1	7.9
4	4.6	39.9	7.1
5	8.3	47.8	13
6	4.2	64.8	9.1
7	5.9	30.5	26.3
8	6	60.8	8.1
9	3.5	38.7	12.5
10	7.3	36.3	12
11	4.8	58	13.9
12	4.2	27	14.2
13	4.4	65.2	12.3
14	5.2	13.4	17.6
15	5.5	27.1	15.5
16	4	30.5	13.5
17	4.9	45.6	11.3
18	4.4	31.8	12.6
19	1.3	36.4	8.8
20	9.3	37.1	10.3

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Vertisol	20	105	5.25	3.227895
VR+CF	20	792.1	39.605	187.4068
VR+Comp	20	238.1	11.905	22.11734

ANOVA

Source of Vari	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between (	13278.97	2	6639.484	93.62284	9.76E-19	3.158843
Within Gro	4042.289	57	70.91735			
Total	17321.26	59				

Appendix 4: Mean number of branches per plant of *Guizotia abyssinica* seedlings grown in Vertisol only, VR+CF and VR+Comp at maturation

sample	Vertisol	VR+CF	VR+Comp
1	2	55	4
2	4	7	2
3	3	25	5
4	1	15	12
5	2	25	10
6	4	20	2
7	8	21	17
8	5	17	6
9	1	13	9
10	7	26	13
11	1	27	9
12	2	3	4
13	3	21	8
14	2	5	9
15	3	13	4
16	5	17	4
17	1	11	5
18	3	12	8
19	1	12	8
20	3	14	9

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Vertisol	20	61	3.05	3.944737
VR+CF	20	359	17.95	123.5237
VR+Comp	20	148	7.4	14.77895

ANOVA

Source of Vari	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between (	2348.233	2	1174.117	24.76215	1.82E-08	3.158843
Within Gro	2702.7	57	47.41579			
Total	5050.933	59				

Appendix 5: Mean leaf number of *Guizotia abyssinica* seedlings grown in Vertisol, VR+CF and VR+Comp (90 DAG)

Sample	Vertisol	VR+CF	VR+Comp
1	16	92	19
2	17	33	18
3	15	71	21
4	12	43	39
5	13	87	30
6	25	57	17
7	34	59	37
8	24	49	32
9	14	38	20
10	34	51	43
11	13	85	31
12	18	16	15
13	18	37	24
14	15	19	19
15	25	29	15
16	28	50	22
17	16	31	25
18	14	46	32
19	11	47	34
20	12	52	27

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Vertisol	20	374	18.7	50.85263
VR+CF	20	992	49.6	448.7789
VR+Comp	20	520	26	69.68421

ANOVA

Source of Vari	SS	df	MS	F	P-value	F crit
Between (	10433.73	2	5216.867	27.49019	4.38E-09	3.158843
Within Gro	10817	57	189.7719			
Total	21250.73	59				

Appendix 6: Mean leaf area (mm2) of *Guizotia abyssinica* seedlings grown in Vertisol only, VR+CF and VR+Comp (90 DAG)

Sample	Vertisol	VR+CF	VR+Comp
1	28.62	139.04	24.58
2	27.77	83.27	28.36
3	26	150.64	34.58
4	28.65	155.84	49.3
5	25.45	106.25	35.31
6	26.1	198.05	30.12
7	37.61	82.11	78.64
8	30.47	141.44	62.92
9	16.98	172.7	34.94
10	56.97	147.89	42.86
11	29.82	228.25	70.37
12	24.47	93.04	39.67
13	26.14	210.87	47.18
14	19.66	62.08	36.55
15	29	83.53	32.15
16	27.35	168.79	39.98
17	17.12	116.71	44.08
18	16.18	124.31	35.29
19	9.38	122.68	56.42
20	19.82	133.89	40.41

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Vertisol	20	523.56	26.178	93.13934
VR+CF	20	2721.38	136.069	2026.265
VR+Comp	20	863.71	43.1855	200.7417

ANOVA

Source of Vari	SS	df	MS	F	P-value	F crit
Between (	139950.9	2	69975.44	90.47979	2.05E-18	3.158843
Within Gro	44082.77	57	773.382			
Total	184033.7	59				

Appendix 7: Mean root collar diameter (cm) of *Guizotia abyssinica* seedlings grown in Vertisol only, VR+CF and VR+Comp (during harvesting)

Sample	Vertisol	VR+CF	VR+Comp
1	1.2	2.7	1
2	1	1.8	1.5
3	1	2.5	1.2
4	1.3	2	1.3
5	0.9	1.2	1.2
6	1.5	2	1.5
7	1.5	1.9	1.7
8	1.2	2.2	1.2
9	1.3	2.5	1.2
10	1.6	2.5	1.3
11	1.1	2.5	1.3
12	0.9	1.1	1.1
13	1.1	2.4	1.4
14	1	1.2	1.3
15	1.2	1.2	1.1
16	1.5	2.2	1.4
17	1.3	1.3	1.3
18	1.2	1.2	1.1
19	1.2	1.3	1.3
20	1.1	1.3	1.3

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Vertisol	20	24.1	1.205	0.041553
VR+CF	20	37	1.85	0.324737
VR+Comp	20	25.7	1.285	0.026605

ANOVA

Source of Vari	SS	df	MS	F	P-value	F crit
Between (	4.944333	2	2.472167	18.87656	5.12E-07	3.158843
Within Gro	7.465	57	0.130965			
Total	12.40933	59				

Appendix 8: Mean number of capitulae/plant of *Guizotia abyssinica* seedlings grown in Vertisol only, VR+CF and VR+Comp (at maturity)

sample	Vertisol	VR+CF	VR+Comp
1	3	56	5
2	5	8	3
3	4	26	6
4	2	16	13
5	3	26	11
6	5	21	3
7	9	22	18
8	6	18	7
9	2	14	10
10	8	27	14
11	2	28	10
12	3	4	5
13	4	22	9
14	3	6	10
15	4	14	5
16	6	18	5
17	2	12	6
18	4	13	9
19	2	13	9
20	4	15	10

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Vertisol	20	81	4.05	3.944737
VR+CF	20	379	18.95	123.5237
VR+Comp	20	168	8.4	14.77895

ANOVA

Source of Vari	SS	df	MS	F	P-value	F crit
Between (	2348.233	2	1174.117	24.76215	1.82E-08	3.158843
Within Gr	2702.7	57	47.41579			
Total	5050.933	59				

Appendix 9: Mean number of seeds/plant of *Guizotia abyssinica* seedlings grown in Vertisol only, VR+CF and VR+Comp (after harvesting)

Sample	Vertisol	VR+CF	VR+Comp
1	81	999	59
2	75	163	58
3	90	712	161
4	36	415	194
5	64	615	225
6	138	420	88
7	248	230	526
8	38	131	140
9	55	114	162
10	243	316	300
11	47	581	170
12	56	121	129
13	99	634	127
14	70	82	224
15	92	276	89
16	113	351	72
17	35	299	79
18	31	196	86
19	78	192	254
20	112	250	141

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Vertisol	20	1801	90.05	3666.155
VR+CF	20	7097	354.85	58439.29
VR+Comp	20	3284	164.2	11844.38

ANOVA

Source of Vari	SS	df	MS	F	P-value	F crit
Between (	746431.2	2	373215.6	15.14063	5.32E-06	3.158843
Within Gr	1405047	57	24649.94			
Total	2151478	59				

Appendix 10: Mean seeds weight/plant of *Guizotia abyssinica* seedlings grown in Vertisol only, VR+CF and VR+Comp (after harvesting)

Sample	Vertisol	VR+CF	VR+Comp
1	0.2	1.8	0.4
2	0.3	0.7	0.2
3	0.2	1.1	0.5
4	0.2	0.9	1
5	0.2	0.5	0.9
6	0.4	1	0.3
7	0.6	1	1.1
8	0.5	1	0.5
9	0.1	1.1	0.8
10	0.5	1.1	0.4
11	0.3	1.2	0.8
12	0.2	0.5	0.3
13	0.3	1	0.3
14	0.2	0.4	0.4
15	0.4	0.9	0.6
16	0.3	1.2	0.3
17	0.1	1.1	0.2
18	0.4	0.3	0.5
19	0.2	0.4	0.3
20	0.5	0.7	0.4

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Vertisol	20	6.1	0.305	0.0205
VR+CF	20	17.9	0.895	0.128921
VR+Comp	20	10.2	0.51	0.072526

ANOVA

Source of Vari	SS	df	MS	F	P-value	F crit
Between (	3.589	2	1.7945	24.25575	2.39E-08	3.158843
Within Gr	4.217	57	0.073982			
Total	7.806	59				

Appendix 11: Mean total dry weight (gm) of *Guizotia abyssinica* seedlings grown in Vertisol only, VR+CF and VR+Comp

Sample	Vertisol	VR+CF	VR+Comp
1	1.6	15	1.2
2	1.5	4.9	0.7
3	1	8.3	1.1
4	0.3	6.1	2.8
5	0.7	3.8	2.7
6	1.4	7.3	1
7	2.2	5.1	4.1
8	1.9	4.1	1.3
9	0.3	5.2	2.6
10	2.1	8.6	3.3
11	0.4	7.4	2.6
12	0.7	2.7	1.2
13	1.1	6.2	1.7
14	0.9	1.5	2.2
15	1.5	3	1.3
16	1.6	6.6	1.1
17	0.3	4.3	1.1
18	1.4	2.5	1.8
19	0.6	3.6	2
20	1.5	3.8	2.2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Vertisol	20	23	1.15	0.367895
VR+CF	20	110	5.5	8.9
VR+Comp	20	38	1.9	0.807368

ANOVA

Source of Vari	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between (	216.3	2	108.15	32.20263	4.38E-10	3.158843
Within Gro	191.43	57	3.358421			
Total	407.73	59				

Appendix 12: Fifteen days old *G. abyssinica* Seedlings grown in equal sized plastic bags under nursery bed conditions where the daily minima and maxima temperatures during the study period were 22.3 ± 24.1 ^{0}C noon and 16.7 ± 20.2 ^{0}C nights respectively.

C

B

A

Appendix 13: Thirty seven days old *G. abyssinica* seedlings grown in vertisol only (A), VR + CF (B) and VR + Comp (C) under nursery bed conditions in Bichena town in 2018.

C

A

B

Appendix 14: Ninety days old *G. abyssinica* seedlings grown in vertisol only (A), VR + CF (B) and VR + Comp (C) under nursery bed conditions at Bichena town in 2018.

A B C

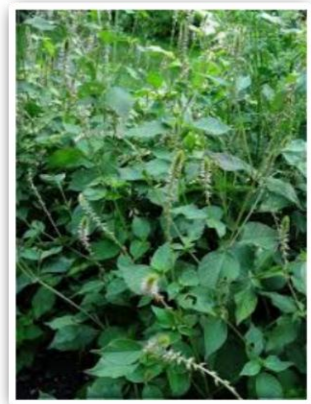
Appendix 15: Roots of *G. abyssinica* seedlings grown in vertisol only (A), VR + CF (B) and VR + Comp (C) under nursery bed conditions after harvesting the seeds.



ሰንሰል/ስሚዛ/*Juusticia schimperiana* ግራዋ/*Vernonia amygdalina* የቁራ ሐረግ/*Cucumis dipsaceus*



አስተናግር/*Datura stramonium* ሳስባንያ/*Sesbania sesban* የፈረንጅ ፅድ/*Cupressus lusitanica*

ሰርዶ/*Cynodon dacctylon* ሙጃ/*Snowdenia polystachya* ጠለንጅ/*Achyranthes aspera*

የአህያ እሾህ/*Silybum marianum* ጫቅማ/ጉሎ/*Ricinus communi* ልት/*Malva parviflora*

ብሳና/*Corton macrostachyu*

Appendix 16: List of plant samples photo used for compost manufacture. The plant samples were collected from Bichena Debre kebele, Enemay Wereda, East Gojjam Zone, Amhara National Regional State.

DECLARATION

I, the undersigned, declare that this Thesis is my original work, has not been presented for a degree in any other University and that all sources of materials used for the Thesis has been fully acknowledged.

Name Addisu Edemealem

Signature______________

Date _________________

This Thesis has been submitted for examination with my approval as a university advisor.

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Legesse Negash (Prof.)

Addis Ababa, Ethiopia

September, 2018