Agronomic practices with a special focus on transplanting methods for optimum growth and yield of enset [*Ensete ventricosum* (Welw.) Cheesman] in Ethiopia

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Summary

Introduction – **Transplanting enset suckers or plants is practiced by the majority of small-scale farmers across the enset-growing belt in Ethiopia. Enset suckers, obtained from a multiplication nursery, are first intensely managed in a small plot (one plant 0.5–1.0 m^{-2}) from where plants are consecutively transplanted into ever more widely spaced arrangements with a final minimal spacing of one plant 2–4 m^{-2}. This review summarizes relevant information on transplanting methods from randomized controlled field trials and on-farm observations.** *Results and discussion* – **Transplanting frequency impacts the crop cycle duration and yield. Transplanting once results in plants with a higher growth rate and hence a shorter crop cycle, while more frequent transplanting results in higher yields per plant. For example, plants transplanted once were harvested at 2 years and yielded 27 kg dry matter (DM) $plant^{-1}$, while plants transplanted two or three times were both harvested at 4.5 years and yielded, respectively, 44 and 31 kg DM $plant^{-1}$.** *Conclusion* – **This review endeavours to help determine the enset transplanting methods that give optimum growth, biomass production and yield.**

Keywords
enset, Ethiopia, *kocho*, small-scale farming, transplanting frequency, vegetative propagation

Résumé

Pratiques agronomiques en relation avec les méthodes de repiquage pour une croissance et un rendement optimum de l'ensète [*Ensete ventricosum* (Welw.) Cheesman] en Ethiopie.

Introduction – **La transplantation de rejets ou de plants d'ensète est pratiquée par la majorité des petits agriculteurs de l'ensemble de la zone de culture de l'ensète en Ethiopie. Les rejets d'ensète obtenus à partir d'une pépinière de multiplication sont d'abord cultivés densément sur une petite parcelle (une plante par 0,5 à 1,0 m^2) à partir de laquelle les plantes sont successivement transplantées dans des arrangements de plus en plus espacés avec une densité minimale finale d'une plante 2–4 m^{-2}. Cette revue résume les informations pertinentes sur les méthodes de transplantation tirées d'essais contrôlés randomisés et d'observations à la ferme.** *Résultats et discussion* – **La fréquence de repiquage a une incidence sur la durée du cycle de production et le rendement. Une fois repiquées, les plantes ont un taux de croissance plus élevé et, par conséquent, un cycle de culture plus court, tandis que des transplantations plus fréquentes entraînent des rendements plus élevés par plante. Par exemple, les plantes transplantées une fois ont pu être récoltées à 2 ans et produire 27 kg de matière sèche (MS) par plante, tandis que les plantes transplantées deux ou trois fois ont été récoltées à 4,5 ans et ont donné respectivement 44 et 31 kg MS par plante.** *Conclusion* – **Cette revue contribue à déterminer les méthodes de transplantation de l'ensète offrant une croissance, une production de biomasse et un rendement optimum.**

Mots-clés
ensète, Ethiopie, fréquence de repiquage, *kocho*, multiplication végétative, petite agriculture

Significance of this study

What is already known on this subject?
- Transplanting enset suckers or plants is practiced by the majority of small-scale farmers across the enset-growing belt in Ethiopia.

What are the new findings?
- The review paper endeavours to help in determining the enset transplanting methods that give optimum growth, biomass production and yield.

What is the expected impact on horticulture?
- Improved farm land-use arrangements for optimal annual enset yields.

Introduction

Enset [*Ensete ventricosum* (Welw.) Cheesman] is closely related to banana, belonging to the order *Zingiberales* and the family *Musaceae*. Domesticated in Ethiopia, it is an important component of cropping systems, contributing to food security and livelihoods for more than 20 million people in

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south and southwestern Ethiopia (Azerefegne *et al.*, 2009). Enset has many food and non-food uses. The pseudostem comprising of leaf sheaths, the real stem and the corm are scraped and grated to harvest starch, which is subsequently fermented into *kocho*. *Kocho* can be kept in large fermentation pits, hence providing a long-term food storage option. The corms of young enset plants can also be cut into pieces and boiled, which is known as *amicho*. The ideal moment for harvesting is at flowering. At that time, dry matter yield is highest and best for *kocho* production, because after flowering assimilates will be redirected towards the inflorescence and away from the pseudostem and corm (Tsegaye and Struik, 2000). Enset is also used as fodder for livestock. In addition, certain plant parts from some clones are used for medicinal purposes. High-quality fibre from enset can be woven into ropes, mats, bags and can be used for roof construction.

The *kocho* yield from enset/unit growing space and over time (in terms of weight and energy) is higher than any other crop grown in Ethiopia, making it one of the most important food crops (Tsegaye, 2002). Enset-based agriculture is considered the most sustainable of the indigenous farming systems in the country and is able to support dense populations in the highlands of south and southwestern Ethiopia. Nevertheless, with increasing population numbers and shrinking farm sizes, traditional farming practices are under pressure to maintain the same levels of productivity (Tsegaye and Struik, 2002). Only a limited amount of data supporting best practice management for optimum yield of enset is found in the literature. Most publications focus on surveys of enset-farming regions to determine farmer practices, varietal diversity and sometimes yield of enset. The three main sites and dates where agronomic trials have been carried out are (1) the Debre Zeit agricultural research centre of the Alemaya College (now University) of Agriculture in the 1970s, (2) the Woladu Agricultural Development Unit at Soddo under the supervision of Teketel Makiso from the mid-1970s until 1982, and (3) the Institute of Agricultural Research at Areka in Boloso Sorie Awraja since 1989 (Alemu and Sandford, 1991).

Numerous factors impact on enset yield, including variability in transplanting frequency, plant spacing, time of harvest (which can be anywhere between 3–16 years; Seifu (1984; cited in Aggrey and Tuku, 1987), rainfall, altitude, consumption patterns across seasons and years depending on a family's food needs and variation in individual plant yield because of differences between enset cultivars, husbandry methods and cultural practices (Shank and Eritiro, 1996). This review aims to summarize relevant information, where possible from randomized controlled field trials, that support best practice enset transplanting methods for optimum growth, biomass production and yield.

Enset propagation

Enset is a more robust, taller and wider plant than its relative the banana. The fruit is not edible and the leaves are larger and semi-erect. Similar to banana, the true botanical stem (corm) is underground. The apical meristem is located on the apex of the corm, forming the leaves and eventually producing the true stem and the inflorescence/bunch. When a banana or enset plant flowers, the flower stalk pushes up through the pseudostem to emerge at the whorl in the middle of the leaf bases. Unlike banana plants, field-grown enset plants seldom produce suckers unless stimulated to do so. This is because the dominance of the apical meristem prevents the development of lateral buds.

Although enset can propagate by seed, farmers' planting material is vegetatively propagated in field nurseries through corms or corm pieces which originate from field-grown mother plants. When a plant is 2 to 4 years old with a 10–35 cm corm diameter, the farmer will cut down the pseudostem at 10–30 cm above the ground. The corm is then uprooted and the apical meristem is destroyed, after which the corm may be exposed to sunlight for a few days in order to heal/dry the cut corm surfaces. A mixture of soil and compost is sometimes placed onto the space where the apical bud was removed, although experimental data show no benefit on the number or vigour of suckers produced using this practice (Diro *et al.*, 1996). Farmers may use the whole intact corm or a split corm/corm pieces to produce suckers. Thereafter, the corm or corm piece is buried again in the soil to which decomposed manure is often added. After at least 4 weeks and up to 3 months, suckers will emerge (Bezuneh and Feleke, 1966; Negash, 2001; Brandt *et al.*, 1997). Suckers from split corms show a lower rate of failure to emerge and emerge earlier, which is associated with more vigorous growth (Diro *et al.*, 1996; Karlsson *et al.*, 2014).

Makiso (1996) describes a method to increase propagation rates further by vertically cutting the corm with its leaf bases intact into small pieces and then planting the pieces in moist soil in plastic tubes or bags and raising them in a growth chamber at 20 °C. This is believed to result in more rapid propagation to facilitate production of disease-free and vigorous planting material (Makiso, 1996). Whether an increased propagation rate is desirable to small farmers is uncertain. Tsegaye and Struik (2002) report from a rapid rural appraisal that the Wolaita people claimed that splitting the corm into four equal parts, for example, would produce "too many" suckers.

After about 1 year, the plant is dug out and the shoots are separated from the mother corm. Propagation rates range between 6–200 suckers per mother corm depending on the enset cultivar, the type of soil and climate (Bezuneh and Feleke, 1966; Hiebsch, 1996; Negash, 2001). Seventy percent of enset clones produce more than 40 suckers/corm (Diro *et al.*, 1996) (Figure 1).

Transplanting

Given the amount of hard labour involved in the production of enset suckers, farmers are careful to maximize success. Enset plants are first intensely managed in a small nursery plot, most often located adjacent to the house, where they are grown at a density of one plant 0.5–1.0 m^{-2} (Figure 1). From here, suckers are consecutively transplanted into ever more widely spaced arrangements (Figures 1–3) with a final minimal spacing of one plant 2-4 m^{-2} (Figure 4) (Bezuneh and Feleke, 1966; Hiebsch, 1996). Much variation is observed. Enset transplanting may entail the removal of all plants or the selective thinning of some plants only. Plants might be transplanted to a uniform stand of only removed plants or incorporated into a field with plants of similar size, but of different ages (Brandt *et al.*, 1997).

Ultimately, successive transplanting from a small land area to a larger area makes it easier for farmers to provide more protection for the young plants. It also allows more intense weeding when plants are small, as well as limiting the need to transport water and manure. The continuous leaf canopy cover also provides protection for the soil from rain splash erosion. Maximum growth rate/unit area and over time is associated with complete interception of solar radiation (Hiebsch, 1996). As plant size increases, continuous

Figure 1. Enset sucker production (centre front of the photo) and transplanted young plantlets of various ages at various planting densities (in the background) (Source: Guy Blomme).

Figure 2. Newly transplanted young enset suckers (Source: Guy Blomme).

leaf canopy coverage is maintained/assured despite a wider spacing (Brandt *et al*., 1997).

Peregrine (1992) criticized the apparent 'lack of rational reason' involved in traditional decision-making other than ancestral custom. He wrote: *'Current agronomic practices of most farmers leave much to be desired. Spacing is far too close, a factor, which seriously affects productivity in both ensete and intercrops. Very often, planting is haphazard, which mitigates operations such as weeding, leaf pruning, fertilizing, etc. during the life of the crop. The 4–5 transplantations before the final one is a complete negation of usual sound horticultural practices. It is well known that transplanting produces a shock, which sets back plants for some time; the bigger the plant, the greater the setback. Despite numerous interviews with farmers, there seems to be no rational reason for this technique other than traditional custom. The system is clearly responsible for the long life-cycle of the plant. Experimental evidence suggests that with a single transplanting, the life cycle could be reduced to 3–4 years, which would mean a substantial productivity increase. Coupled with proper spacing, weeding and fertilizing, there would also be scope for bigger yields of the various intercrops'*.

While Peregrine's criticism holds elements of truth, it negates farmer decision-making based on contextual constraints and desires. To state that there is a lack of rational reason negates farmers' experience. For example, Wolaita and Hadiya farmers claim that repetitive transplanting results in more vigorous growth of both pseudostem and corm, and larger plants at harvest (Tsegaye and Struik, 2002). It could be postulated that the removal of all cord roots during transplanting removes the majority of nematode populations that might be present on the root system. In case enset plants would not be transplanted and as a plant cycle covers many years (>4), a gradual nematode build-up would occur in infected fields. Transplanting steps would then, to a large extent, create cleaner plants or planting material possibly contributing to subsequent more vigorous plant growth.

A comparison of the suitability of different management options used by farmers is complicated by the difficulty of obtaining survey data on enset yield. These complicating factors include: (1) the long lifespan/crop cycle duration, variability in transplanting, spacing and harvest time of enset, which give rise to difficulties in expressing enset yield in comparable terms, such as kg ha^{-1} $year^{-1}$, with other crops; (2) the need to sample the yield on more than one complete plant, which can amount to a relatively high proportion of a farmers total annual production; and (3) the fact that an enset plant does not come to maturity at a particular time of year and the main product, *kocho*, takes 15–30 days to reach the fermented, edible and thus measurable state. Also, *kocho* is not the only edible product derived from enset and *kocho*

Figure 3. Newly transplanted medium-sized enset stems in Woliso (Source: Guy Blomme).

Figure 4. Final transplanting plot from which mature enset plants will be harvested for further processing (Source: Guy Blomme).

itself goes through various processing stages (raw scraped, fermented, cooked), each with different moisture contents (Alemu and Sandford, 1991).

Estimating enset yield and production in experimental field trials is also conceptually challenging. The area and time used in the calculation of yield must account for the area and time duration at each of the transplanting stages up to harvest of a particular plant (Hiebsch, 1996). Enset commonly yields between 4 and 7 t ha^{-1} $year^{-1}$, with recordings as high as 12 t ha^{-1} $year^{-1}$ (Hiebsch, 1996). Under experimental conditions, with a density of 1,600 plants ha^{-1}, yields of 5,200 kg ha^{-1} or 33 kg $plant^{-1}$ have been achieved (Deckers *et al.*, 2001). Below, factors known to influence enset yield are discussed in more detail.

Plant spacing and transplanting frequency

The limited size of most enset farms and the low planting densities required in mature enset plots favour repeated transplanting (*i.e.*, increasing plant spacing with increased plant age and size) in order to minimize overall land needs for enset cultivation. Various authors assessed effect of plant density/spacing and transplanting steps on plant vigour, yield increase over time and time to flower emergence/harvest.

For example, the effect of nine arrangements of plant spacing, which ranged from 1 plant 3 m^{-2} to 1 plant 7.5 m^{-2}, on yield was evaluated by Aggrey and Tuku (1987). Suckers were planted on 4 April 1976 and harvesting was carried out during the first half of October, 1978. In view of limited land availability for enset cultivation, a 3.0 × 1.5 m spacing was advised. This allows for 1 plant 4.5 m^{-2} and a yield of 31 kg $plant^{-1}$ after 2.5 years. A larger spacing of 1 plant 7.5 m^{-2} or a spacing of 3.0 × 2.5 m achieves a higher yield per plant (41 kg $plant^{-1}$). However, yield per ha was considerably higher (68.9 t) for the 3.0 × 1.5 m spacing compared with 54.7 t for the 3.0 × 2.5 m spacing (Aggrey and Tuku, 1987).

Between 1977 and 1980, a field trial examined the impact of transplanting frequency on the production of *kocho* (Makiso, 1980, cited in Makiso, 1996). Two batches of suckers were planted at a spacing of 1.0 × 0.5 m in March 1977, 1 year after separation from the mother plant. This was termed the first transplant. In December 1977, one batch was thinned resulting in a spacing of 3.0 × 1.5 m, while another batch was transplanted a second time to a new field and planted at the same spacing of 3.0 × 1.5 m. Both batches were harvested 38 months later at the same time. A higher average yield of 25.9 kg $plant^{-1}$ was recorded with the material transplanted twice compared to an average yield of 20.7 kg $plant^{-1}$ with plants that remained after thinning and thus were transplanted only once.

Tsegaye and Struik (2000) also evaluated the effect of transplanting frequency in on-station field trials, demonstrating higher dry matter yields/plant (excluding roots) at maturity for plants transplanted twice compared with plants transplanted once or three times. Flowering on twice transplanted material was prolonged to 234 weeks (after separating suckers from the mother corm) compared to 104 weeks with plants transplanted only once. However, this was sooner than plants transplanted three times where the time to flowering was 260 weeks. Hence, plants transplanted once reached a maximum yield of 27 kg $plant^{-1}$ at flowering, *i.e.*, 2 years after separation from the mother corm, which corresponds to an average increase of 13.5 kg $plant^{-1}$ $year^{-1}$. Plants transplanted twice reached an average yield of 44 kg $plant^{-1}$ when they were flowering after 4.5 years. This corresponds to an average yield increase of 9.7 kg $year^{-1}$. Plants transplanted three times reached an average yield of 31 kg $plant^{-1}$ after 4.5 years, which was before they flowered. This corresponds to an average yield increase of only 6.9 kg $plant^{-1}$ $year^{-1}$.

As it is the corm and pseudostem that are harvested, higher yields at flower emergence can be expected by delaying flowering, and allowing a longer period of time for vegetative growth, which includes assimilation of starch in the pseudostem and corm. Transplanting once results in plants with higher growth and production rates. However, more frequent transplanting results in slower growth, an increase in time to flower emergence and hence harvesting, and a higher yield at flower emergence (Tsegaye and Struik, 2000). A more effective utilization of space occurs in the frequently transplanted treatments (Tsegaye and Struik, 2000). Thus, direct transplanting is advised when early yields are the objective or to reduce the chance of attack by pests and diseases. However, more frequent transplanting delays flowering and results in higher plant yields at flower emergence, although yield increase per year decreases with each additional transplanting step (Tsegaye and Struik, 2000).

Makiso (1976; cited in Hiebsch, 1996) noted that a typical 8-year enset production system, with four transplanting stages (respectively, 1, 1, 2, and 4 years, for time in sucker nursery, twice time between transplantings, and time between final transplanting and harvest) requires a total of 2,455 m^2 in order to harvest 80 nearly mature enset plants annually. Only after 8 years will the production system reach equilibrium, with each field and nursery containing plants, and an annual harvest from one 500 m^2 field (Makiso, 1976; cited in Hiebsch, 1996). In this system, all plants that have reached the four respective stages of transplanting maturity within a single season are transplanted. Transplants planted in the same season move together as a cohort through each successive stage of rotation and are harvested in the same season 8 years later (Shack, 1966; Aggrey and Tuku, 1987).

Once equilibrium of an enset farm has been achieved, annual yields will be higher for twice transplanted plants compared to once transplanted plants. An additional benefit of repeated transplanting is the smaller overall space required compared to planting once at low planting density (Tsegaye and Struik, 2000).

Table 1. Comparison of yield for four hypothetical enset management systems. Source: Hiebsch (1996).

Systems	Transplanting frequency#	Spacing (m)	Fresh wt $plant^{-1}$ (kg $plant^{-1}$)	Dry wt $plant^{-1}$ (kg $plant^{-1}$)	Dry wt $area^{-1}$ (t ha^{-1})	Dry wt $area^{-1}$ $time^{-1}$ (t ha^{-1} y^{-1})*	Dry wt $(area \times time)^{-1}$ t $(ha \times y)^{-1}$
8-year	1,1,2,4	2.5 × 2.5	30	15	24	3.0	4.9
7-year	1,6	2.5 × 2.5	36	18	29	4.1	4.8
5-year	1,4	2.5 × 2.5	22	11	18	3.5	4.4
5-year	1,1,3	2.0 × 2.0	13	6.5	16	3.3	5.1

#: Time in sucker nursery, time in between transplants, and time from last transplanting to harvest.
*: Dry weight per area and per number of years to harvest.

In an effort to identify a best practice scenario, Hiebsch (1996) examined the potential of four hypothetical enset management systems that differed in transplanting frequencies and plant spacing (Table 1). The first was the 8-year system by Makiso (1976; cited in Hiebsch, 1996) as described above. The second was a direct-transplant system that took 7 years (1 and 6 years, *i.e.*, time in sucker nursery, and time between transplant and harvest). The third was a direct-transplant system that took 5 years (1 and 4 years, *i.e.*, time in sucker nursery, and time between transplant and harvest). The fourth was a two-transplant 5-year system (1, 1 and 3 years, *i.e.*, time in sucker nursery, time between transplants, and time between transplant and harvest) with closer plant spacing in the final field compared to the other three management systems. Table 1 shows the effect of transplanting frequency on fresh weight plant^{-1}, dry weight plant^{-1}, dry weight area^{-1}, dry weight area^{-1} year^{-1} and dry weight (area × time)$^{-1}$. It is clear that, although the three-transplant 8-year and the direct-transplant 7- and 5-year systems have higher individual plant yields, it is the higher density planting in the two-transplant 5-year system that annually produces the most *kocho* at 5.1 t DW ha^{-1} year^{-1}.

Effects of climate and elevation on plant development

Rainfall for enset cultivation regions in southwestern Ethiopia ranges from 1,100 to 1,500 mm year^{-1}, relative humidity ranges from 60% to 80% in the rainy seasons and temperature from 18 °C to 28 °C (Bezuneh *et al.*, 1967; Diro and Tabogie, 1994). The crop is mostly grown on deep, well-drained, red soils (nitisols, luvisols) or black soils (phaeozems) with pH values ranging from 5.6 to 7.3. In addition, enset has a tolerance for water-saturated/swampy zones that banana does not (Deckers *et al.*, 2001).

Different optimal elevations for cultivation of enset have been reported: 1,700–2,000 m above sea level (m a.s.l.) (Bezuneh *et al.*, 1967), 2,000–2,750 m a.s.l. (Brandt *et al.*, 1997), 1,800–2,450 m a.s.l. (Seifu, 1984) and 1,500–3,000 m a.s.l. (Diro and Tabogie, 1994). Under conditions of evenly distributed rainfall and average temperatures between 16 °C and 20 °C, Bezuneh and Feleke (1966) estimate a total period of 3 years is needed before enset plantlets can be planted into the final field. This is equivalent to 3 years from the emergence of shoots from the mother plant and 2 years after the first transplant. Increased elevation increases the number of years that plants remain at each stage, because cooler temperatures slow plant growth (Brandt *et al.*, 1997). The time until the first transplant will be 1 year at 1,600–2,000 m a.s.l., but is 18 months to 2 years at 2,400–3,000 m a.s.l. Above 3,000 m a.s.l., 2–3 years are needed before shoots can be separated from the mother corm (Bezuneh and Feleke, 1966). Similarly, the period until harvest is shorter at lower altitudes (3 years at 1,600–2,000 m a.s.l.) and longer at higher altitudes (>4 years at 2,500–3,200 m a.s.l.) (Bezuneh and Feleke, 1966). Enset cultivation is rare/limited at elevations below 1,300 m a.s.l. in Ethiopia.

Fertilizer

Few fertilizer response trials for enset are found in literature. Bezuneh (1984) applied 3 kg manure compost, 500 g N and 400 g P_2O_5 plant^{-1} in an effort to determine the yield potential of enset. Plants were transplanted once at a spacing of 5 m^2 plant^{-1} and harvested at 40 months at a site with an elevation of 1,800–2,000 m a.s.l. They obtained fresh *kocho* weights plant^{-1} of 18.5, 22.2 and 29.8 kg from the cultivars Ferezae, Tuzuma and Adow, respectively.

Uloro and Mengel (1996) reported that an application of 100 kg ha^{-1} N and 100 kg ha^{-1} P fertilizer improved general plant appearance, plant growth, total fresh biomass and fresh rhizome yield of enset in soils which were low to medium in their nutrient status. Inclusion of 200 kg ha^{-1} K in the fertilization program further improved plant morphology plus rhizome size and rhizome-derived starch production, although it did not have a noticeable effect on above-ground biomass yield. Optimum fertilizer application gave dry weight starch yields in the range of 10–12 t ha^{-1}, which is 3 to 4 times higher than without fertilizer application. Fertilizer response curves are needed to determine optimum fertilizer rates (Uloro and Mengel, 1996).

Intercropping

Farmers acknowledge that intercropping prolongs the growth cycle of enset. However, no research data are available to quantify the effects of such cropping strategies on the performance of enset or other crops in the system (Brandt *et al.*, 1997). Weeds can greatly reduce growth before the first or second transplant stage when plants are small. As plants become larger, the leaf canopy cover suppresses weeds. Numerous intercrops have been reported, including chat, coffee, kale, peppers, taro, yam, pulses (beans, lentils) and cereals (maize, sorghum and barley). When plants are intercropped, younger plants are mostly planted with annual crops, such as maize and cabbage, whereas older plants are intercropped with perennials, such as coffee and citrus (Brandt *et al.*, 1997). Intercropping with legumes or vegetable crops is possible during the early stage of last transplanting, provided a spacing of one enset plant per 3.0 × 1.5 m is maintained (Aggrey and Tuku, 1987).

Ethnic cultural practises

Farmers' decision making is determined by the environment. However, the ethnic group to which the farmer belongs also influences management practices. For example, a study of the 60 households in the Gurage, Sidama and Hadiya regions showed differences in enset farming practices between ethnic groups, and also within these groups depending on household income levels. Spring *et al.* (1996) describe variability in enset transplanting practices, planting methods, planting densities and intensity of management (Table 2).

There is also an important gender component in decision-making at the household level. For example, harvesting of nearly mature plants is stressed as preferential by male farmers while female farmers in some of the same ethnic groups prefer harvesting smaller plants for better taste and ease of fermentation (Habte-Wold *et al.*, 1996).

Tsegaye and Struik (2002) examined farmers' traditional practices in the Sidama, Wolaita and Hadiya regions of southwestern Ethiopia. They found that cultivation practices varied more strongly between ethnic groups than between wealth categories within these groups. For example, in Sidama, plants are progressively thinned to eliminate the less promising plants. As a result, the dense leaf canopy continuously conserves soil moisture, suppresses weed growth and reduces organic matter decomposition by reducing soil temperature. A major disadvantage is that other crops cannot be intercropped during the early stages of enset growth. In Hadiya and Wolaita, farmers are confident that repetitive transplanting results in more vigorous growth of both pseudostem and corm. As a result, plants are progressively transplanted every 1 or 2 years.

TABLE 2. Diversity in enset farm management by ethnic group and household income. Source: adapted from Spring *et al.* (1996) cited in Brandt *et al.* (1997).

Zones	Staples	System characteristics	Major cash crops	Transplanting numbers	Planting methods	Plant density	Weeding/ cultivation	Manuring/ fertilization
Gurage	Enset	Less diversified enset clones, no inter-cropping	Chat	3 years (nursery time)	Structured row planting (all households)	4 × 4 m (all households)	Less intense	Ring and broadcast application, year round (all households)
		More diversified enset clones, some inter-cropping		4 years (nursery time)			More intense	
Sidama	Enset	Less diversified enset clones	Coffee (all households)	1 and 2 times (all households)	Random (all households)	Close spacing (all households)	Poor	One side application and broadcasting, inorganics
		More diversified enset clones					Good	Cattle manure
Hadiya	Enset > Cereal		Cereal and eucalyptus	2 times	Random planting	Closer spacing	Weakly managed	Poorly manured, broadcast application, year round
	Cereal > Enset			3–4 times	Some use row planting	Wider spacing	Better managed	Well manured, ring application, season specific

Conclusion

Research and development agendas in Ethiopia have focused on cereal grains, particularly maize, whereas enset has received much less attention. To date, very few agronomic recommendations are found that may be useful for extension services or farmers. Agronomic field trials that produced evidence-based guidelines are summarized in this review. From these trials it is apparent that optimal growth, biomass production and yield of enset can be achieved through manipulation of the transplanting frequency and plant spacing. The minimal spacing in the final field should be one plant 4 m^{-2}.

Deciding which frequency of transplanting to implement depends on the disease pressure, environmental conditions, household needs, available resources, including land, labour, capital, and other food crops in the system (Brandt *et al.*, 1997; Tsegaye and Struik, 2000). Cultural habits are formed over generations, and the ethnic group, but also gender-related household decisions, will impact on the practices that farmers use. The development of advisory guidelines for enset agronomy must consider enset farming in the context of these diverse communities and agro-ecologies.

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References

Aggrey, G.S.W., and Tuku, B.T. (1987). Review of enset research in Ethiopia and proposals for future research and development direction. In Proceedings of the First Ethiopian Horticultural Workshop, 20–22 February 1985, W.G.S. Aggrey, and B.S. Tuku, eds. (Addis Abeba, Ethiopia).

Alemu, K., and Sandford, S. (1991). Enset in North Omo region. FRP Technical pamphlet Nr. 1 (Addis Abeba, Ethiopia: Farm Africa), 49 pp.

Azerefegne, F., Addis, T., Alemu, T., Lemawork, S., Tadesse, E., Gemu, M., and Blomme, G. (2009). An IPM guide for Enset root mealybug (*Cataenococcus ensete*) in Enset production (Bioversity International, Uganda and France offices).

Bezuneh, T. (1984). Evaluation of some *Ensete ventricosum* clones by yield with emphasis on the effect of length of fermentation on carbohydrate and calcium content. Trop. Agr. *61*, 111–116.

Bezuneh, T., and Feleke, A. (1966). The production and utilization of the genus Ensete in Ethiopia. Econ. Bot. (USA) *20*, 65–70. https://doi.org/10.1007/BF02861927.

Bezuneh, T., Feleke, A., and Beyie, R. (1967). The cultivation of the genus Ensete in Ethiopia. Soil and Crop Sci. Soc. Florida *27*, 133–141.

Brandt, S.A., Spring, A., Hiebsch, C., McCabe, J.T., Tabogie, E., Diro, M., Wolde-Michael, G., Yntiso, G., Shigeta, M., and Tesfaye, S. (1997). The “tree against hunger”. Enset-based Agricultural Systems in Ethiopia (Washington DC, USA: American Association for the Advancement of Science), 66 pp.

Deckers, J., Tessera, M., Alemu, K., Abate, T., and Swennen, R. (2001). Ensete. In Crop Production in Tropical Africa, R.H. Raemakers, ed. (Brussels, Belgium: DGCI), p. 587–591.

Diro, M., and Tabogie, E. (1994). Preliminary investigation on enset culture. In Proceedings of the Second National Horticultural Workshop of Ethiopia, 1–3 Dec. 1992, E. Herath, and L. Dessalegn, eds. (Ethiopia: IAR), p. 120–131.

Diro, M., Haile, B., and Tabogle, E. (1996). Enset propagation research review. In Enset-based Sustainable Agriculture in Ethiopia. Proceedings from the International Workshop on Enset, Addis Abeba, Ethiopia, 13–20 December 1993, T. Abate, C. Hiebsch, S.A. Brandt, and S. Gebremariam, eds. (Institute of Agricultural Research), p. 242–249.

Habte-Wold, T., Sandford, S., and Kindness, H. (1996). The age and sex structure of enset plantations in north Omo. In Enset-based Sustainable Agriculture in Ethiopia. Proceedings from the International Workshop on Enset, Addis Abeba, Ethiopia, 13–20 December 1993, T. Abate, C. Hiebsch, S.A. Brandt, and S. Gebremariam, eds. (Institute of Agricultural Research), p. 149–163.

Hiebsch, C. (1996). Yield of *Ensete ventricosum*: A concept. In Enset-based Sustainable Agriculture in Ethiopia. Proceedings from the International Workshop on Enset, Addis Abeba, Ethiopia, 13–20 December 1993, T. Abate, C. Hiebsch, S.A. Brandt, and S. Gebremariam, eds. (Institute of Agricultural Research), p. 15–35.

Karlsson, L.M., Dalbato, A.L., Tamado, T., and Mikias, Y. (2014). Effect of cultivar, traditional corm pre-treatment and watering on sprouting and early growth of enset (*Ensete ventricosum*) suckers. Exp. Agr. *51*, 232–243. https://doi.org/10.1017/S0014479714000246.

Makiso, T. (1976; cited in Hiebsch, 1996). Study on the yield of enset. In Proceedings of the 6th Annual Resesarch Seminar, 12–14 November 1975 (Addis Abeba, Ethiopia: IAR), p. 246–254.

Makiso, T. (1980; cited in Makiso, 1996). Cultural practice studies on enset at Wolaita Sodo. In Agronomic Report 1979/80. Pub. No. 60. WADU (Wolaita Sodo: Wolaita Agricultural Development Unit), p. 26–27.

Makiso, T. (1996). Mode of enset propagation. In Enset-based Sustainable Agriculture in Ethiopia. Proceedings from the International Workshop on Enset, Addis Abeba, Ethiopia, 13–20 December 1993, T. Abate, C. Hiebsch, S.A. Brandt, and S. Gebremariam, eds. (Institute of Agricultural Research), p. 250–255.

Negash, A. (2001). Diversity and Conservation of Enset (*Ensete ventricosum* Welw. Cheesman) and Its Relation to Household Food and Livelihood Security in South-western Ethiopia. Ph.D. thesis (Wageningen, The Netherlands: Wageningen University and Research Centre), 247 pp.

Peregrine, T. (1992). Endemic crop plants of Ethiopia: False banana (*Ensete ventricosum* (Welw.) Cheesman). Walia *14*, 29–34.

Seifu, G.M. (1984; cited in Aggrey and Tuku, 1987). Enset research in Ethiopia. Review and proposal (Addis Abeba: IAR), unpublished, 37 pp.

Shack, W.A. (1966; cited in Aggrey and Tuku, 1987). The Gurage. A people of enset culture (London: Oxford University Press), Ch. II, p. 33; Ch. III, p. 52–64.

Shank, R., and Ertiro, C. (1996). A linear model for predicting Enset plant yield and assessment of Kocho production in Ethiopia. May, 1996, (Addis Ababa, Ethiopia: World Food Programme, Ministry of Agriculture, Southern Nations, Nationalities, Peoples' Regional State, UNDP Emergencies Unit for Ethiopia). http://www.africa.upenn.edu/eue_web/enset96.htm (accessed February 1, 2016).

Spring, A., Haile, B., Tesfaye, S., Abebe, Y., Amaldegn, A., Woldemichael, G., Tabogie, E., Surur, O., Tsegaye, A., Shimeles, S., Habte, T., Menjeye, T., and Tadesse, T. (1996). Enset farming systems in southern region, Ethiopia. Report on a Rapid Rural Appraisal in Gurage, Hadiya, and Sidama zones (Addis Ababa, Ethiopia: Deutsche Gesellschaft fur Technische Zusammenarbeit), mimeo.

Tsegaye, A. (2002). On indigenous production, genetic diversity and crop ecology of enset (*Ensete vertricosum* (Welw.) Cheesman). Ph.D. thesis (The Netherlands: Wageningen University), 194 pp.

Tsegaye, A., and Struik, P.C. (2000). Influence of repetitive transplanting and leaf pruning on dry matter and food production of enset [*Ensete ventricosum* Welw. (Cheesman)]. Field Crops Res. *68*, 61–74. https://doi.org/10.1016/S0378-4290(00)00111-8.

Tsegaye, A., and Struik, P.C. (2002). Analysis of enset (*Ensete ventricosum*) indigenous production methods and farm-based biodiversity in major enset-growing regions of southern Ethiopia. Expl. Agric. *38*, 291–315. https://doi.org/10.1017/S0014479702003046.

Uloro, Y., and Mengel, K. (1996). Yield and yield components of enset with the application of mineral fertilizers of N, P, K and S. In Enset-based Sustainable Agriculture in Ethiopia. Proceedings from the International Workshop on Enset, Addis Abeba, Ethiopia, 13–20 December 1993, T. Abate, C. Hiebsch, S.A. Brandt, and S. Gebremariam, eds. (Institute of Agricultural Research), p. 276–286.

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