Effect of modern cultivation techniques on yield and profit of African eggplant

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1 Summary

By Rijk Zwaan Afrisem and Wageningen University and Researchcentre a demonstration field on African Eggplant (*Solanum aethiopicum*) cultivation was organized from August 2011 till February 2012. The activities were funded by the Dutch Ministry of Economic Affairs, Agriculture and Innovation.

The purpose of the demonstration field was to show farmers the impact of improved techniques on yield and to collect data on the effect of different techniques on yield.

In the field demonstrated was the effect of:

- OP (open pollinated) or hybrid variety
- Bare root and tray transplant raising method
- Furrow or drip tape irrigation system
- Application of black plastic mulch

A first field test with hybrid African eggplant varieties was performed with this demo. The varieties were developed in a joint breeding program carried out by Rijk Zwaan Afrisem at Arusha on behalf of Rijk Zwaan and East West Seed. These hybrid varieties were specifically developed to achieve better uniformity, earliness, pest and disease resistance and higher yield. Since the development of hybrid African Eggplant varieties is quite recent no other information is available yet.

Original it was intended to perform this test with two other varieties which are expected to perform better than the tested hybrid varieties in this report, however not enough seeds were available from those varieties. Expected is that based on the experience gained from this research better improved hybrid varieties will be developed.

Data collected from the demonstration field shows that with the use of the tested varieties:

- Drip tape in combination with black plastic mulch showed a big increase in yield
- Without plastic mulch the effect of drip tape on yield is limited.
- With transplant raising in trays a higher seed use efficiency was present compared to raising in field nurseries. A higher yield is present with tray transplants.
- Yield of bitter type eggplant is lower than the sweet type eggplant
- With bitter type eggplant a higher yield was present when growing a hybrid variety. This was not present with the in this experiment used sweet type eggplant variety, this might due to the already good performance of the OP variety. In this experiment disease pressure was low, when disease pressure is high one might expect an even better performance of the hybrid variety over that of the OP variety due to disease resistance of the hybrid variety.
- Cost – benefit analysis shows that the use of tray transplants is highly profitable. The use of drip tape irrigation/fertigation and mulch are quite expensive and only with a good crop productivity and good market prices these techniques could be profitable.

For introduction of the new techniques into practice it is recommended to train the farmers in the use of these techniques. Besides it is necessary to give farmers access to capital in order to purchase the materials needed for introducing the described techniques.

Visits were organized for farmers and other stakeholders to observe the results and to discuss the possible impact of the new techniques when introduced on the farms. Besides these formal organized visits farmers were welcome to visit the field whenever they like to observe the progress of the cultivation.

2 Aknowledgements

This demonstration on African eggplant cultivation was made possible by Mrs. Heleen Bos of Rijk Zwaan and Mr. Arij Everaarts of WUR-PPO. Special thanks goes to Mr. Abel Kuley, product development manager at Rijk Zwaan Q-sem, and to Mr. Harald Peeters, director of Rijk Zwaan Afrisem. Without their efforts the described activities in this report could not be carried out. Also the staff of Rijk Zwaan Afrisem should be mentioned who took care of the crop maintenance and observations. Finally we would like to thank Mr. Mbatia for his cooperation to have the demo field at his premises.

3 Introduction

The demonstration on African eggplant was part of the project "Demonstration of modern field vegetable cultivation techniques for African field vegetable producers" with internal APR number 3250203111. This project was funded by the Ministry of Economic Affairs, Agriculture and Innovation of the Netherlands.

The activities were jointly carried out by Rijk Zwaan Afrisem Tanzania and by Applied Plant Research, Lelystad, part of Wageningen UR.

Rijk Zwaan Afrisem carries out a breeding program for the companies Rijk Zwaan and East West Seed. In the breeding program new varieties are developed for the crops African eggplant (*Solanum aethiopicum*), Sukumawiki or Ethiopian kale (*Brassica integrifolia*) and chili pepper (*Capsicum chinense*). Hybrid varieties for African eggplant are specifically developed with attention to uniform fruits, earlier production and resistance to major pests and diseases in this crop. Above all hybrid varieties are developed to result in a higher yield.
The potential of these varieties is high, expected is that under already existing farming methods farmers can have higher yields. However, to benefit fully from the hybrid varieties farmers may have to adopt also improved cultivation practices. More attention should be given to seedling raising methods, fertilization, irrigation and water management.

In August 2011 a demonstration field with African Eggplant was started. The demonstration field served two purposes, namely to show the farmers the potential benefits of the use of new cultivation techniques and or improved varieties and secondly to collect data on the impact of the use of new technologies.
Tested technologies were irrigation, mulch and hybrid variety use. All these aspects can result in better yields with a more sustainable use of inputs. More importantly with these techniques it is expected that farmers can increase the productivity per field and increase their income.

4 Materials and methods

4.1 Demonstrated technologies

A total of 16 different treatments were demonstrated (Table 1). The lay out of the field was designed as a randomized block with four replications (Table 2). Each plot was 1 x 9 m large and per plot 24 plants were planted.

In the demonstration the following topics were present to be demonstrated:

- Improved varieties (hybrid versus open pollinated (OP) varieties)
- Irrigation/fertigation (drip tape with nutrients versus furrow irrigation with broad cast fertilizer)
- Raising method (Tray transplants raised in nurseries versus bare root transplants raised in open field nurseries)
- Mulch application (covering crop row with plastic sheet versus bare soil)

Table 1. Treatments demonstrated in the field.

Code	Raising Method	Mulch	Irrigation	Type	Variety
A	Field	no mulch	furrow	Sweet-T2	Common OP
E	Field	no mulch	with drip	Sweet-T2	Common OP
F	Field	no mulch	with drip	Sweet-T2	Hybrid 101
C	Field	with mulch	with drip	Sweet-T2	Common OP
D	Field	with mulch	with drip	Sweet-T2	Hybrid 101
M	Tray	no mulch	furrow	Sweet-T2	Common OP
J	Tray	no mulch	with drip	Sweet-T2	Hybrid 101
O	Tray	with mulch	with drip	Sweet-T2	Common OP
H	Tray	with mulch	with drip	Sweet-T2	Hybrid 101
N	Field	no mulch	furrow	Bitter-T1	Common OP
L	Field	with mulch	with drip	Bitter-T1	Hybrid 103
B	Tray	no mulch	furrow	Bitter-T1	Common OP
K	Tray	no mulch	furrow	Bitter-T1	Hybrid 103
I	Tray	no mulch	with drip	Bitter-T1	Common OP
G	Tray	with mulch	with drip	Bitter-T1	Common OP
P	Tray	with mulch	with drip	Bitter-T1	Hybrid 103

Table 2. Technical data about the demonstration field.

Crop	:	African Eggplant (*Solanum aethiopicum*)
Sowing date	:	18 August 2011
Number of seeds sowed per variety	:	Trays:264 seeds at Qsem Farmers practice: 500 seeds at Kilimo Impact Ltd Farm
Location of demonstration field	:	Kilimo Impact Limited Farm (John C.W. Mbatia) Mailer Farm USA River, PO BOX 15574 Arusha.
Transplant date	:	2 October 2011
Number of plants per plot	:	24
Gross plot size	:	2 x 9 m
Net Plot size	:	1 x 9 m
Planting distance	:	75 x 75 cm
Plants per hectare	:	12,600
Harvest	:	November 21, 2011 till February 24, 2012
Number of replications	:	4
Experimental design	:	Randomized block design

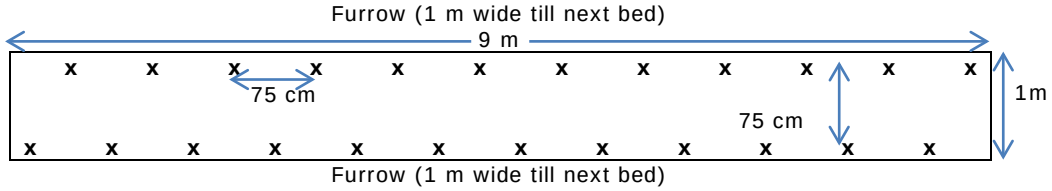

Figure 1. Layout of an individual plot with 24 plants.

4.2 Varieties and raising of transplants

In the demonstration field two types of African eggplant were present. Farmers in Tanzania either cultivate a sweet tasting type or a bitter tasting type. Both types were present in the experiment. Usually farmers cultivate local open pollinated varieties. Seeds for this crop are bought at agro shops or quite common is that seeds are used collected by farmers from ripe fruits of their previous crop. Currently Rijk Zwaan Afrisem is in the process of breeding hybrid varieties for African eggplant and expected is that within a few years the first commercial variety will become available. The breeding program I sa joint activity of Rijk Zwaan and East West seed. The advantages of hybrid varieties are higher yields, better resistance against diseases and pests. Other aspects that have attention in the breeding are uniformity and earliness of production. Advantage of seeds purchased from shops or companies is that seed production is controlled and therefore germination percentage is higher compared to the seeds that are saved by the farmers themselves from a previous crop.

Commonly transplants for African eggplant cultivation are raised by farmers. The method they use is field bed raising. With this method mostly a small corner of the main field is reserved for transplant raising. Seeds are broadcasted or sometimes sowed in lines in the soil. After sowing sometimes the soil is treated with a fungicide and an insecticide to prevent soil borne pests and diseases. This method is quite cheap in terms of required capital. However, loss of seeds can be quite high due to pests and diseases but also due to heavy rains that can reduce germination by flooding. Also seedlings can be damaged by wild life or even by livestock. Besides with this method quality of seedlings can be disappointing as well, uniformity is low and small as well as large seedlings can be present at the same time. With dense plant populations elongated seedlings may be present as well which are quite tall but weak. Finally with uprooting these seedlings roots will be damaged resulting in a higher transplant shock compared to tray seedlings. Raising of seedlings in trays reduces loss of seeds in the first place. Secondly since transplants are transplanted with a complete root ball transplant shock is reduced. Usually when seeds are raised in trays the germination percentage of hybrid varieties is 98% while that of OP varieties about 50% is. When sowed in field beds the germination percentage of hybrid varieties is slightly lower with 90% while the germination percentage of OP varieties drops to 35%.

This is especially important when farmers are using hybrid seeds which might require more capital for purchasing. Seed costs of open pollinated seeds is 1.5 Tsh/seed which is about 2% of the total production costs of farmers' fields. In this experiment the percentage was slightly lower with 1.2% due to a higher usage of fertilizer in this experiment as compared to the usage in farmers' fields. So far no seed prices are known yet for hybrid African eggplant seeds.

Figure 2. Fruits of the African eggplant (*Solanum ethiopicum*).

Plants were either raised in open field nursery beds (Fig. 3) or as tray transplants (Fig. 4) inside a greenhouse. Four replications were present with raising transplants in trays. With raising of bare root transplants in field bed nursery no replications were present.

Figure 3. **Raising of bare root transplants in the open field.**

Figure 4. **Raising of tray transplants in a nursery.**

Figure 5. **Transplanting of seedlings to the field on October 2nd, 2011.**

Figure 6. Overview of the experimental field.

4.3 Fertilization, irrigation and mulch

Irrigation was either done by standard furrow irrigation or by drip tape. Furrows were present at both sides of the beds and once to twice a week irrigation with clean water took place when deemed necessary according to climatic conditions. With drip tape irrigation water together dissolved fertilizers was applied once a week. In the period from 24 October till 6 December a vegetative nutrient solution was applied, from December 6 onwards a generative nutrient solution was applied 10 times. Table 3 shows the fertilizers dissolved in the irrigation water and the cost of fertigation per liter.

Table 3. Nutrient solution applied with drip tape irrigation (g fertilizer per liter water).

Fertilizer	Vegetative (g/l)	Generative (g/l)	Price of fertilizer (Tsh/kg)	costs of vegetative fertigation (Tsh/l)	costs of generative fertigation (Tsh/l)
$CaNO_3$	0.83	0.94	1122	0.93	1.05
KNO_3	0.42	0.25	2380	1.00	0.60
K_2SO_4	0.00	0.28	2414	0	0.68
$MgSO_4$	0.50	0.55	646	0.32	0.36
MPP (KH_2PO_4)	0.24	0.22	2805	0.67	0.67
Microsol B	0.06	0.06	15300	0.92	0.92
		Fertigation costs per liter (Tsh/l)		3.85	4.27

A basal application of CAN was applied just before planting. With drip tape treatment a total of 248 kg/ha N, 71 kg/ha P_2O_5 and 180 kg/ha K_2O is applied (Table 4). With the generative solution a higher content of potassium was applied as compared to the vegetative solution. With furrow irrigation treatment only nitrogen fertilization was applied with urea and CAN and total of 331 kg/ha N was applied. This is compared to practice fields higher were on average only 70 kg/ha N is applied.

Table 4. Applied major nutrients with drip tape treatment.

	N	P_2O_5	K_2O
Vegetative solution content (g/l)	0.28	0.12	0.27
Generative solution content (g/l)	0.29	0.11	0.33
Amount per ha (kg/ha)	173	71	180
Basal application 278 kg/ha CAN (27% N)	75	0	0
Total (kg/ha)	248	71	180

Mulch treatments consisted of applying black plastic sheet on top of the beds before planting. Holes were punched in the plastic at the positions were transplants would be planted. Per bed of 9 m^2 a total of 2.5 kg mulch was used. For one hectare, taking into account surface that is not covered with mulch such as paths and furrows, a total of 1390 kg mulch is needed. The price of one kg mulch is 3,814 Tsh resulting in a total of 5,301,460 Tsh/ha.

Figure 7. Furrow irrigation of African eggplant.

Figure 8. Growth of weeds on the beds with African eggplant.

Figure 9. Position of drip tape immediately next to the African eggplant plants.

Figure 10. Weeding of African eggplant.

4.4 Observations

4.4.1 Germination

Germination was observed 15 and 21 days after sowing. Counted were all seedlings present on a tray or in the field bed nursery per variety. At transplant date only good healthy seedlings were counted. Based on the total number of sowed seeds the percentage germination or useable seedlings at transplanting was calculated.

4.4.2 Plant development

Each week number of missing plants was observed per plot. Based on the number of transplanted plants the percentage of missing plants was calculated. Each week also plant height of the plants was measured. The distance from the soil till the top of the canopy was considered as plant height. Height was measured in centimetres.

4.4.3 Harvest

Twice a week harvest took place. Fruits were harvest at optimum ripening stage. Per plot number of total and marketable fruits was counted. Rejected fruits were classified according to the main reason of rejection. Classes were unripe, over mature, affected by pests or by diseases, or misshapen.

4.4.4 Economic analyse

During the demonstration records were kept of used inputs per treatment. Also per treatment the activities such as irrigation, weeding and fertilization were noted. Based on these records the profitability of the different treatments were calculated and results were compared to the result of the standard farmers practice. Observed was that in practice most labour is hired and that only a fraction is done by the farmers himself. For this reason profitability of the treatments in this demonstration was calculated taking into account 100% hired labour. Per activity wages can be different but in this case an average wage of 800 Tsh/hour was taken. This figure was calculated based on data on labour collected at African eggplants near Arusha. Simultaneously with the cultivation of African eggplant a survey was carried out amongst eight African eggplant farmers of whom four were growing the bitter type and four the sweet type. Also data was collected through daily recording of the cultivation by four farmers of whom two where growing the sweet type and the other two the bitter type eggplant. With the daily recording all spend materials and costs were written down in a book. Besides all spend labour hours and costs were recorded. Every two weeks the data was collected at the farmers and analysed to check if the records were complete.

Since the plots in the demonstration field are quite small it was concluded that taking records of spend time per activity would not be useful. To calculate required time per treatment data on required time per activity from the farmers records were used.
For application of mulch and drip tape some estimations on labour need and costs had to be made since data of this is not available on farmers level. To a certain extend in the demo field the percentage in labour requirement was assessed and based on labour need for weeding and irrigation on commercial farms needed labour with the new techniques was calculated.
For weeding it was estimated that compared to farmers practice a reduction of 75% in labour is possible when applying plastic mulch. The beds are covered and almost no weeds are growing in between the plants on the beds. However, weeding is still required to remove weeds from the furrows.
For applying mulch estimated is that it takes 4 labourers one day to mulch 1 hectare.
With drip irrigation it only takes some time to open the valves. In this situation fertilizers were added to the water and therefore total time required for dissolving fertilizers, for operating the system and maintenance the reduction in labour needed for irrigation compared to irrigation with furrow irrigation is 90%.
Compared to farmers practice were 8 t/ha was harvested, it takes more time for harvesting the fruits at treatments were a substantial increase in yield is present. For this purpose assumed is a linear relation, although most likely is that the relationship between required yield and yield volume is not linear. With high fruit number per surface area, which are present when yield is higher, harvesting can be more efficient than with a low fruit number.

5 Results

5.1 Seedling raising

Germination of seeds sowed in trays was significant better than those sowed in the open field (Table 5). Germination percentage after 15 days of seeds sowed in trays was more than 80%, in the field this was only 17 to 79%.

Germination of the OP varieties was better than that of the hybrid varieties. This was not be related to the variety but merely to the seed quality of the used batches. Since the hybrid varieties used in this experiment are not introduced yet, seed availability is limited and therefore a lower seed quality had to be accepted in order to have sufficient seeds.

Table 5. Germination results 15 and 21 days after sowing and final percentage of healthy seedlings at the time of transplanting.

Variety	Germination after 15 days (%)		Germination after 21 days (%)		Healthy seedlings at transplanting (%)	
	Tray	Field	Tray	Field	Tray	Field
Bitter OP	98	17	98	38	97	18
Bitter Hybrid	86	34	87	29	85	20
Sweet OP	96	79	97	77	95	60
Sweet Hybrid	83	44	83	46	79	37

5.2 Plant development

Bare root transplants grown with furrow irrigation showed at both bitter and sweet type African eggplant a significant lower percentage of present plant six weeks after transplanting than tray transplants (Table 6). With tray transplants the survival rate was 99 to 100 % at all treatments. When bare root transplants were grown with driptape and mulch the survival rate was also close to 100% and not significantly different from tray transplants. With driptape alone the survival rate was slightly lower but not significantly different from driptape with mulch treatment.

Table 6. Plant survival on 16 November 2011, 6 weeks after transplanting (%).

		Drip irrigation		Furrow
Variety	Raising method	bare soil	mulch	bare soil
Bitter type				
Hybrid	Field	-	99	-
OP	Field	-	-	68
Hybrid	Tray	-	100	99
OP	Tray	99	100	100
Sweet type				
Hybrid	Field	92	98	-
OP	Field	91	94	72
Hybrid	Tray	100	100	-
OP	Tray	-	100	100

- = not demonstrated in the field.

p=<0.001; LSD0.05 = 9.9

Plant height of plants grown with driptape and mulch was the highest on December 7 (Table 7). Between plants grown with furrow irrigation or with driptape alone no significant differences were present. Per irrigation treatment no significant differences were present in plant height between the different raising methods. Only with the bitter type grown with furrow irrigation a taller plant was present with the hybrid variety than with the OP variety.

Table 7. Plant height on 7 December 2011(cm).

		Drip irrigation		Furrow
Variety	Raising method	bare soil	mulch	bare soil
Bitter type				
Hybrid	Field	-	104	-
OP	Field	-	-	77
Hybrid	Tray	-	110	90
OP	Tray	87	109	94
Sweet type				
Hybrid	Field	84	112	-
OP	Field	78	102	71
Hybrid	Tray	88	108	-
OP	Tray	-	103	78

- = not demonstrated in the field.
p=<0.001; $LSD_{0.05}$ = 10.9

Tray transplants were taller at transplanting on October 4 already (Figure 11). Development of bare root transplants is slower than the tray transplants. When plants are grown with driptape and mulch plant height development accelerates in November while tray transplants grown with furrow irrigation showed a more gradually linear increase in plant height.

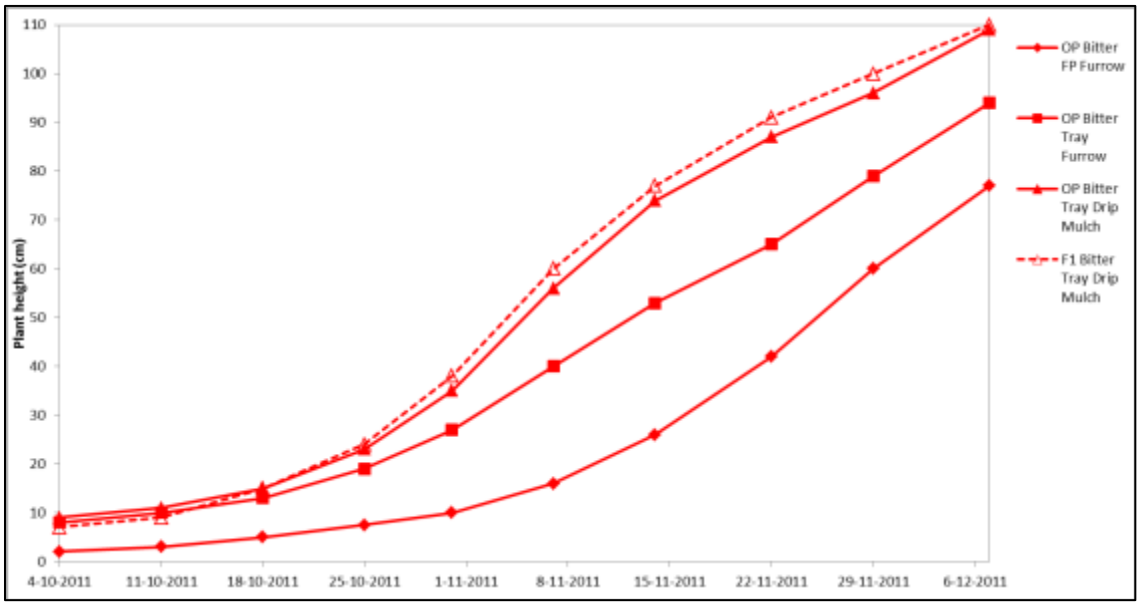

Figure 11. Plant height development of bitter type African eggplant (cm).

With sweet type African Eggplant tray transplants were taller at transplanting on October 4 (Figure 12). Plant height development of bare root transplants was slower than the tray transplants. Similar to bitter type African eggplant plant height development of tray transplants grown with driptape and mulch is faster than with furrow irrigation.

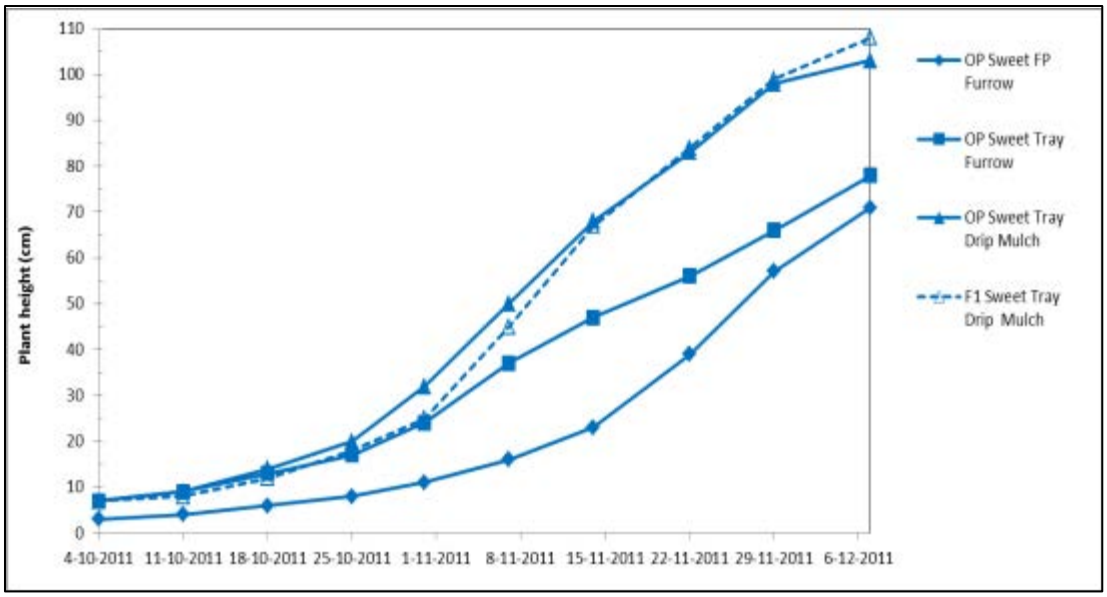

Figure 12. **Plant height development of sweet type African eggplant (cm).**

Figure 13. **Plant development of African eggplant grown on bare soil (left) and grown with plastic mulch (right).**

5.3 Yield

Figure 14. **Mature fruits ready for picking.**

Figure 15. **Harvest of African eggplant fruits.**

Figure 16. Harvested fruits of African eggplant.

Bare root transplants grown with furrow irrigation (farmers practice) of the bitter type African eggplant yielded 8 t/ha (Table 8). Tray transplants showed a significant higher yield, both with furrow and driptape irrigation. Compared to cultivation of eggplant with driptape alone the yield of eggplant grown with driptape and mulch was 4.9 t/ha higher. The yield of the hybrid variety was significantly higher than the OP variety. With furrow irrigation yield of the OP was 18.5 t/ha while with the hybrid variety this was 28.9 t/ha. With growing plants with driptape and mulch the difference between OP and hybrid yield was even bigger with 42.2 t/ha for the hybrid variety and 29.6 t/ha for the OP variety.
Sweet African eggplant showed a yield of 12 t/ha with bare root transplants and furrow irrigation, which was almost significant higher than the yield of the bitter type African eggplant. Tray transplants showed in all cases higher yields than the respective bare root transplants. Plants grown with furrow irrigation showed significant lower yields than plants grown with driptape. Driptape alone showed lower yields than cultivation of plants with driptape and mulch combined. No significant differences between OP and hybrid variety were present in yield.

Table 8. Marketable yield (ton/ha).

		Drip irrigation		Furrow
Variety	Raising method	bare soil	mulch	bare soil
Bitter type				
Hybrid	Field	-	38.6	-
OP	Field	-	-	8.0
Hybrid	Tray	-	42.2	28.9
OP	Tray	24.7	29.6	18.5
Sweet type				
Hybrid	Field	26.5	34.1	-
OP	Field	24.9	34.4	12.2
Hybrid	Tray	33.3	44.9	-
OP	Tray	-	43.7	28.9

- = not demonstrated in the field.
p= <0.001; $LSD_{0.05}$ = 4.7

Harvest of bitter type African eggplant showed for farmers practice, bare root transplants of an OP variety grown with furrow irrigation, a slow development at the beginning of the harvest period and a commercial short harvest period. From December 12 till mid-January most fruits were harvested with a maximum of about 250 kg/ha per harvest date (Figure 17). With tray transplants harvest started earlier and also per harvest date a larger volume was harvested. Commercial harvest period ended at the end of February where still significant volumes could be harvested. In February some rain showers were present which as a result boosted production of the crops grown with mulch. Plants of farmers practice were deteriorating already and did not profit from those rains while plants grown on mulch were still viable.

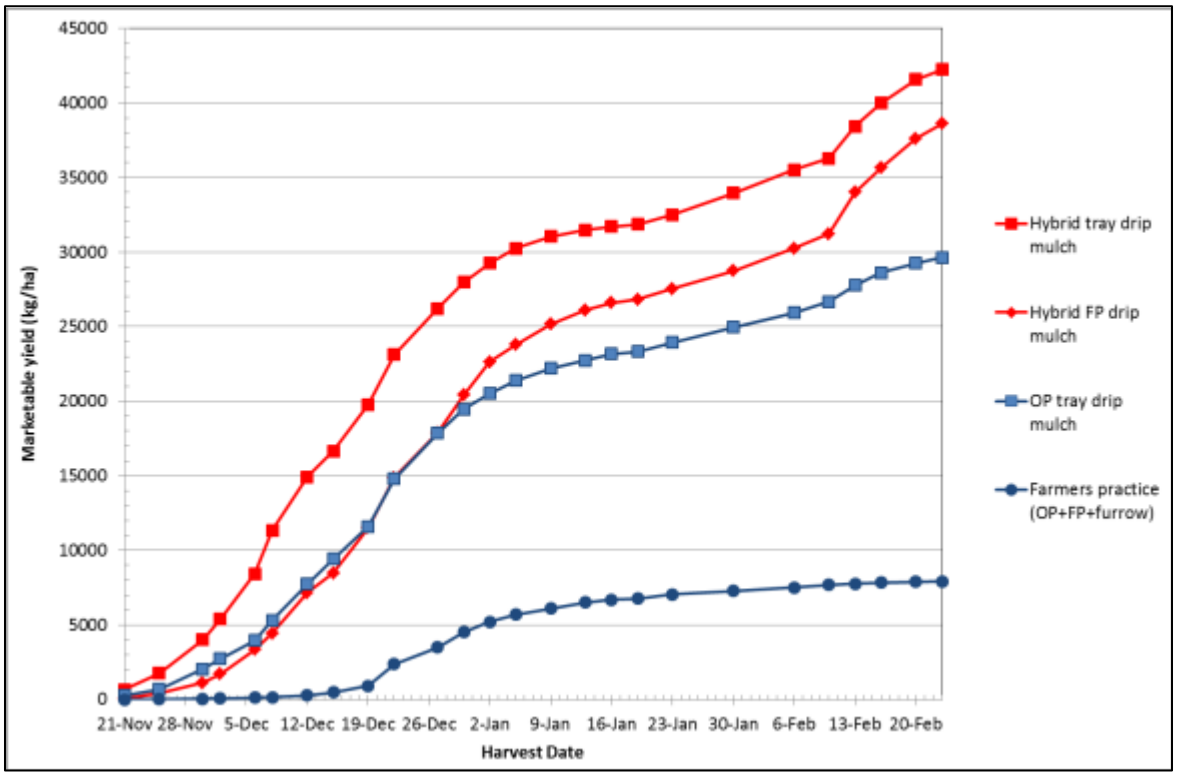

Figure 17. Marketable yield of bitter type African eggplant (kg/ha).

With sweet type African eggplant harvest of tray transplants started earlier than with bare root transplants (Figure 18). Farmers practice where bare root transplants were grown with furrow irrigation showed the latest start of harvest. All treatments showed a commercial harvest period till the end of February. Bare root transplants grown with drip and mulch showed a similar harvest pattern than tray transplants grown with drip and mulch. No difference between the OP variety and hybrid variety was observed. In February an increase in production again could be observed for tray transplants.

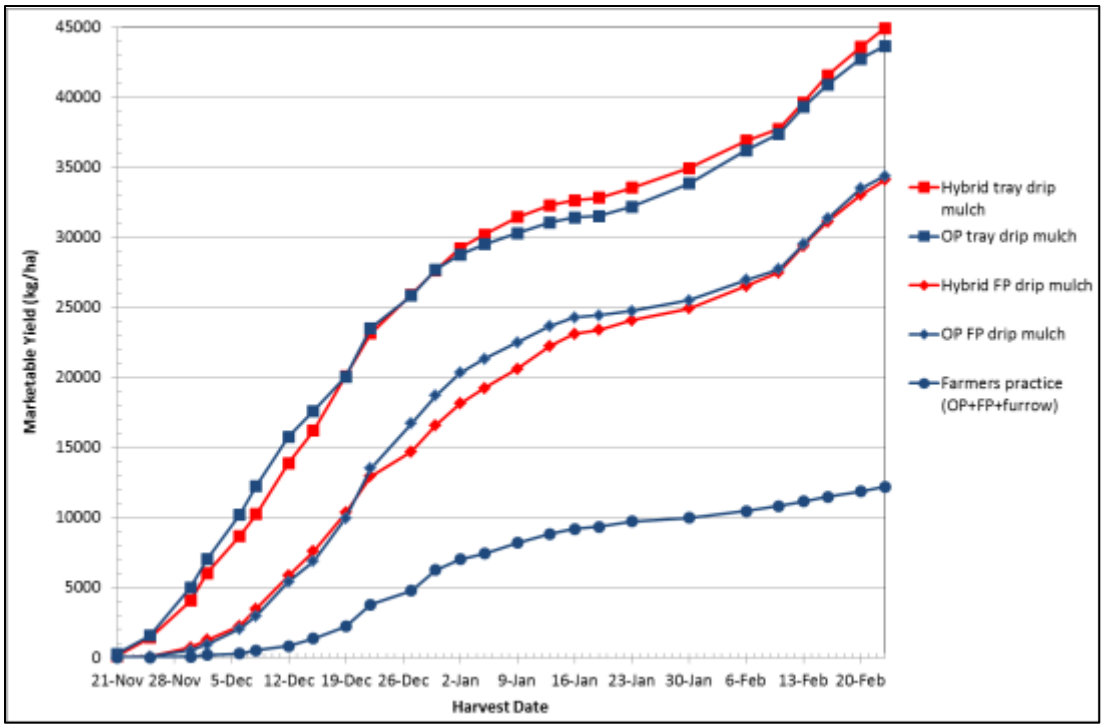

Figure 18. Marketable yield of sweet type African eggplant (kg/ha).

Since final plant density per plot was different at the time of harvest, more plants were lost with bare root transplants and furrow irrigation, also marketable yield per plant was calculated (Table 9).
Marketable production of cultivation with furrow irrigation was at both bitter and sweet type African eggplant lower than the production per plant of drip tape and mulch. With furrow irrigation tray transplants showed a higher yield than bare root transplants. With bitter African eggplant yield of the hybrid was higher than the yield per plant of the OP variety.

Table 9. Marketable yield (kg/plant).

		Drip irrigation		Furrow
Variety	Raising method	bare soil	mulch	bare soil
Bitter type				
Hybrid	Field	-	3.1	-
OP	Field	-	-	1.0
Hybrid	Tray	-	3.3	2.3
OP	Tray	2.0	2.3	1.5
Sweet type				
Hybrid	Field	2.5	2.9	-
OP	Field	2.2	2.9	1.4
Hybrid	Tray	2.6	3.6	-
OP	Tray	-	3.5	2.3

- = not demonstrated in the field.
p= <0.001; $LSD_{0.05}$ = 0.40

Harvest percentage of bare root transplants and furrow irrigation of the bitter African eggplant was 78% (Table 10). No significant differences between tray or bare root transplant were present. Also between irrigation method no significant differences were present. The hybrid variety showed a higher harvest percentage than the OP variety.
Harvest percentage of the sweet type African eggplant was 80% with OP bare root transplants and furrow irrigation. Tray transplants showed no significant different harvest percentage than with bare root transplants.

Table 10. Harvest percentage (% of total yield).

		Drip irrigation		Furrow
Variety	Raising method	bare soil	mulch	bare soil
Bitter type				
Hybrid	Field	-	89	-
OP	Field	-	-	78
Hybrid	Tray	-	88	86
OP	Tray	83	81	79
Sweet type				
Hybrid	Field	89	87	-
OP	Field	86	82	80
Hybrid	Tray	86	87	-
OP	Tray	-	81	83

- = not demonstrated in the field.
p=<0.001; $LSD_{0.05}$ = 3.2

Per harvest date percentage of marketable fruits differed more for OP varieties of both sweet and bitter type than for the hybrid variety (Figure 19). Between bitter and sweet type not much differences were present in harvest percentage.

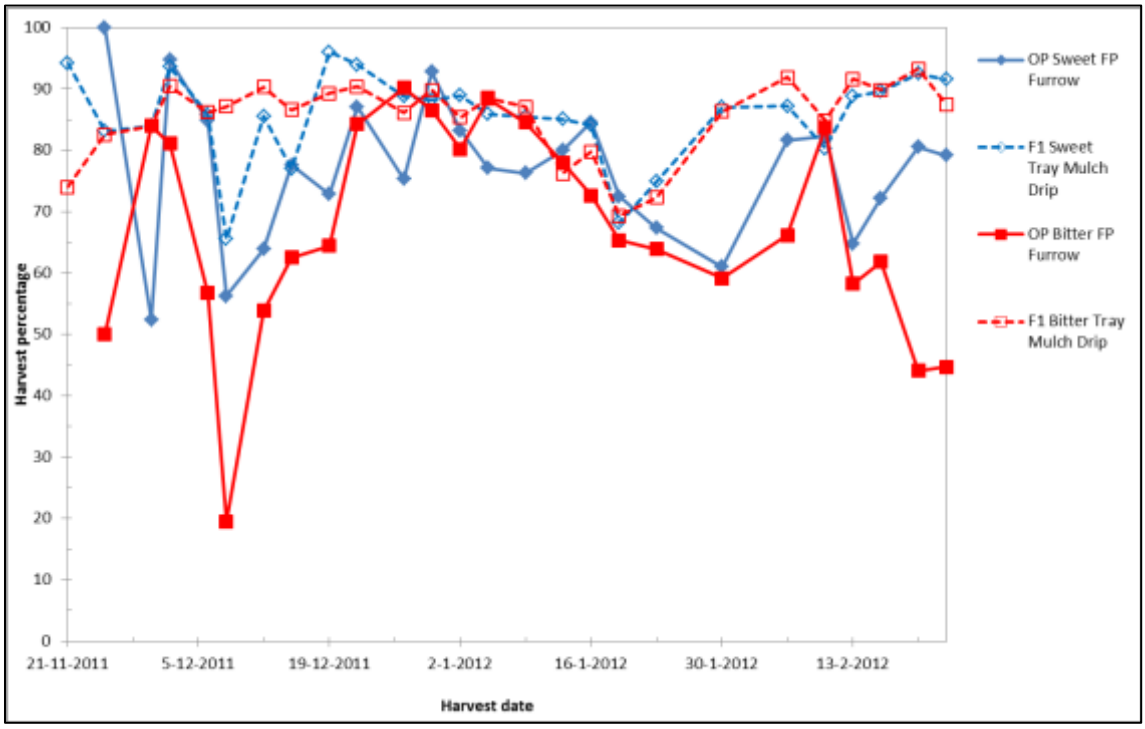

Figure 19. Percentage of marketable fruits per harvest date of African eggplant.

Most fruits, over 50%, were rejected due to disformed shape (Figure 20). Between different treatments no significant differences in percentage of rejected fruit classification were present.

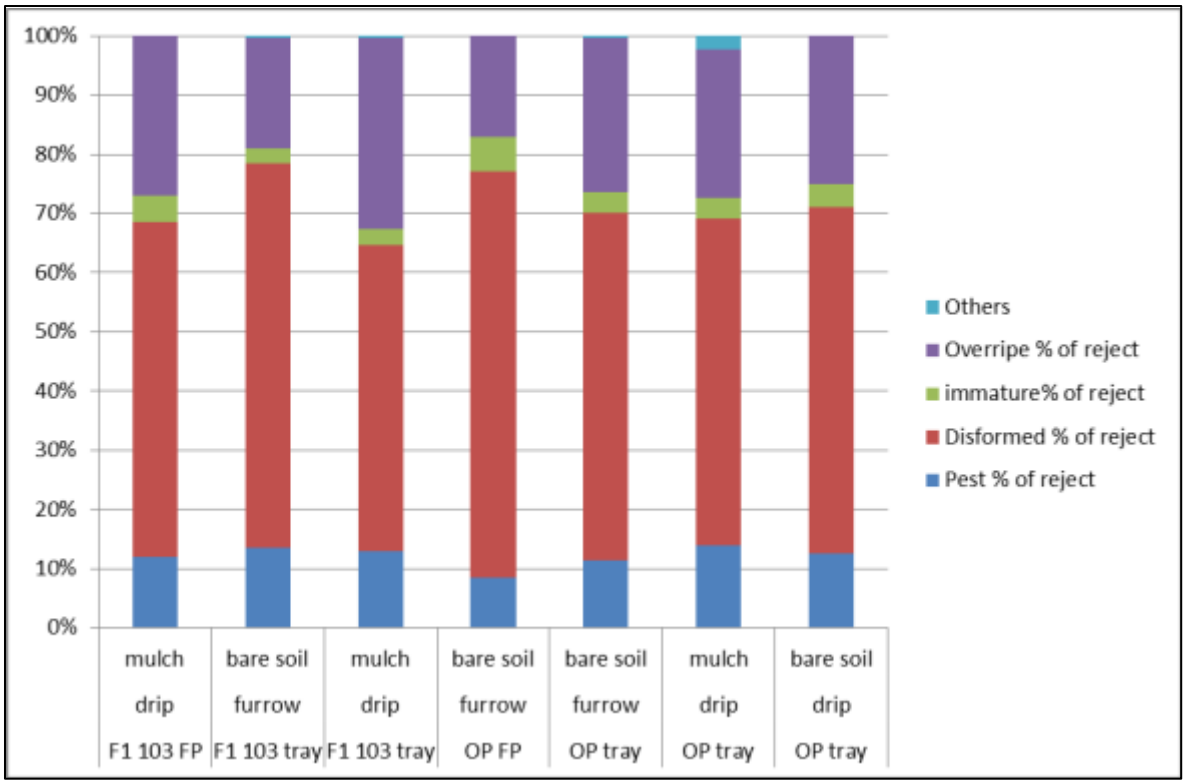

Figure 20. Rejected fruits per category of total number rejected fruits of bitter type African eggplant (%).

With sweet type African eggplant disformation of fruits was the most important reason for rejection with the hybrid variety (Figure 21). OP variety showed 40% of rejection due to disformation while with the hybrid variety this was 50 to 60%. The OP variety showed more overripe fruits. However, due to the lower harvest percentage of OP variety compared to the hybrid variety the absolute volume of rejected fruits due to disformation are for both OP and hybrid almost the same.

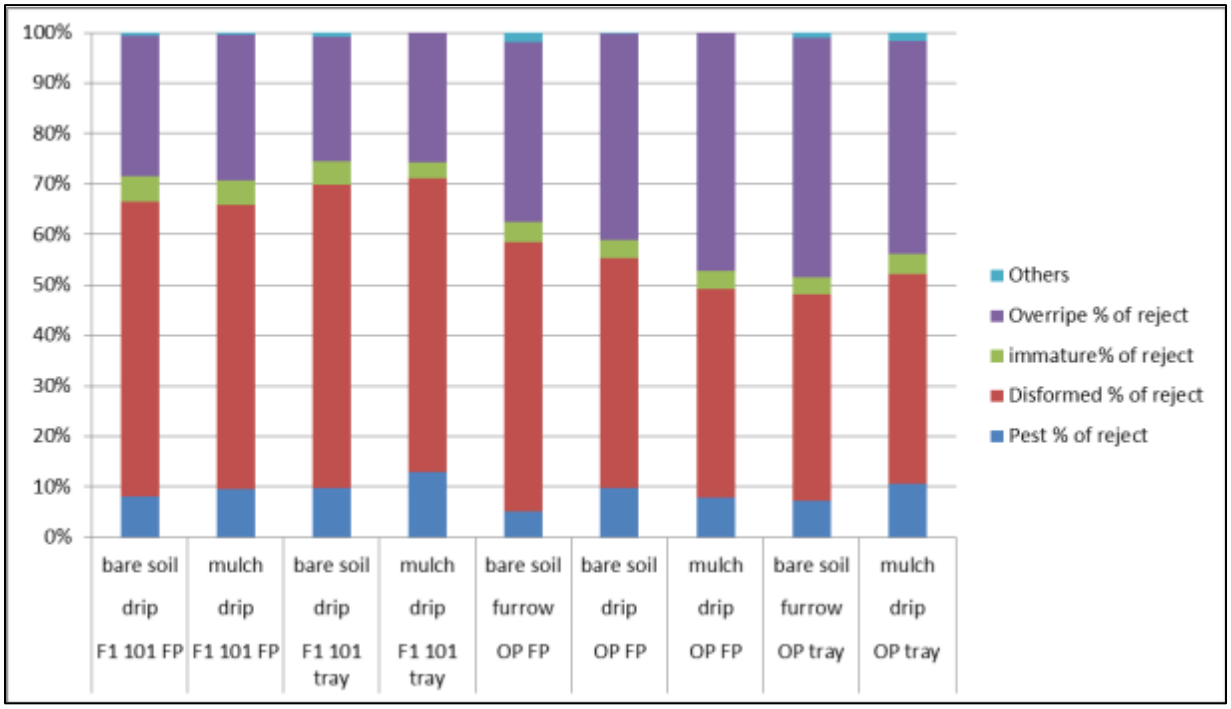

Figure 21. Rejected fruits per category of total number rejected fruits of sweet type African eggplant (%).

Average fruit weight of the total production was 23 g per fruit with farmers practice where bare root transplants of an OP variety were cultivated with furrow irrigation (Table 11). No significant differences between variety, raising method or irrigation were present with the bitter type. With the sweet type the lowest fruit weight was present with OP bare root transplants grown with drip tape irrigation only. No significant difference with driptape and mulch or with furrow irrigation were present. When grown with drip tape only the average fruit weight of the OP variety was lower than with the hybrid variety. At the other treatments no difference between OP and hybrid was present.

Table 11. Average fruit weight (g).

		Drip irrigation		Furrow
Variety	Raising method	bare soil	mulch	bare soil
Bitter type				
Hybrid	Field	-	23	-
OP	Field	-	-	23
Hybrid	Tray	-	24	23
OP	Tray	25	25	25
Sweet type				
Hybrid	Field	23	22	-
OP	Field	20	22	22
Hybrid	Tray	22	24	-
OP	Tray	-	23	24

- = not demonstrated in the field.
p=<0.00; $LSD_{0.05}$ = 2.0

Fruit weight differed per harvest date (Figure 21). At the first harvest date average fruit weight was 35 to 40 gram while at the last harvest dates average fruit weight was 15 to 20 gram. Sweet and bitter type showed no different fruit weight. Also between bare root transplants with furrow or tray transplants with mulch and drip tape no difference in fruit weight was present.

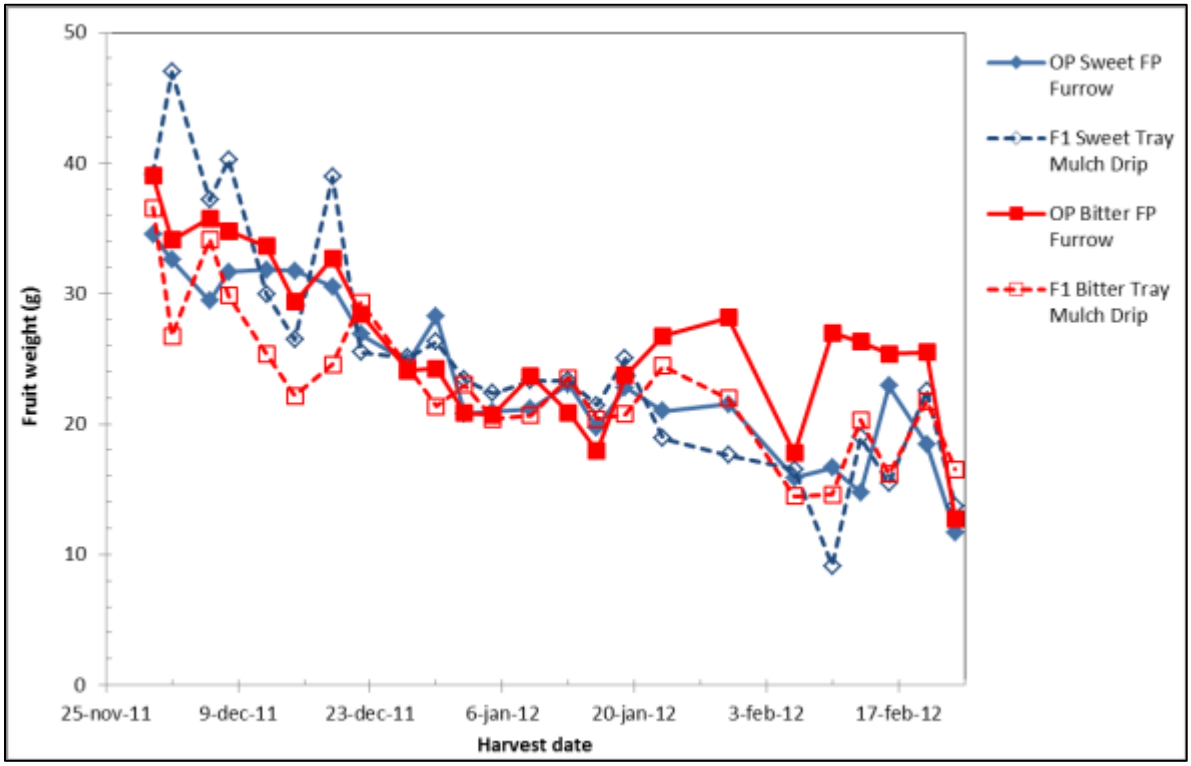

Figure 22. Average fruit weight per harvest date of African eggplant (g).

5.4 Cost – benefit analyse of African eggplant of current farmers cultivation practice

Data on African eggplant cultivation on farmers level were collected in the Arusha region. This was done to compare the results of the demonstration field with farmers results. Data was collected in two ways, per African eggplant type five farmers were interviewed about the cultivation while two other farmers were asked to keep daily records of the spend inputs and income (Table 12).
Between the two methods large differences in outcome were observed. When interviewed farmers could not recollect the exact yield and could only reply how many bags per week they had harvested on average. Total yield was calculated by multiplying this number with 10. For sweet type eggplant a yield of almost 26 t/ha and for bitter type eggplant a total yield of 18.5 t/ha was calculated in this way. Records showed that yield of sweet type was not more than 7.5 t/ha and for bitter type about 6.5 t/ha. Market price in all cases is around 200 Tsh/kg (0.1 USD/kg). Seed costs of farmers with sweet African eggplant was 92,838 Tsh/ha, while for the bitter eggplant farmers this was only 17,084 Tsh/ha. However, the sweet eggplant farmers had purchased transplants while the bitter eggplant farmers had bought seeds and raised their own bare root transplants.

Table 12. Overview of income, costs and profit of farmers, data collected with a survey and data collected through daily records.

	Survey Sweet type (n=5)	Recorded data Sweet type (n=2)	Survey Bitter type (n=5)	Recorded data Bitter type (n=2)	
Harvest period	4	3	4	3	months
Yield	25,791	7,497	18,533	6,667	kg/ha
Price	198	191	230	196	Tsh/kg
Income	4,713,350	1,433,877	4,297,069	1,343,075	Tsh/ha
Seed s	74,130	92,838	74,130	17,084	Tsh/ha
Fertilizers	714,284	182,145	876,101	137,847	Tsh/ha
Insecticides	50,870	37,290	44,353	37,764	Tsh/ha
Fungicides	14,497	21,391	16,309	35,083	Tsh/ha
Others (ploughing)	3,945	91,358	12,256	2,777	Tsh/ha
100% hired labour	1,532,079	1,022,583	1,655,977	835,716	Tsh/ha
Total costs	3,181,271	411,293	2,641,092	507,358	Tsh/ha
Profit	3,185,216	502,651	2,653,348	510,135	Tsh/ha
Return on investment	1.0	1.2	1.0	1.0	
Own labour	197	10	267	17	hr/ha
Hired labour	141	667	193	810	hr/ha
Total hrs	338	677	460	828	hr/ha
Own labour use	58	2	58	2	%
N use	232	78	271	60	kg/ha

Fertilizer costs are estimated much higher when farmers were interviewed compared to the recorded amount. The used amount of nitrogen was 60 to 78 kg/ha based on records, while based on the survey data more than 230 kg/ha nitrogen was applied. Labour need in hours was estimated lower by farmers when interviewed compared to the recorded number of hours needed for the crops. Labour costs on the other side were estimated higher when interviewed than the recorded labour costs. Interviewed farmers estimated a high share of family labour involved in the cultivation which was 58% while the records showed only a very limited share of family labour involved in African eggplant cultivation.
Due to these factors profit estimated by farmers when interviewed was quite higher than the profit calculated based on the daily records. Records showed that profit of both sweet and bitter type African eggplant is about 500,000 Tsh/ha. AVRDC data based on interviews too, showed a profit of 1200 USD/ha which is approximately 1,900,000 Tsh/ha which is lower than the survey data but still four times higher than indicated by the data based on daily records. Return of investment is in all cases about 1, meaning

that each shilling spend will return 2 shilling. Based on the data collected with the daily data recording the highest share in total cost is labour with about 60 to 70%. Fertilizer costs accounts for about 17%, crop protection 6-9% and seed costs for about 2%. In the case of transplant use the planting costs accounts for 9% in total costs. Cultivation of African eggplant in Ghana showed similar percentages, 70% labour costs, 12% fertilizer costs, 8.5% crop protection costs and 4% seed costs.

5.5 Economic analyse of treatments in the demonstration field.

Differences in production were observed between the different treatments. However, a higher production does not necessarily mean a higher profit. Depending on the investment and the final production and market price, an improved technique will result in a better profit or not. If the costs of investment are higher than the revenues based on yield times market price than the new technique will lead to a loss even if the final production in terms of kg/ha is higher than the original situation.

5.5.1 Costs of tested techniques

Seed price of hybrid varieties are not known yet and therefore no profit calculation could be made at this time. Only for the treatments with the OP variety some profit calculations were made.
Method of raising influences germination, with bare root transplant raising in field bed nurseries germination is about 35 to 50% while with tray transplants germination is 90 to 98% depending on the seed quality. Raising of bare root transplants is not capital intensive since not much inputs are required. Raising costs of a bare root seedling raised in a field bed is about 2 Tsh/seedling. The costs of raising a seedling in a tray including nursery costs is 100 Tsh/seedling. The higher costs are caused by investment in nursery construction, trays, potting soil and more labour. In the experiment a total number of 12,600 plants per hectare (acreage including paths and furrows) were grown. However, when raising transplants an additional 5 to 10% is present to ensure enough seedlings at transplanting and for possible replanting at empty places where plants have died. When 13,500 seedlings are raised for 1 hectare the cost is 81,000 Tsh with bare root seedlings of an OP variety (Table 13).

Table 13. Seedling costs per raising method of the OP variety.

	Field bed	Tray
Price per seed	1.5	1.5
Raising costs	2	100
Germination %	35	90
Cost price per seedling	10	113

Based on data collection amongst commercial African eggplant farmers a total of on average 752 hours labour is required (Table 14). Most time is spent on harvest followed by irrigation and weeding. Labour saving techniques on these aspects therefore can be worthwhile. With mulching and drip tape no data could be found for Tanzania. Based on experience in the experimental field estimated is that with drip tape labour on irrigation can be reduced by 90% and labour on weeding with 75%. To apply mulch in the field a total of 32 labour hours is needed per hectare.

Table 14. Total required time per activity recorded by farmers (n=4) in commercial African eggplant fields (hour/ha).

	Minimum	Maximum	Average
Land preparation	0	121	57
Sowing	4	4	4
Transplanting	17	72	41
Irrigation seedbed	42	42	42
Irrigation field	84	225	164
Fertilization	8	76	34
Crop protection	21	88	43
Weeding	100	167	142
Harvesting	117	408	227
Others	0	40	18
Total	652	956	752

Operational costs of fertigation with drip tape is quite expensive due to the amendment of the trace element boron and the water soluble phosphorus fertilizer to the irrigation water. Each application cost 231,000 Tsh/ha with the vegetative nutrient solution and 106,750 Tsh/ha with the generative solution (Table 15) . Cost per liter of the vegetative solution is lower than the generative solution but a higher volume is applied. A basal application with CAN is applied as well resulting a total cost of 2,842,700

Tsh/ha with drip tape fertigation. In the cost benefit calculations the investment in the drip tape installation itself is not included.

Table 15. Fertilizer costs of drip tape treatments.

	Vegetative fertigation	Generative fertigation
Fertigation costs per liter (Tsh/l)	3.85	4.27
Applied water volume per irrigation per hectare (l/ha)	60,000	25,000
Fertigation costs per application per ha (Tsh/ha)	231,000	106,750
Number of irrigation applications	6	10
Total fertigation costs (Tsh/ha)	1,386,000	1,067,500
Costs of basal application of 278 kg/ha CAN (27% N) at 1400 Tsh/kg	389,200	
Total fertilizer costs (Tsh/ha)	2,842,700	

With the furrow irrigation fertilizer is applied only as a broadcast application (Table 16). A basal application is applied with CAN and three split applications with urea is applied. This amount is already higher than what commercial African eggplant farmers are applying. Commonly only about 50 to 100 kg/ha nitrogen is applied while in the experiment 331 kg/ha is applied. Fertilizer costs of the broadcast application is 945,000 Tsh/ha.

Table 16. Fertilizer costs of furrow irrigation treatment.

	costs per ha (Tsh/ha)
Basal application of 278 kg/ha CAN at 1400 Tsh/kg	389,200
3 times split applications of 556 kg/ha Urea at 1000 Tsh/kg	556,000
Total costs (Tsh/ha)	945,200
Total applied N (kg/ha)	331

Use of plastic mulch costs about 900,000 Tsh/ha. Imported mulch cost 180 Tsh/m^2 and only the beds need to be covered so that per hectare only 5,000 m^2 mulch is needed. Local mulch might be even cheaper giving even higher profits.
When looking at the production costs of the different treatments one can observe that the farmers practice has the lowest costs (Figure 23 and 24). Total costs are below 2,000,000 Tsh/ha. When transplants are raised in a tray total costs increased to a total of more than 3,000,000 Tsh/ha. The most costly treatments are the mulching treatments with 6,000,000 to 7,000,000 Tsh/ha.

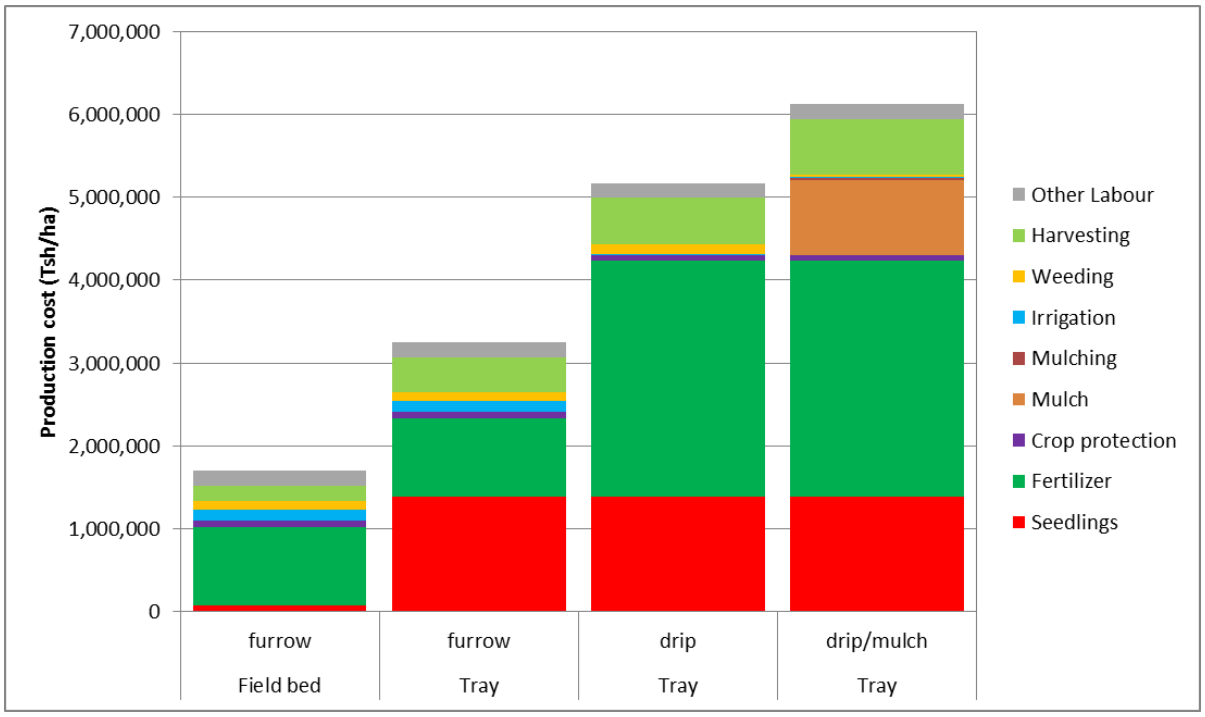

Figure 23. Production cost per item (material and labour) of Bitter type African eggplant (OP variety).

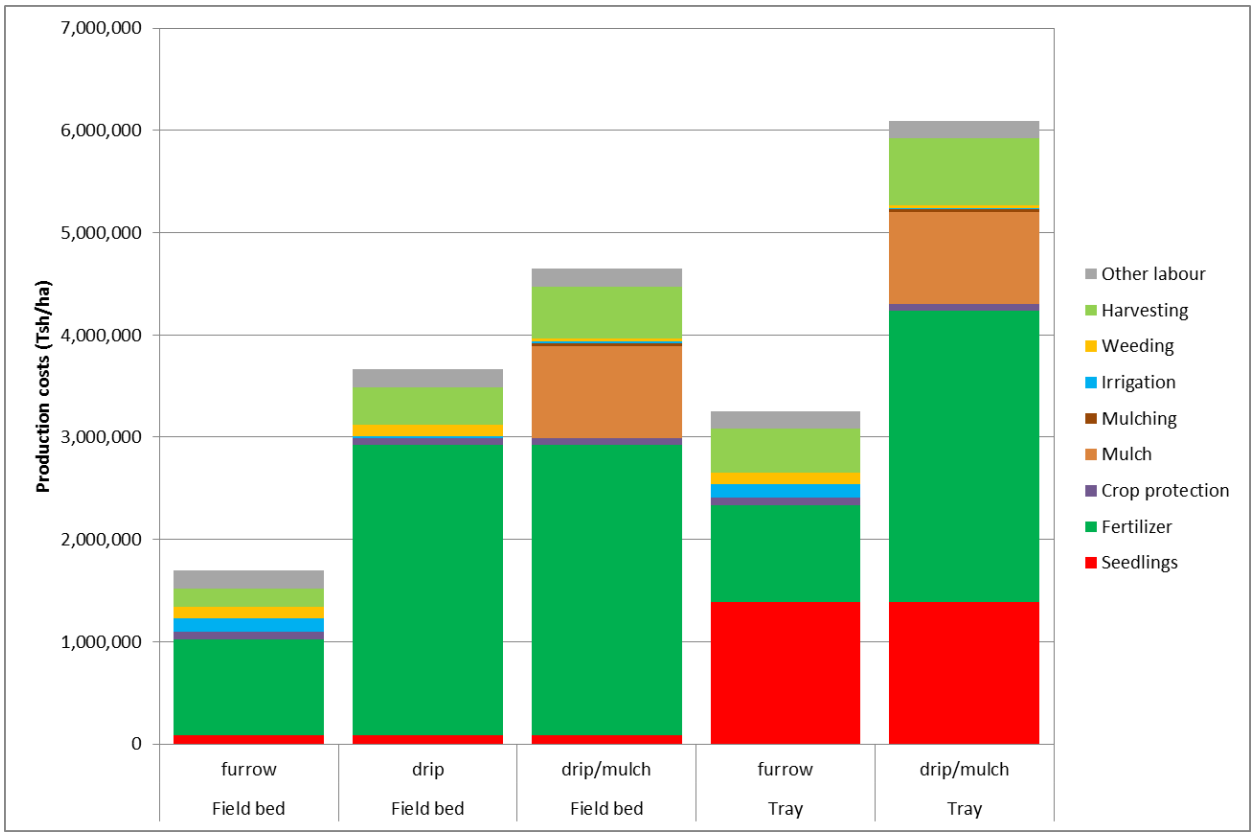

Figure 24. **Production cost per item (material and labour) of Sweet type African eggplant (OP variety).**

5.5.2 Profit of African eggplant with new cultivation techniques

Taking into account the investment costs and additional yield and a normal market price of 200 Tsh/kg (about 10,000 Tsh/bag) the farmers practice treatment of bitter type African eggplant showed a loss of 97,800 Tsh/ha (Table 17). Only when the OP variety was raised as a tray transplant but cultivated with the standard furrow irrigation a positive result was present. With raising of the OP variety on a tray and grown with drip/mulch the additional increase in yield and income did not outweigh the costs and resulted in a loss. Also when grown without mulch a loss occurred.

Table 17. **Yield (t/ha) and profit (Tsh/ha) of bitter type African eggplant with a market price of 200 Tsh/kg.**

Raising/variety/irrigation method			Yield	Income	Material costs	Labour costs	Profit
Field bed	OP	furrow	8	1,600,000	1,096,200	601,600	*-97,800*
Tray	OP	drip/mulch	30	5,920,000	5,203,200	914,240	*-197,440*
Tray	OP	furrow	19	3,700,000	2,405,700	839,950	454,350
Tray	OP	drip	25	4,940,000	4,303,200	862,610	*-225,810*

With sweet type African eggplant profit of farmers practice was 742,200 Tsh/ha with a market price of 200 Tsh/kg (Table 18). In general profit of sweet type African eggplant was higher than the profit of bitter type. With transplant raising in a tray of an OP variety and grown with furrow irrigation profit was three times higher than with raising as a bare root transplant. When cultivating with drip/mulch instead of furrow irrigation profit increased still with 100,000 Tsh/ha. Cultivation with drip only without mulch did not result in slightly higher profit than with furrow irrigation while when drip irrigation was applied with mulch showed a bigger increase in profit.

Table 18. Yield (t/ha) and profit (Tsh/ha) of sweet type African eggplant with a market price of 200 Tsh/kg.

Raising/variety/irrigation method			Yield	Income	Material costs	Labour costs	Profit
Field bed	OP	furrow	12	2,440,000	1,096,200	601,600	742,200
Tray	OP	drip/mulch	44	8,740,000	5,203,200	892,805	2,643,995
Tray	OP	furrow	29	5,780,000	2,405,700	850,184	2,524,116
Field bed	OP	drip/mulch	34	6,880,000	3,893,700	754,372	2,231,928
Field bed	OP	drip	25	4,980,000	2,993,700	672,563	1,313,737

Break-even market price for farmers practice (use of bare root transplants of an OP variety and grown with furrow irrigation) of bitter type African eggplant is about 200 Tsh/kg or 10,000 Tsh/bag (Figure 25). When using tray transplants the breakeven price is approximately 175 tsh/kg and possible profits are higher than farmers practice. Cultivation of African eggplant with drip and mulch possible profits are higher while the breakeven price is about similar to that of the current farmers practice, but with lower prices the losses can be higher too.

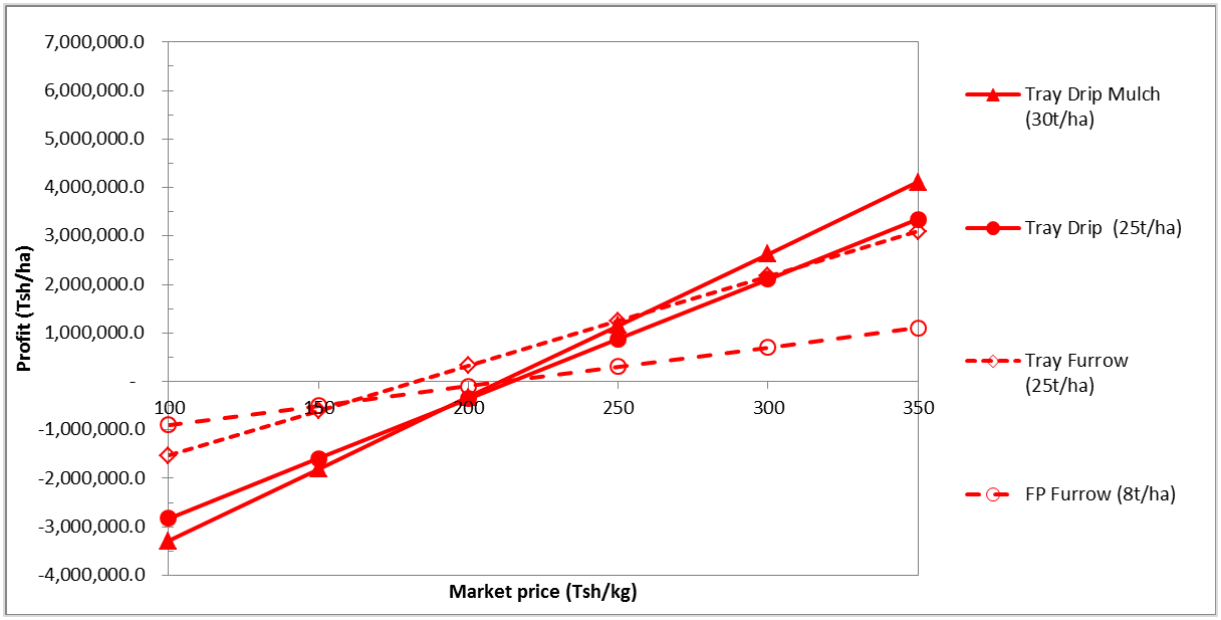

Figure 25. Profit with different market prices for the OP variety of bitter type African eggplant with different cultivation treatments.

With sweet type eggplant the breakeven price for farmers practice is about 150 Tsh/kg (Figure 26). The other cultivation methods showed lower break even prices and also higher possible profits with increasing market prices.

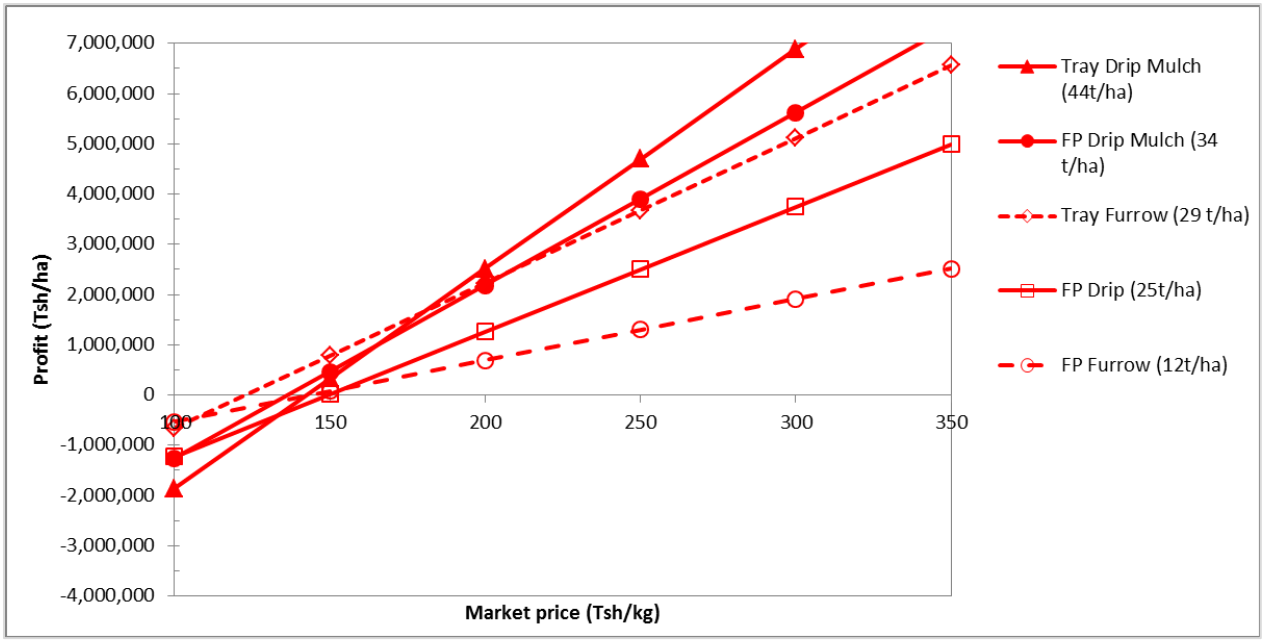

Figure 26. **Profit with different market prices for the OP variety of sweet type African eggplant with different treatments.**

With farmers practice (bare root transplants of an OP variety and furrow irrigation) the break even production has to be 10 t/ha when the market price is 200 Tsh/kg (Figure 27).
With OP tray transplants and furrow irrigation the break-even production should be about 30 t/ha when the market price is 100 Tsh/kg or slightly below 20 t/ha when the market price is 200 Tsh/kg.

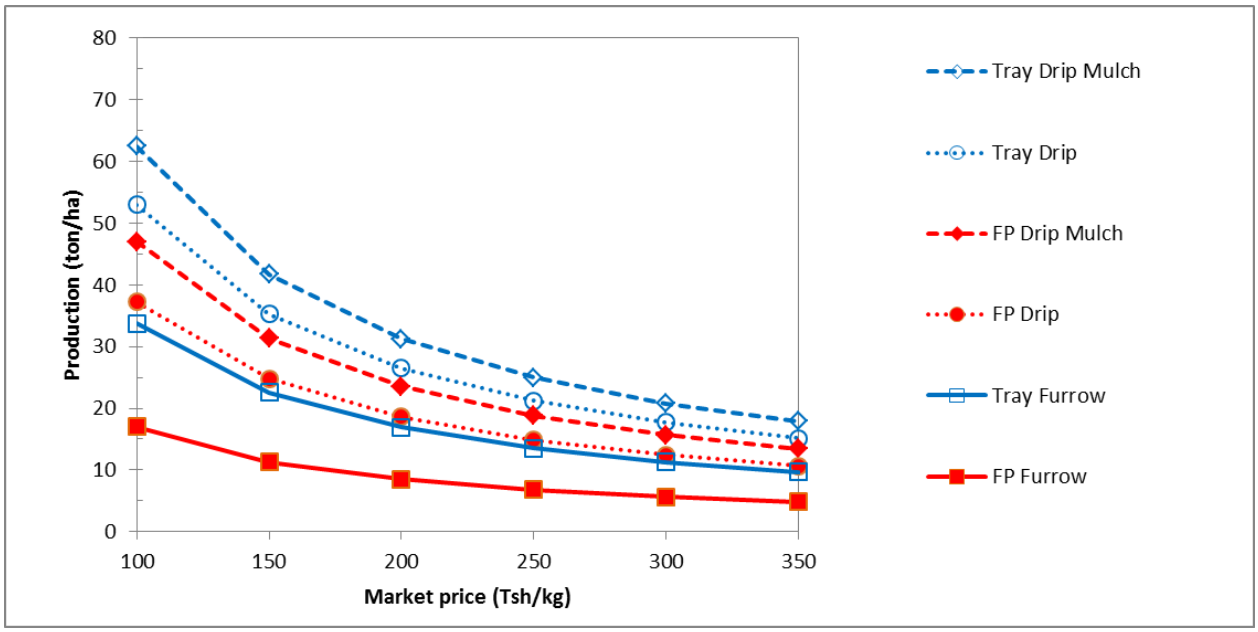

Figure 27. **Required break even production for different cultivation methods with the OP variety of African eggplant.**

6 Visits to demonstration field

Frequent visits to the field were organised to give farmers from nearby the chance to observe regular the progress of crop growth and performance of the different treatments. A total of approximately 250 farmers have visited the field and observed the performance of the different treatments.
Besides these frequent informal visits two formal field visits for farmers and other relevant stakeholders such as extension service officers, researchers, suppliers of horticultural inputs, to the demonstration field were organized. A first visit was organized on November 29, 2011. It was a successful event and farmers were keen on observing the results in the field. Based on their observation they stated that the hybrid crops grown with drip tape and mulch performed the best.
They indicated that they would like to start trying out the cultivation with hybrid varieties and inquired where they could buy seeds of these varieties. They were informed that the first commercial hybrid variety would be available in 2012.
Another point of discussion was whether plastic mulch could be used without the drip tape installation. This because investment costs in drip tape are rather high and if the mulch could be used in combination with furrow irrigation this already could lead into an improvement. Tests at other locations (countries) have indeed show that this is possible and it would be a good idea also to demonstrate this in Arusha.
The farmers raised also the idea to obtain a gravity operated drip tape unit for a small plot size. With this they could produce a higher amount per surface unit and therefore generate a higher income.

Figure 28. Visit of farmers to the demonstration field.

7 Conclusions

The use of hybrid varieties in combination cultivated with improved techniques results in higher yields. However, a farmer must not look only to yield but has to evaluate if the additional profit compared to his current situation outweighs the investment in improved techniques. Besides, the new techniques requires capital to invest in these and sometimes the cash involved is quite high. Expected is that most smallholder farmers will lack the capital for this. Therefore it is essential to look into possibilities to provide the farmers access to capital.

Bitter African eggplant and sweet African eggplant

In this experiment the yield of bitter type African eggplant was on average 75% of that present with sweet type African eggplant. A survey performed in 2011 also indicated that in farmers' fields yield of bitter type eggplant is about 75% of the sweet type.

Yield of the bitter OP variety using farmer field bed raising with furrow irrigation was 8 t/ha while sweet OP variety showed a yield of 12 t/ha under the same treatments. Also at other treatments that were present at both bitter and sweet type African eggplant, the yield of the sweet type was equal or higher than the yield of the bitter type.

Compared to current farmers practice yield of the OP varieties grown with furrow irrigation was similar. In commercial fields the average yield achieve by farmers is about 7 t/ha.

Although production of the bitter type is in general lower than the production of the sweet type, profitability is about the same since market price of bitter type ranges from 6 to 17 thousand Tsh per 50 kg while prices for sweet type are on average lower ranging between 5 to 15 thousand Tsh per 50 kg

Hybrid or OP varieties

The use of seeds from hybrid varieties resulted in higher yields, but only with the bitter type African eggplant. No significant differences in yield were observed when growing sweet type African eggplant.

In this experiment seeds of certified OP variety were used which showed a high germination percentage. In practice farmers mostly use seeds they have saved from a previous crop. The quality of those seeds is quite low since no efficient selection or seeds treatment has been taken place by the farmer in the field. Seed germination and viability therefore can be quite low. Germination of the hybrid varieties tested in this experiment was dissatisfactory, because efficient hybrid seeds production was not yet present for African Eggplant. However, one must consider the fact that the used hybrid varieties are in a test phase still and as a reason it is hard to get hold to enough seeds with good germination characteristics. Expected is that later batches are available for commercial purposes that have excellent germination characteristics.

Seed price of hybrid varieties is expected to be higher than that of OP varieties. Not known yet is what the price will be. Advantage of hybrid varieties are quite clear, firstly due to a better germination of hybrid seeds difference in price with OP seeds will be reduced since less seeds are needed with a hybrid variety. Besides, the yield of hybrid varieties is in most cases significant higher than the yield possible with OP varieties thus more than sufficient compensating for higher seed costs. Hybrid varieties might also show an earlier start of production. Although not evaluated in this demonstration field, another positive effect of hybrid varieties is the pest and disease resistance and better uniformity. The only disadvantage to smallholder farmers is that for each cultivation investment needs (cash) for seeds are higher than before while farmers with saved seeds don't require capital. Taking into account the current total capital requirement for cultivation of African eggplant including labour costs when using OP varieties the fraction of seed costs in total costs is about 2%, or 17,000 Tsh/ha. A higher investment in seeds is expected when growing African eggplant using hybrid seed use but this will be no doubt more than rewarding.

Tray or bare root transplant

With tray transplants higher yields were observed than with bare root transplants. The production of tray transplants was high enough to compensate for the higher costs needed for tray transplants. Also seed use efficiency is higher with tray transplants than with bare root transplants. In this experiment percentage usable transplants with bare root transplants was on average 34% while with tray transplants this was 89%. Raising costs of bare root transplants is about 2 Tsh per seedling while for tray transplants this is about 100 Tsh per seedling. Higher costs for tray seedlings is because of higher investment costs in materials such as a nursery construction, trays and potting soil but also because of higher labour costs. Per seedling 98 Tsh additional income is required meaning that with a market price of 200 Tsh/kg an increase of at least 0.5 kg per plant is required to break even.

Furrow irrigation or drip tape fertigation

With drip tape fertigation substantial higher yields were obtained. Compared to furrow irrigation yield may increase with 30 to 100%. With drip tape savings are possible on water use and on labour costs. In situations where water use is restrictive or taxed than the farmers can profit more from the drip tape system. Compared to furrow irrigation with optimal water volumes only 25% of the needed water volume is required with drip tape to have a similar or better crop production.

In this experiment the possible yield increase outweighed the material costs for drip tape fertigation. However, not included yet are the investment costs in a drip tape system.

In this experiment drip tape irrigation was combined with fertilizer application. Total fertilizer costs were almost 3,000,000 Tsh/ha with fertigation compared to 945,000 Tsh/ha with broadcast application only. Based on the costs in relation to possible yield increase it seems that this method is too expensive. Proposed is to apply as much as possible fertilizer to the crop with broadcast applications while only simple nitrogen fertilizers can be applied with drip tape. With this the farmer can still use cheap fertilizers and profit from the more steady supply of nitrogen to the crop with drip tape technique.

Mulch with drip tape or bare soil

Yield increases with 45 to 180 % compared to the yield present with furrow irrigation and bare soil when using drip tape in combination with mulch. With mulch moisture is better retained in the soil resulting in a more steady crop growth. Another effect is a reduced weed growth in the beds leading to less competition and also leading to reduced labour requirement for weeding.