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# IMPROVING INDIGENOUS KNOWLEDGE OF PROPAGATION FOR THE DEVELOPMENT OF ENSET AGRICULTURE: PROMOTING FARMERS' ADAPTATION CAPACITY TO CLIMATE CHANGE

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**ABSTRACT:** In order to provide knowledge for enset agriculture, seed germination, seedling development and vegetative reproduction were studied to envisage improved cultivars by crossing and selection and to enhance on-farm practices by acknowledging and evaluating farmers' indigenous knowledge. Seed set vary considerably for enset, and the factors influencing fruit and seed developments should be studied further. Seed germination vary between seed lots from different mother plants, and requires additional studies even though placing the seeds on moist sand gives some germination from most seed lots. There was informal information that corms buried for vegetative reproduction would rotten if manure was applied directly on them or if they were watered. However, these two treatments gave large and strong suckers. When the corm was split in smaller (about 1 $dm^3$) pieces, emergence was quicker and total production was higher than if the corm was kept entire. However, if there is risk for extended drought, using an entire corm is preferred for its water holding capacity. In the case of complete absence or little precipitation, watering on buried corm is beneficial if water is accessible.

**Key words/phrases**: Conventional breeding, Seed germination, Seed morphology, Seedling, Vegetative propagation.

## INTRODUCTION

Enset agriculture contributes to soil fertility and environmental sustainability as any perennial crop by avoiding or reducing erosion and keeping nutrients and moisture. Enset fields have higher soil organic matter and nutrients than other fields (Asnaketch Wolde Tensaye *et al*., 1998). Similar to forests, enset is a carbon dioxide sink (Mesele Negash and Starr, 2015). Enset is known as a drought-tolerant crop, it is said that there was no starvation among enset-growing farmers during famines in the 1970s and 1980s (Brandt *et al*., 1997). As food resource, enset is similar to potato (Mohammed *et al*., 2013), and it gives the highest yield in terms of edible energy per area and time unit of crops grown in Ethiopia (Admasu Tsegaye

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and Struik, 2001).

Enset agriculture has for long proven as farmers' adaptation strategy to climate change effects. It has obviously a wide range of economic, social and environmental benefits. Enset propagation, management and food processing techniques rely on indigenous technical knowledge of farmers.

In nature, wild enset is reproduced through seeds when mature mother plant ends life cycle, new plants grow from seedlings. Further, when enset is grown as ornamental plant around the world (Cheers *et al*., 2004) or simple as a source of wrapping material or similar, seeds may be used for propagation. For food utilisation, enset is usually harvested at the onset of flowering, when corm, pseudostem and flower stalk are fresh, thus not allowing seed set other than randomly. As there has not been a conscious breeding for genotype improvement, farmers use the same landraces as always. They propagate with vegetative methods (i.e., cloning), by burying a corm with removed apical meristem, which gives about 30-100 new plants (Karlsson *et al*., 2015) with the same characteristics as the parent plant, and farmers are well aware that this method preserves the familiar plant quality. This propagation method is a wise decision of farmers, because seeds produce new and unknown plants due to genetic recombination which occurs under sexual reproduction. Thus, the plants with genetic variation may not possess the desired phenotype for the intended purpose, if seedlings are used directly. However, seedlings can be selected and used for genotype improvement through conventional breeding. Areka Research Centre (the national centre for enset research) released six landraces as cultivars with described characteristics (Mikias Yeshitila *et al*., 2011), but there are requests for novel characteristics and new combinations of characteristics. It is necessary to encourage farmers, increase research and extension efforts to maximise the benefits of enset agriculture. This includes acknowledging indigenous knowledge; which is for example important to mitigate climate change effects by maintaining and developing local agriculture and forestry (IPCC, 2014), but also investigating the efficiency in farmers' inherited knowledge – just because one method functions and is utilised it is not necessarily the best possible method.

Our aim is to provide knowledge for enset agriculture. We have studied (1) seed germination and seedling development and (2) vegetative reproduction.

## METHODS

## Seeds and seedlings

### Seed collection

Collection sites were within the area Sodo – Tercha – Wolkite – Asela – Haramaya, i.e. N 06°50'–N 09°25', E 37°11'–E 42°02', in Ethiopia (Karlsson *et al*., 2013a;b). During seed collection, all encountered plants that had reached fruit stage were checked for seeds, and seeds per plant and fruit were counted. Seeds from 14 enset plants were collected at maturity, when the fruits were deep orange to brown. At this stage, the seeds were dark and very hard, and completely filled. Seeds came from either wild or cultivated plants. After collection, seeds were separated from the fruit flesh and dried before stored until onset of each experiment.

### Seed morphology and germination

Seed morphology was studied in 117 seeds, by observing, measuring (precision 0.01 mm: seed coat in three dimensions and embryo width and length) and placing additional 200 seeds with different water contact to investigate water uptake. For germination test, totally 805 seeds from eleven mother plants (one mother plant equal one replicate) were placed on moist sand at ca. 25°C. Seeds were also subjected to physical and chemical treatments known to induce germination for so called hard coat seeds. Germination was recorded at least bi-weekly during 52 weeks (Karlsson *et al*., 2013a).

### Seedling growth

Newly germinated seeds were planted in pots, after recording seed-size in three dimensions, and subjected to local soil only, local soil with manure or local soil with 1, 2, 4 or 8 g of DAP (Grade 18-46-0 [N-P-K, Ammophos, Cherepovet, Russia], containing 18% N and 20% P [IPNI, 2013]). Totally 412 seedlings were planted and placed within a fenced plot at Wolaita Sodo University campus (N 06°50'00" E 37°45'08", 1891 m a.s.l.), Ethiopia. Seedling characteristics were recorded after three weeks and after six months of growth. Additional ten seedlings were planted directly in the field, soil mixed with dry cow manure, when five weeks old and thereafter allowed to develop freely (Karlsson *et al*., 2013b).

Twenty newly germinated seedlings were planted in pots with ceramic pellets and placed with light daytime (ca. 100 µmol $m^{-2}$ $s^{-1}$, 12 h) at ca. 20°C. These seedlings were given slow-release (60 days at 20°C) complete and balanced fertilizer spikes for vegetative growth of pot plants (Blomstra näringspinnar för gröna växter, Cederroth, Upplands Väsby, Sweden), 0, ½, 1 or 2 spikes; 1 spike was recommended dose for the used pot-size (12 cm diameter). In addition, five seedlings were planted in pots with soil intended for sowing (Så-och kaktusjord, Weibulls, Åby, Sweden). Seedlings were watered when needed and allowed to grow for five weeks.

## Vegetative reproduction

Corms were provided from Areka Research Centre, N 07°04'02", E 37°41'22", 1785 m a.s.l., and experiments were conducted at Wolaita Sodo University, N 06°50'00", E 37°45'07", 1882 m a.s.l. The six released cultivars (Mikias Yeshitila *et al*., 2011) were included. Corm pre-treatment before burial for multiplication was studied with all cultivars and ‘Zerita’ in addition to investigation of watering after corm burial. Apical meristem was removed and corms were either kept entire, split in two pieces or split in four pieces. All corms were buried in holes dug to 40 cm deep and 50 cm wide, bottom was refilled with 10 cm softened top soil, and the corms were placed thereon and on them 15 L of 50/50% dry cow dung and soil. The corms allocated to watering were irrigated with 5 L per corm every day, when also the area was checked for emergence. Sprouts were harvested and recorded nine months after corm burial (Karlsson *et al*., 2015).

Sprouts (N = 162 [3 corm pre-treatments × 3 original corms × 6 cultivars × 3 replicates]) were replanted within the same area, not adding any additional nutrients, and harvested after one year of growth.

# RESULTS

## Seeds and seedlings

### Seed set

Far from all plants observed when flowering set fruits, and some with fruits did not set seeds, while some produced only a few seeds. Recorded seed set per plant with fruits was 0-1,713 seeds from 3-141 fruits on individual plants. There was no obvious relation between plant conditions or environment to seed set, e.g. one large and strong plant in Wonago (N 06°19'27", E 38°15'45", 1788 m.a.s.l.) was observed when flowering, not far from other enset, and the owner kept it until seed maturity. The entire harvest was 37 seeds; most fruits were seedless.

## Seed morphology

Seed sizes varied between ca. 10 and 20 mm in all directions (length × width × height average [sd] = 16.1 [2.6] × 14.7 [2.0] × 11.0 [1.3]); shapes being irregular. Imbibition occurred mainly through thin channels between the main seed coat and the operculum in the micropyle (Fig. 1). At germination, operculum was pushed out by the expanding root, thereafter the scutellum expanded during several weeks, until all endosperm was distributed to the growing seedling (Karlsson *et al*., 2013a).

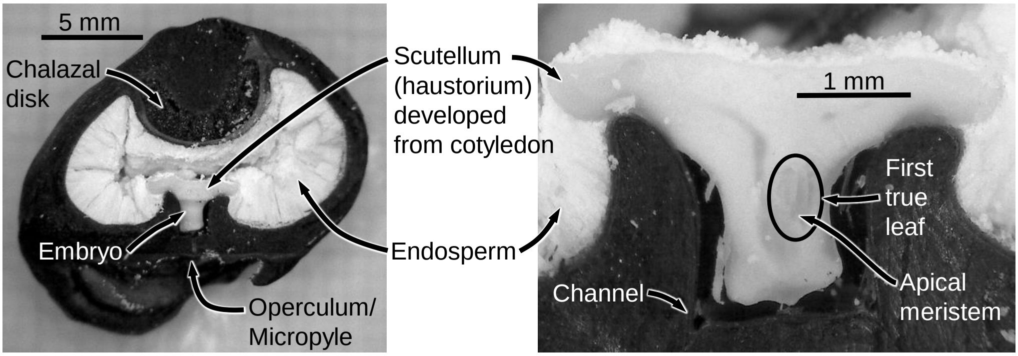


Fig. 1. Seed morphology (mature seed) of *Ensete ventricosum*. Photo: L.M. Karlsson. See McGahan (1961), Graven *et al*. (1996), Puteh *et al*. (2011) and Karlsson *et al*. (2013a) for details.

## Seed germination

The first germination occurred after 10 days, most germination was achieved within 14 weeks and the last germination was observed after 24 weeks. Final germination varied from 5 to 55% for the different seed batches, average 24.8%, sd=15.6. There was no positive response to physical or chemical treatments (Karlsson *et al*., 2013a).

## Seedling growth

After three weeks of growth, there was no correlation between seed size and seedling pseudostem diameter ($r^2$=0.024, p=0.365). After three weeks of growth, there was no significant difference between seedlings with or without manure, but after six months those with manure were significantly larger (Karlsson *et al*., 2013b). Diammonium phosphate (DAP) fertilizer had no significant positive effect, but mortality increased from 3-4% in local soil, soil with manure or 1-2 g DAP to 30% and 82% with 4 and 8 g of DAP per pot, respectively (Karlsson *et al*., 2013b).

Seedlings planted in the field reached up to 2.67 m pseudostem circumference within 22 months, five plants flowered within 24 months and had ripe seeds after 36 months.

Seedlings grown with one or one half spike (i.e., the recommended dose or half the recommended dose) of balanced fertilizer developed significantly stronger than non-fertilized seedlings regarding number of leaves, leaf area and fresh weight (Table 1, Fig. 2). The pseudostem was wider and larger in those plants given one half and one spike, respectively, compared to non-fertilized plants. Seedlings provided with two fertilizer spikes did not differ significantly from seedlings grown without any fertilization (Table 1, Fig. 2).

Table 1. Performance of newly germinated seedlings of *Ensete ventricosum* grown in ceramic clay pellets without any additional fertilizer compared (t-test) with seedlings provided half, full and double recommended dose slow-release balanced fertilizer for pot plants or fertilized sowing soil. Significant differences indicated with bold, N=5.

| **Factor** | **Half dose** | | **Recommended dose** | | **Double dose** | | **Sowing soil** | |
|---|---|---|---|---|---|---|---|---|
| | **T** | **P** | **T** | **p** | **t** | **p** | **T** | **P** |
| Number of leaves | 2.558 | 0.034 | 3.464 | 0.008 | 1.500 | 0.172 | 0.000 | 1.000 |
| Leaf area | 3.550 | 0.008 | 3.048 | 0.016 | 0.657 | 0.530 | 1.058 | 0.321 |
| Pseudostem circumference | 4.670 | 0.002 | 3.420 | 0.054 | 0.764 | 0.467 | 0.436 | 0.674 |
| Pseudostem height | 2.222 | 0.057 | 3.560 | 0.007 | 2.034 | 0.076 | 1.582 | 0.152 |
| Fresh weight | 4.414 | 0.003 | 2.810 | 0.023 | 0.952 | 0.369 | 0.751 | 0.474 |

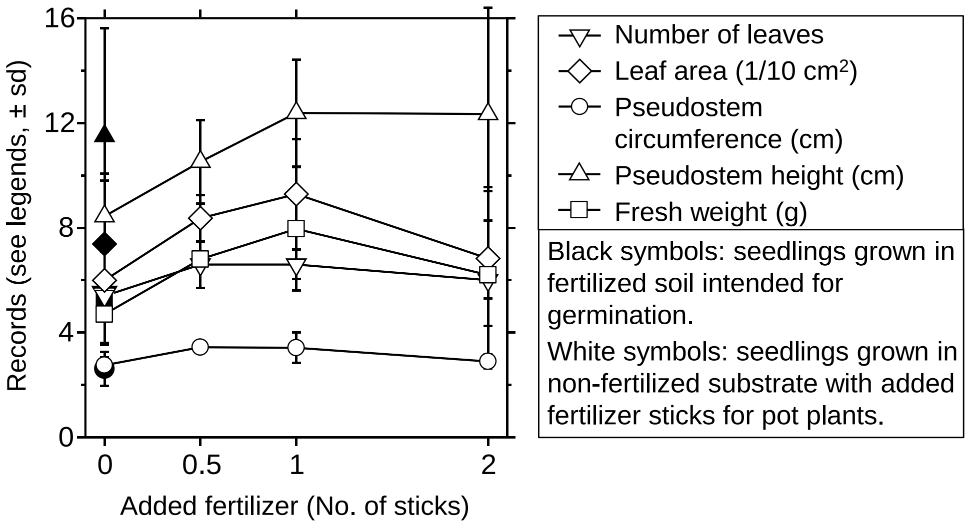


Fig. 2. Performance of seedlings of *Ensete ventricosum* when grown at ca. 20°C during five weeks after germination.

## Vegetative reproduction

Emergence occurred from all 63 buried corms, emergence of first sprout per corm occurred 50-112 days after burial, during a period with little rain only (Karlsson *et al*., 2015), thereafter sprouts grew during the rainy season. Emergence for entire corms was later than for split corms and watering decreased average time to emergence. Cultivars differed regarding number of sprouts (from around 35 for 'Mesena' to around 100 for 'Endale'), but splitting increased the number of sprouts (from around 30 for entire to around 80 for quarters) per buried corm (Karlsson *et al*., 2015); there were totally 4,405 sprouts from 63 corms. Average pseudostem diameter of the seven largest sprouts from all buried corms was 28.7 cm, while the average of all remaining sprouts was about 10 cm; watering gave more equal-sized sprouts (Karlsson *et al*., 2015).

Pseudostem volume of individually planted sprouts after one year of growth was dependent on volume at planting ($R^2 = 0.37$, $p < 0.001$, Fig. 3).

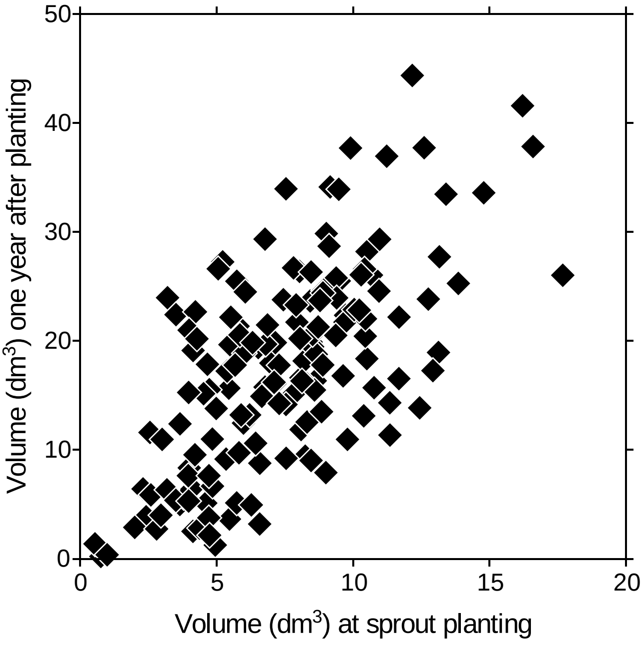


Fig. 3. Pseudostem volume of *Ensete ventricosum* sprouts, calculated from linear records, when replanted after being detached from mother corm and after one year of further growth. Plants were from six different cultivars; a few strongly growing plants were excluded from the graph. Correlation: $R^2 = 0.42$, $p < 0.001$.

## DISCUSSION

*Ensete ventricosum* plants growing in the wild are generally not utilised as a food source. However, the gene pool of wild plants can be important for development of cultivars (Genet Birmeta *et al*., 2004) and some people are prepared to accept the unfamiliar food product qualities from these plants (Abraham Bosha *et al*., 2016). Therefore, requirements for seed set and seed germination (Karlsson *et al*., 2013a) need to be studied further to make it possible to utilise that gene pool consciously. Growth of seedlings is uncomplicated and efficient by applying manure (Karlsson *et al*., 2013b), thus seedlings can be used for conventional breeding. However, recommendations for manure application should be supported by systematic studies.

It is important not to apply too much chemical fertiliser, because at least young seedlings of enset are sensitive to that (Karlsson *et al*., 2013b, Fig. 2). Too much manure may harm young seedlings.

Increased number of sprouts at multiplication is desired, and one way to achieve that can be to part parent corms in much smaller pieces: the quarters (ca. 0.9 $dm^3$) produced more sprouts and totally larger volume of pseudostem than entire corms (Karlsson *et al*., 2015).

When discussing with farmers, there are some myths on enset cultivation running around, such as "the new shoots must be planted close to house to get smoke", "you cannot grow enset in the field, keep it only in a garden", "you cannot put manure directly on corm, because it will rotten" and "you cannot water on planted corm, since it will rotten". These myths are now falsified.

When applying dry cow manure, mixed with soil, directly with corms we got 100% emergence, which is unusual (Mulugeta Diro, 1997). This result may arise from careful corm pre-treatment (the same experienced person split and removed the apical meristem of all corms) and appropriate depth and width of holes for corm burial, including softened topsoil placed under corms and mix of 50/50% dry cow manure and soil directly placed on corm (instead of the common way to place manure on top of soil, claiming it will cause rotting otherwise).

It is important to consider indigenous knowledge; farmers have a lot of inherited knowledge on what is functional. However, just because one way functions is not a proof that it is the best way, and farmers' practice should be tested systematically. Our sprouts were considerably larger than expected

(Karlsson *et al*., 2015), and farmers who saw them were sure we used some "secret chemical". Rotten corms may be the results of using fresh (not dry) manure directly on corm. In our field, we provided the enset root system with direct access to manure, instead of feeding the weeds on ground surface. Neither the watering gave any rotten corm (Karlsson *et al*., 2015), instead uniform and healthy sprouts. Of course overwatering can cause problem, which is a truth for all plants.

Sprouts from corms parted in smaller pieces emerged sooner, and had more sprouts per corm, which imply that it is better for farmers to part corms into such relatively small pieces. The drawback with that is the survival of the corm if there is risk for prolonged drought, and water access is limited: an entire corm will retain its moisture better than a small piece.

Regarding the habit to plant enset directly around houses: after recording of the sprouts, we planted them individually back in the field. The field was far from any house, but still they performed very well. As studied by Tilahun Amede and Mulugeta Diro (2005) enset close to the houses makes it practical to provide household organic wastes and waste water, but otherwise there is no need to plant enset in the vicinity of houses, even though it is understandable and desired to have enset close to houses to improve microclimate.

## CONCLUSION

Our results imply that productivity of enset can be much increased by taking relatively simple measures. Putting effort at corm burial and achieving larger sprouts than currently common is beneficial for the future growth because the plant size depends on sprout size at planting (Fig. 3). For seedlings, fully mature, flowering plants were achieved within two years from germination (Karlsson *et al*., 2013b).

Further studies will contribute with more and more detailed knowledge; as with all crops, there is no end of development. However, already now the most recent knowledge can be compiled and merged to existing enset agricultural advice. For corm burial, we provided a brochure in Amharic (Karlsson *et al*., 2012). It is important to make sure advisers possess desired level of knowledge about enset agriculture so that they can provide meaningful advice to farmers.

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