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Effects of *Albizia gummifera, Millettia ferruginea* and *Cordia africana* Leaf Litter on the Germination of *Coffea arabica* L. Seed

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ABSTRACT
In most *Coffea arabica* growing areas of Ethiopia, *A. gummifera, C. africana* and *M. ferruginea* are among the commonly used shade trees. The role of these species on germination of *C. arabica* seed has been little studied. This study assessed the impacts of these tree species' leaf litter on *C. arabica* seed germination. The leaf litter was collected from mature standing and naturally growing plants, air dried and ground. Seed from *C. arabica* plant was collected and prepared. The ground leaf litter of each species was uniformly mixed with nursery bed soil in proportion of 50, 100 and 200 g m^{-2}. Complete random block design with three replications were applied. Hundred undamaged seeds were randomly chosen and sown in uniform spacing within each plot (1 m^{-2}). Rate of seed germination was recorded after 60, 90 and 120 days from the sowing date. Variations were analyzed using LSD method for one way ANOVA at alpha 0.05. The result showed that after 60 days of sowing, a significantly higher germination was observed in Ag2, Ag3, Ca1, Mf2 and Mf3 compared to the control. After 90 and 120 days of sowing, no significant variation was observed between control and treatments. From the results, it was concluded that leaf litter of the studied tree species stimulate germination of *C. arabica* seed in field condition, however, the level is not linearly related with germination rate. In situations where early, uniform and high germination rates are required, leaf litter of these species, preferably: Ag1, Ag3, Ca1, Mf2 and Mf3, can be used.

Key words: Agroforestry, *Coffea arabica*, germination, leaf litter, shade tree, seed

INTRODUCTION
Growing coffee in Agroforestry systems is common practice in the Central and South America and Africa (Nair, 1993; Soto-Pinto *et al.*, 2000). Ethiopia, in the horn of Africa, is well known for being origin of arabica coffee (Kitila *et al.*, 2011).*Coffea arabica* L. is among economically important crops grown in Ethiopia even though it has some production related constraints like coffee berry disease (Abera *et al.*, 2011). In Ethiopia, coffee production system has been classified in to forest coffee, semi-forest coffee, garden coffee and plantation coffee mainly based on management practice. Botanically, Coffee is a member of the Rubiaceae family and the genus *Coffea*. Among many species of Coffee (more than 70), only two are economically important: *Coffea arabica* L. and *Coffea canephora* (Eira *et al.*, 2006).

Despite some disadvantages, tees and/or shrubs in agroforestry system are well studied and understood for their effect on improving soil organic matter and nutrients and their cycling (Young, 1989). Even though recommendation of shade tree utilization is controversial

(Campanha *et al.*, 2004), in some situations, shade trees favor the coffee crop, increasing its productivity (Soto-Pinto *et al.*, 2000). Bedimo *et al.* (2008) reported that shade plants grown with coffee trees could considerably reduce losses of coffee product due to coffee berry disease by acting as a physical barrier to efficient pathogen dispersal.

Recent research suggests that allelopathy can be used for controlling and management of weeds (Sharangi, 2011; Travlos *et al.*, 2007). Wakjira *et al.* (2011) based on the laboratory scale experiment reported that leaf aqueous extract of *Albizia gummifera* (among others) inhibited germination and seedling growth of *Parthenium*, aggressive noxious weed.

Allelopathy is one of the predominant force that influence plant community and their spatial distribution (Travlos *et al.*, 2007). Allelopathy (inhibitory effect) has the direct or indirect detrimental effect of one plant on the germination, growth, or development of another plant through the production of chemicals that escape into the environment (Sasikumar *et al.*, 2001). Because of the adverse effects of trees on crops, many farmers are unenthusiastic to grow trees in their agricultural fields. Hence, planting of tree crops on agricultural land has not yet flourished as expected (Kumar *et al.*, 2006). The level of inhibitory chemicals and its effect may vary with species. Thus, assessing the effect of indigenous tree species on the germination of commonly used middle story agroforestry species (coffee) can give insight for judging more appropriate agroforestry species for the system.

Among tree components, leaves are the most important potential source of allelochemicals, but the toxic metabolites are also distributed in various concentrations in all other plant parts including flower, fruit, seed, stem, roots or barks (Kumar *et al.*, 2006; Bhatt and Todaria, 1990). It has been reported that allelopathy can influence plant ecology including its occurrence, dominance, diversity and productivity (Ferguson and Rathinasabapathi, 2009). Moreover, Yamane *et al.* (1992) reported that basic plant processes including respiration, photosynthesis and plant water relations can be affected by allelopathy.

Leaf litter effect on germination of various agricultural crops has been repeatedly carried out by many scholars. Few such experiments have been carried out for coffee. Instead other form of germination test such as effect of pre-sowing treatment with removing parchment and soaking in water (Gebreselassie *et al.*, 2010) soil compaction (Masaka and Khumbula, 2007) and partial shading at nursery (Kufa and Burkhardt, 2011) has been investigated.

Currently, Wondo Genet College of Forestry and Natural Resource has begun expanding its under-shade grown coffee plantation by converting the monocrops agricultural systems into coffee. Additionally, there is an already existing 8 hectares of coffee plantation which is managed under the natural forest of dominantly *Albizia gummifera* C.A. Smith, *Cordia africana* Lam. and *Millettia ferruginea* Hoechst. Bak tree species.

Limited coffee overstory studies have been conducted at Wondo Genet even though coffee agroforestry farming is in need of research-based technical assistance. This reveals the significance of conducting research on the inhibitory or stimulating impacts of Wondo Genet's major trees on *C. arabica* seed. More specifically, it is highly important to examine the chemical effects of agroforestry trees on the germination of the accompanying crops. This study therefore, assessed the impacts of the leaf litter of the three most widely grown agroforestry tree species in Ethiopia and at Wondo Genet College of Forestry and Natural Resources, namely: *Albizia gummifera, Cordia africana* and *Millettia ferruginea*, on seed germination.

MATERIALS AND METHODS

This experiment was conducted in the Wondo Genet College of Forestry and Natural Resource nursery, which is located 13 km South West of Shashemene, Ethiopia. Wondo Genet is

Fig. 1: The experiment site

geographically located with in 7°6'N latitude and 38°7'E longitudes (Fig. 1). The Wondo Genet catchment lies within altitudinal range 1600-2580 m.a.s.l. (Belaynesh, 2002). The experimental site is located at 1820 m above sea level and experiences a bimodal rainfall distribution with 1244 mm total precipitation annually. The short rainy season occurs from March to May and the long rainy season lasts for five months from June to October (Teshale, 2003). The mean monthly temperature is 19.5°C, with mean monthly maximum temperature of 26.3°C and mean monthly minimum temperature of 12.4°C. Clay-loam and loamy are the dominant soil types with soil variability along altitude, topography and vegetation type. Soil depth varies from four meters to a shallow depth on steep slopes (Eriksson and Stern, 1987). *Celtis africana, Cordia africana, Croton macrostachyus, Albizia gummifera, Podocarpus gracilior, Millettia* and *Phoenix* sp. are found to be the area's principal tree species (Eriksson and Stern, 1987).

Treatment: *Albizia gummifera*, *Cordia africana* and *Millettia ferruginea* were considered as the donor plants and *Coffea arabica* the receptor plant. The donor plants' leaf litter was collected from mature and naturally growing plants within the college compound. The leaves were air dried and ground in the Wondo Genet College of Forestry and Natural Resources laboratory. The entire process of collection and preparation was conducted between January and March 2011. Seed of *Coffea arabica* was collected and prepared between December 2010 and January 2011.

The nursery bed which had an east to west orientation was thoroughly prepared, watered and weeded for one month before sowing. The bed was leveled and all weeds and other debris were removed. Finally, the ground leaf litter was uniformly mixed with soil (adapted from Ahmed *et al.*, 2008) in the following proportions representing the treatments of:

C: Seeds of *Coffea arabica* sown in bed with soil only (Control)
Ag1: Seeds of *Coffea arabica* sown in bed mixed with litter of *Albizia gummifera* 50 g m^{-2}

Ag2: Seeds of *Coffea arabica* sown in bed mixed with litter of *Albizia gummifera* 100 g m^{-2}
Ag3: Seeds of *Coffea arabica* sown in bed mixed with litter of *Albizia gummifera* 200 g m^{-2}
Ca1: Seeds of *Coffea arabica* sown in bed mixed with litter of *Cordia africana* 50 g m^{-2}
Ca2: Seeds of *Coffea arabica* sown in bed mixed with litter of *Cordia africana* 100 g m^{-2}
Ca3: Seeds of *Coffea arabica* sown in bed mixed with litter of *Cordia africana* 200 g m^{-2}
Mf1: Seeds of *Coffea arabica* sown in bed mixed with litter of *Millettia ferruginea* 50 g m^{-2}
Mf2: Seeds of *Coffea arabica* sown in bed mixed with litter of *Millettia ferruginea* 100 g m^{-2}
Mf3: Seeds of *Coffea arabica* sown in bed mixed with litter of *Millettia ferruginea* 200 g m^{-2}

Complete Random Block Design (CRBD) was used. Three seed beds (each as a block) were used representing three replications. Each treatment was randomly assigned in a bed which was sectioned to 1 m^{-2} areas (plot) for treatments with a 0.5 m wide path between each treatment. The path between blocks was 1 m wide and blocks were arranged in a down-slope direction.

Seeds of *Coffea arabica* were sown the same day the leaf litter was mixed with the nursery bed soil, which occurred in May 2011. One hundred undamaged seeds were randomly chosen from the collected seeds and sown using uniform spacing within each plot (1 m^{-2} areas). The plot was mulched with dried grass (common nursery mulch) in sufficient thickness. The treatments were watered and weeded periodically.

Germination of the seed was observed and regularly recorded apparently up to last germination. Germination in this case is the emergence of plumule to soil surface. The seedlings were allowed to grow and the observation was continued for two months from the date of first count.

Statistical analysis: The effect of various level of leaf litter of the three agroforestry species on germination percent of *C. arabica* seed was compared with the control using LSD method for one-way analysis of variance (ANOVA) at alpha 0.05 in SPSS 12.0 for window software. Similarly, variation among treatments was compared.

RESULTS

In observations conducted after 60 days from sowing, significant variation between the control plot and those applied with leaf litter occurred. In this phase, none of the treatments has less germination than the control. In addition, germination percent under treatment Ag3 significantly varied from Ca2 and Ca3 (Table 1).

The record taken in the first round (Table 1) showed that the lowest germination rate of *C. arabica* seed was observed in control for which only 40.3% of sown seed germinated followed by Ca2. In this phase, highest germination was observed for *C. arabica* seed bed treated with Ag3 in which germination was greater by 31% compared to control. In general, the result showed treating *C. arabica* seed bed with leaf litters of those agroforestry species enhances germination in this phase.

The results observed 90 days from sowing, 30 days after previous observation, showed change in percentage of *C. arabica* seeds germinated. The variation between control and treatments with various level of leaf litter of three agroforestry species was insignificant. As observed earlier, variation between Ag3 and Ca2 was significant. Significant variation was observed between Ca1

Table 1: Germination of *Coffea arabica* seed treated with leaf litter of *Albizia gummifera, Cordia africana* and *Millettia ferruginea* and control 60 days from sowing date

Treatment	Mean germination (%)	SD	SE	Variation in germination
C	40.3	10.0	5.8	40.3
Ag1	61.0	12.2	7.0	20.6*
Ag2	58.7	10.4	6.0	18.3
Ag3	71.3	5.1	3.0	31.0*[a]
Ca1	64.3	12.3	7.1	24.0*
Ca2	51.0	11.5	6.7	10.7[a]
Ca3	51.3	17.6	10.2	11.0[a]
Mf1	57.7	8.1	4.7	17.3
Mf2	69.7	4.0	2.3	29.3*
Mf3	67.3	15.0	8.7	27.0*

*Significantly different from control at α 0.05 level, [a]Ag3 is significantly different from Ca2 and Ca3 at α 0.05 level according to LSD for one way ANOVA

Table 2: Germination of *Coffea arabica* seed treated with leaf litter of *Albizia gummifera, Cordia africana* and *Millettia ferruginea* and control 90 days from sowing date

Treatment	Mean germination (%)	SD	SE	Variation in germination
C	77.0	1.7	1.0	77.0
Ag1	82.3	2.5	1.5	5.3
Ag2	80.7	1.5	0.9	3.7
Ag3	84.0	3.6	2.1	7.0[a]
Ca1	85.0	3.5	2.0	8.0[b]
Ca2	71.3	14.6	8.4	-5.7[abc]
Ca3	73.7	7.5	4.3	-3.3
Mf1	76.0	6.0	3.5	-1.0
Mf2	83.7	11.7	6.7	6.7[c]
Mf3	80.0	5.6	3.2	3.0

No significant difference was observed on comparison with LSD method at α 0.05 level compared to control, -: Less, +: More germination percent as compared to control

and Ca2. In this stage, figuratively highest germination rate of *C. arabica* seed was observed on the treatment Ca1 which was by 8% greater than germination rate in control. The lowest germination rate was observed in Ca2 which was by 5.7% less than control (Table 2).

Results show treatments have significant difference in LSD at α 0.05.

After an additional month (120 days from sowing) observation was once again carried out for comparing germination rates. Table 3 summarizes the results in which no significant variation was observed between control and the various levels of incorporated leaf litter from the three agroforestry species under consideration. In addition there was no significant difference among the treatments on germination percent of *Coffea arabica* seed treated with leaf litter of those tree species in specified levels. Even though it was not significant, highest germination was recorded for Ca1 in which germination of *C. arabica* seed was by 8.7% greater than germination of it in control. The lowest germination was observed in Ca3 for which germination was by 2% less than the rate in control.

When whole the germination progress of treatments and control observed in the course of time it initially varied and gradually the variations among treatment reduced (Fig. 2).

Table 3: Germination of *Coffea arabica* seed treated with leaf litter of *Albizia gummifera, Cordia africana* and *Millettia ferruginea* and control in 120 days from sowing date

Treatment	Mean germination (%)	SD	SE	Difference
C	79.0	2.6	1.5	79.0
Ag1	84.7	4.6	2.7	5.7
Ag2	82.3	1.2	0.7	3.3
Ag3	85.0	5.3	3.1	6.0
Ca1	87.7	1.5	0.9	8.7
Ca2	77.3	18.3	10.5	-1.7
Ca3	77.0	7.0	4.0	-2.0
Mf1	80.3	5.5	3.2	1.3
Mf2	85.0	9.5	5.5	6.0
Mf3	80.0	5.6	3.2	1.0

-: Less, +: More germination percent as compared to control

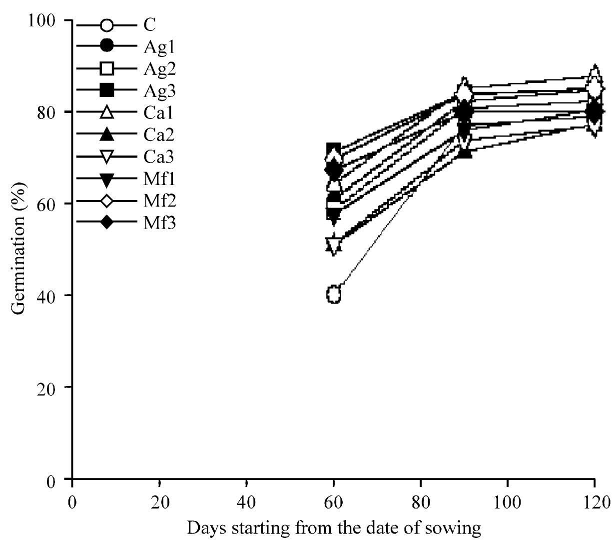

Fig. 2: Germination rate of *Coffea arabica* seeds having seed bed treated with leaf litter of *A. gummifera*, *C. africana* and *M. ferruginea* and control

DISCUSSION

Even though germination of coffee seed takes a fairly long time (50-60 days) due to its inherent physiological processes including presence of endosperm (Eira *et al*., 2006), seed germination ecology (climate and weather condition, soil environment, water potentials, etc.) in the field may slow down or speed up its germination. This study showed that the rate of germination of seeds sown on the nursery beds mixed with leaf litter of three commonly used shade tree: *A. gummifera*, *C. africana* and *M. ferruginea*, was higher than the control plot, in the observations taken 60 days from seed sowing. Even though the observed variation was not linear with the amount of leaf litter applied, it was significantly higher for some concentrations: Ag1, Ag3, Ca1, Mf2 and Mf3.

The variation in rate of *C. arabica* seed germination can be explained by the fact that the constituents in those tree species enhanced the processes. The explanations by Brady and Weil (2002), which disagree with Da Silva *et al*. (2005) in which exogenous gibberellins imbibed to experimental seed, states that gibberellins in organic matter stimulate seed germination.

The observed significant variation between Ag3 compared with Ca2 and Ca3 is probably attributed to variation in life form and constituents in leaf litter. Investigation by Teklay *et al.* (2007) confirmed that in both laboratory and field experiments, the rates of C mineralization were higher for *M. ferruginea* followed by *A. gummifera* and lowest for *C. africana* leaves. Investigation by Yisehak and Belay (2011) indicated that because of its digestibility and nutrient constituent, *A. gummifera* is used for livestock feed sources. Those nutrients when incorporated to the soil may promote soil characteristics and seed germination. Accordingly, microbial activity, nutrient release and effect of leaf litter constituent are expected to vary and might have partially affected the observed variation in germination rate.

Germination rates in results observed after 90 days (Table 2) differ compared to the 60 day observation. In this phase of observation, rate of germination in the control compared with treatments under various levels of leaf litter for the three agroforestry species was not significant. During the 30 days interval germination in the control and the various treatments increased progressively. The highest increase was observed in the control and the lowest in Mf3. The results showed seeds that have not been activated by addition of leaf litter, the seeds in the control plot, take more days to complete the germination processes. This longer germination period may increase the chance of those seeds being subjected to fungal and insect damage.

Like the significant variation in 60 days from seed sowing in Ag3 compared to Ca2, in observation of 90 days, Ag3 significantly varied from Ca2. This can probably be explained by variation in species constituent and its influence in stimulating germination. Unlike the significant variation in the 60 day observations in Ag3 compared to Ca3, in the 90 day observations Ag3 insignificantly varied from Ca3.

Cordia africana was the only species for which variation for *C. arabica* seed germination treated with the same species, under varying levels (Ca1 versus Ca2; Table 2) of leaf litter, created a significant variation of germination rate. The experiment results show, among the leaf litter levels from *Cordia africana*, Ca1 might be the optimum level for this particular species to stimulate *C. arabica* seed germination. In the 90 day observations, Ca2 significantly varied from Mf2. This can be explained by the variation in constituent of the leaf litter between the two species.

At 120 days from date of sowing, except for Mf3, all treatments and the control had more seeds germinated compared to the 90 day count. No significant variation was observed between control and treatment and also among treatments. As the whole germination progress observed (Fig. 2) in the course of time, the variation observed in earlier period of germination was progressively reduced. These show that non-stimulated (control) and also less stimulated (incorporating some level of leaf litter of the three species) seeds of *Coffea arabica* can germinate progressively over time. The observation reveals leaf litter of those tree species, even though not uniform in various treatment, enhance early germination of *C. arabica* seed. On other hand, Gebreselassie *et al.* (2010) reported that removing parchment and soaking in water also enhance emergence of coffee seed.

CONCLUSION AND RECOMMENDATION

Uniformity of germination in most of *C. arabica* seed beds treated with shade tree leaf litter is comparatively high at the 60 days observation. From the result of present study, it can be concluded that leaf litter of the three agroforestry tree species: *Albizia gummifera, Cordia africana* and *Millettia ferruginea,* speed up germination of *Coffea arabica* seed in field condition. However, the relation between the level of leaf litter and germination uniformity and speed was not linear.

To a certain extent these measurements vary from one species to the other. Germination of coffee seed in nursery beds treated with leaf litter of *Cordia africana* varied significantly (in some of its level) compared to that of *Albizia gummifera* and *Millettia ferruginea*.

According to investigation findings, when speed and uniformity in germination is important, treating seed beds with leaf litter from these three cover species can speed up germination and has correspondingly more essence. This is reveled in the 60 day which showed significant difference between treatments and control. Variation among treatments becomes insignificant over time indicating that treatments speed up germination but do not change the total germination percentage.

In situation where uniform and earlier germination of *Coffea arabica* seed is required, leaf litter of *Albizia gummifera, Cordia africana* and *Millettia ferruginea* preferably Ag1, Ag3, Ca1, Mf2 and Mf3 can be used. Result of our investigation showed that leaf litter of those agroforestry species can be used for enhancing coffee seed germination. However, the economics of collecting, processing and applying the leaf litter; the exact constituents of leaf litter that favor germination of *Coffea arabica* seed in nursery condition; and preferable levels of leaf litter should be further investigated. Replicating such experiment in controlled and field environments is recommended.

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