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Kenya Agricultural & Livestock Research Organization

THE KENYA CEREALS ENHANCEMENT PROGRAMME – CLIMATE RESILIENT AGRICULTURAL LIVELIHOODS

(KCEP-CRAL)

COMMON DRY BEAN EXTENSION MANUAL

SUPPORTED BY FUNDS FROM EU

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Disclaimer
The information presented in this manual is for advisory use only. Readers using the manual should verify details that relate to their agro-climatic zones from their area agricultural extension officers.

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KALRO Secretariat
P O Box 57811-00200
Nairobi, KENYA
Email: directorgeneral@kalro.org Tel. No(s): +254-722206986/733333223

Edited by: Esilaba, A.O., Nyongesa, D., Okoti M., Otipa M. and Wasilwa L.

Compiling Authors: Macharia D., Waithaka M., Otipa M., Esilaba A. O., Nyongesa D., Okoti M., Mutuma E., Kathuku-Gitonga A.N., Amata, R., Too A., Karanja J. K., Mutisya D., Njunie M., Mulli B. and Wasilwa L.

Production Editors: Mukundi K. T, P. Maina and K. Nyabundi

Design and layout: Nyaola E. A and J. Njeru

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We also thank the researchers, farmers and stakeholders who participated in the project for their support in setting up trials, collecting and processing the data and thus generating large amounts of knowledge and information that KCEP-CRAL has packaged and shared through scientific papers, in seminars and in reports among others. The support of technical officers, laboratory personnel, administrative and support staff is also appreciated as it contributed to the success that the project achieved.

FOREWORD

Kenya Agricultural and Livestock Research Organization (KALRO) is one of the key partners in the Kenya Cereals Enhancement Programme - Climate Resilient Agricultural Livelihoods Window (KCEP-CRAL) Programme funded by the European Union (EU) and implemented by the International Fund for Agricultural Development (IFAD). KALRO participation in this programme is based on proven experience and expertise in agricultural research. Within the programme, KALRO handles the research component, conducting on station and on farm trials, develops farmer recommendations together with training materials for extension staff and service providers and conducts the training. The implementation of KCEP-CRAL is in thirteen (13) counties namely Nakuru, Nandi, Trans Nzoia, Kakamega, Bungoma, Kitui, Tharaka-Nithi, Embu, Machakos, Makueni, Taita Taveta, Kwale and Kilifi.

KCEP-CRAL focuses on the three leading rain-fed cereals (maize, sorghum and millet) and associated pulses (beans, green grams, cowpeas and pigeon peas). The programme's overall objective is to contribute to the reduction of rural poverty and food insecurity of smallholder farmers.

Through this manual, the programme will provide a comprehensive guide to extension officers, service providers and lead farmers on how to successfully produce cereals and pulses in Kenya. The manual is a useful training and reference material for extension officers and other stakeholders seeking to enhance the capacity of farmers, increase commercialization for food security and promote gender inclusion and participation along the commodity value chains.

Initial lessons learnt in this project indicate that enhancing the capacity of the extension staff and service providers has improved uptake of new technologies for dry land farming. It has opened up more land for farming through use of conservation agriculture in areas that hitherto were not under agriculture. Besides easing the pressure on previously arable land, farmers in the project areas have been trained to use alternative disease and pest management regimes using Integrated Disease and Pest Management and Push pull technologies for persistent pests of economic importance.

On behalf of KALRO, I am grateful to the European Union for supporting this project through the IFAD and KCEP-CRAL of the Ministry of Agriculture, Livestock, Fisheries and Cooperatives (MoALF&C). I also appreciate the excellent coordination of the whole process by the KCEP-CRAL Secretariat led by Dr Anthony O. Esilaba, MoALF&C and other partners, scientists in participating centres, Knowledge, Information and Outreach Unit team and secretarial staff. It is my hope and desire that in using this manual, the expectations of all stakeholders will be met.

Eliud K. Kireger, (PhD, OGW)

DIRECTOR GENERAL, KALRO

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ABBREVIATION AND ACRONYMS

AEZ	Agro-ecological zones
°C	Degrees Celsius
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GLP	Grain Legume Research Project
g	Grammes
ha	Hectare
IFAD	International Fund for Agricultural Development
IPM	Integrated Pest Management
KALRO	Kenya Agriculture and Livestock Research Organization
KCEP-CRAL	Kenya Cereals Enhancement Programme - Climate Resilient Agricultural Livelihoods Window
kg	Kilogram
KSC	Kenya Seed Company
MOALF&C	Ministry of Agriculture, Livestock, Fisheries and Cooperatives
NCPB	National Cereals and Produce Board
ppb	parts per billion

1 INTRODUCTION/ BACKGROUND

Pulses, or grain legumes in general, are an essential source of supplementary protein to daily diets based on cereals and starchy for a predominantly vegetarian population and those who cannot afford expensive animal protein. Pulses are therefore often regarded as "poor man's meat". They provide energy, protein, essential minerals, vitamins and several compounds considered beneficial for good health. Their cultivation enriches soil by adding nitrogen, and improves the physical, chemical and biological soil properties. They are also well suited to diverse environments and fit in various cropping systems owing to their wide adaptability, low input requirements, fast growth, nitrogen fixing and weed smothering ability. Their short growing period and photoperiod sensitivity make them suitable for crop intensification and diversification. Notwithstanding their high production potential, their productivity is generally low as these are cultivated on poor lands, with no or little inputs, and are susceptible to several abiotic and biotic stresses.

Dry bean (*Phaseolus vulgaris* L.) is the most important pulse crop in eastern and southern Africa where it is recognized as the second most important source of human dietary protein and third most important source of calories of all agricultural commodities produced in the region. In Kenya, beans ranks second to maize in importance as food crop. It is a major source of crucial proteins (20%), energy (32%), vitamins A and B complex and generous amounts of micro-nutrients such as iron and zinc which are deficient in diets among the poor, particularly pregnant women and children in Africa.

Bean production is mainly at subsistence level by small-scale farmers with limited commercialization. Average yield of beans in Kenya is very low, which is primarily due to continuous cropping with low or no fertilizer inputs, unfavorable climatic conditions, poor agronomic practices and lack of access to high yielding varieties. Beans yield and quality can be improved through the use of improved varieties, balanced fertilizers and also by managing the organic manures properly.

Smallholder grain farmers in Kenya face two key interrelated challenges after harvesting their crop. They experience poor grain handling and management, leading to up to 30% of post-harvest losses contributing to national shortage in food supply. Losses are some of the major reasons why Kenya continues to be insufficient in food supply even when crop yields and land under cultivation have been increasing. Additionally, due to lack of knowledge on appropriate handling and storage, most farmers sell their grain at low prices during harvesting. This forces them to buy grain for family consumption at higher prices later.

Challenges facing Bean production

Despite the many benefits, bean production still faces the following challenges.

Poor quality seeds

Normally farmers recycle or buy seed from neighbours and/or local grain stores and they rarely sort before planting. The varieties of these seeds cannot be verified, making it difficult to achieve full potential of known improved varieties.

Since virus infection of bean crops is widespread, the bean seeds farmers use for growing the next crop are often virus infested.

Soil degradation
Soil fertility has been declining due to intensive land use and low input application. The major soil fertility related problems include low available Nitrogen (N) and Phosphorus (P) and soil acidity. Farmers rarely apply fertilizers or manure when planting beans. These result in low yields compared to full potential of specific varieties.

Poor husbandry practices
Farmers rarely use inputs in bean production and disease control is minimal.

Postharvest losses
A significant amount of beans is lost through mould especially during drying and storage. Mould development result from insufficient drying of beans and the exposure of the dried beans to water or humidity during storage. Poor sorting of beans is another quality problem. Different varieties, sizes, stones and other waste from threshing are always found mixed with the beans.

1.1 Ecological requirement

Ecological factors considered include altitude; rainfall and soil ambient temperature.

1.1.1 Altitude

The crop grows from an altitude of 600 to 2700 masl. In Kenya beans grow best in altitude above 600 masl because below this, high temperatures cause flower and pod dropping leading to poor fruit setting and hence reduced yield. There are also high incidences of diseases such as; bean rust, and bean anthracnose below this altitude. Above 2700 masl, there is the problem of frost damage. Altitudes between 900-2100 masl is ideal.

1.1.2 Rainfall

The crop is mostly cultivated under rain fed conditions. It requires a minimum of 400 to 500 mm of rain during the growing season, but an annual total of 600 to 1500 mm is considered as ideal. Beans require well-distributed rainfall. Too much rain and long spells of drought lead to reduced yields. Beans are not drought tolerant hence they require moist soils throughout the growing period. Excessive rainfall during flowering causes flower drop and increased disease incidences. Medium rainfall is thus required during flowering and pod set. Dry weather is required during harvesting.

1.1.3 Soil type

Although beans can be grown on practically all soil types, deep, well drained sandy loam soils with high organic matter are ideal. Beans grow well in soils with a depth of at least 90 cm that have no mineral and water deficiencies. With sandy soils, problems of low fertility or nematode damage can occur. They can grow in soil with a pH range of 5.0 - 7.5. Below pH 4.5, plant growth is impaired through limitation of development of the *Rhizobium* bacteria that are responsible for the nitrogen fixation. The crop also performs poorly in compacted, alkaline or poorly drained soils.

1.1.4 Temperature

The bean crop thrives in a warm climate at optimal temperatures of 18 to 24 °C. The maximum temperature during flowering should not exceed 30 °C. High temperatures during the flowering stage lead to dropping of flowers, a low pod set, and malformed beans resulting in yield loss. Day temperatures below 20 °C will delay maturity and seed formation causing pods to mature empty. The crop is very sensitive to frost and minimum temperatures should not go below 13 °C.

2 KEY OPERATIONS

2.1 Pre-field operations

2.1.1 Varietal selection

There are many bean varieties that are recommended for production in different agro-ecologicals zones in Kenya as described in Table 1. Before growing a new variety, it is necessary to verify its sources and agro-ecological requirements. Some varieties do well on high altitudes while others in low altitudes; varieties from arid areas may not perform well in humid areas. Some varieties are tolerant to drought and are, therefore, more suitable for drought-prone environments. When selecting a variety, in addition to its yield potential under prevailing conditions, special considerations should be given to resistance or tolerance to prevalent pests and diseases.

Table 1: Recommended bean varieties

Variety name/code	Owner(s)	Maintainer Source Production and seed	Optimal altitude Range (masl)	Duration to maturity (months)	Grain Yield (90kg bags per acre)	Special Attributes
Mwitemania (GLP x 92)	KALRO/ KSC	KALRO/ KSC	900-1600	2- 3	6- 8	Drought tolerant
Rosecoco (GLP 2)	KALRO/ KSC	KALRO/ KSC	1500-2000	2 - 3	8- 10	High yield, wide adaptation. Attractive seed colour. Good taste
Mwezi Moja (GLP1004)	KALRO/ KSC	KALRO/ KSC	1200-1600	2 - 3	5.3 - 6.6	Good performance in dry areas Early maturity. Tolerant to drought and bean fly
New Mwezi Moja (GLP-X 1127)	KALRO/ KSC	KALRO/ KSC	1000-1500	2.5-3.0	4.4 - 6.6	Wide adaptation Resistant to bean common mosaic virus and tolerant to rust
Canadian Wonder (GLP-24)	KALRO/ KSC	KALRO/ KSC	1200-1800	3 - 3.5	5.7- 8	Moderately resistant to angular leaf spot
Red haricot (GLP-585)	KALRO	KALRO	1500-2000	2.5 – 3.0	4.4 - 6.6	Suitable for high rainfall areas. Resistant to bean common mosaic virus

Variety name/code	Owner(s)	Maintainer Source Production and seed	Optimal altitude Range (masl)	Duration to maturity (months)	Grain Yield (90kg bags per acre)	Special Attributes
New Rosecoco	University of Nairobi	University of Nairobi	1100-2000	2.5-3.0	5.7-10.2	Upright growth habitat, Early, Moderate resistance to rust, common bacterial blight, angular leaf spot, anthracnose, bean common mosaic virus & necrotic, Large grains
Wairimu Dwarf	KSC	Simlaw Seeds	500-1700	2.5-2.8	6.6 -7.7	Early, Heat tolerant; Good for maize intercropping, excellent cooking qualities
Kat/Bean 1 Katheka	KALRO	KALRO-Katumani	1000-1800	2.5	5.3 - 6.6	Early maturing
Kat-Bean 9	KALRO	KALRO-Katumani	900-1600	2.5-3.0	4.4 - 8	Tolerant to heat
Kat X56	KALRO	KALRO-Katumani	900-1800	2.5-3.0	6.6- 8	High yielding
Kat X69	KALRO	KALRO-Katumani	1200-1800	2-3	6.6- 8	High yielding
KATRAM	KALRO	KALRO-Katumani	900-1600	2-2.5	7- 8	Drought tolerant High yielding Large red mottled Highly resistant to: Bean rust, Bean Common Mosaic Virus (BCMV) and Bean Common Mosaic and Necrotic Virus (BCMNV). Moderately resistant to: Angular leaf spot, Anthracnose, Common bacterial blight and Web blight

Variety name/code	Owner(s)	Maintainer Source Production and seed	Optimal altitude Range (masl)	Duration to maturity (months)	Grain Yield (90kg bags per acre)	Special Attributes
KAD 02 (Nyota)	KALRO	KALRO-Katumani	900-1800	2-2.5	6- 7	Drought tolerant Early maturing, High grain iron (>95 ppm) and zinc (>39ppm) content. Low phytic acid (1.25mg/g) content, cook fast and good pod clearance
KK 15	KALRO	KALRO-Kakamega	1200-1800	2 – 3	6.6- 8	Tolerant to root rot
KK 8	KALRO	KALRO-Kakamega	1200-1800	2 – 3	6.6- 8	Tolerant to root rot
KK 22 (RWR 719)	KALRO	KALRO-Kakamega	1500-1800	2.5 - 3	8- 8.8	Tolerant to root rot
EMBEAN14 (Mwende)	KALRO	KALRO Embu	1200-2400	3	11.1	Tolerant to Angular leaf spot (ALS), Root rots, Rust and Anthracnose Sugar bean – Rosecoco market type) Medium seeded High potential to fix nitrogen
Nyota	KALRO	KALRO Katumani	900-1800	2.5- 3	6 - 7	Drought tolerant High iron content >95ppm High zinc content>39ppm
Chelalang'	Egerton	Egerton	900-1600	2.5 - 3	10 - 12	High yielding
Ciankui	Egerton	Egerton	900-1600	2.5 - 3	4.4 - 6.6	High yielding
Tasha	Egerton	Egerton	1500-2000	2.5-3.5	8 -10	High yielding

Source: KEPHIS National Crop Variety List – Kenya; hppts/www.kephis.org

2.1.2 Seed selection and treatment

Use of healthy seeds is important to ensure good development of the crop. For successful production of beans, use certified seed. This production cost factor is slight when compared to probable yield losses due to disease or poor stand. Low-quality causes poor and uneven stand, resulting in uneven maturity, harvesting problems and yield losses.

Benefits of using certified seed are:

- Have high germination percentage.
- Guaranteed true to type which ensures uniformity.
- Guaranteed free of weed seeds and foreign matter.
- Guaranteed virus and disease free seeds.

Farmers may select from their stocks of bean harvest. Beans should be well sorted and only the best should be used for planting. Seeds should be selected carefully in order to avoid spreading seed-borne diseases like bean mosaic viruses. Seeds for propagation must only be taken from healthy plants and dried under optimal conditions. Bright sunlight has a certain disinfecting effect. Therefore, beans must be turned regularly during drying to benefit from the sunlight. Optimal germination conditions help the young plants overcome early infestations.

Good quality bean seed has the following properties:

- A high germination rate
- Pure: all seeds are of the same variety and of the same size
- Clean: not mixed with foreign matter such as stones or dirt, or other seeds
- Not damaged: broken, shriveled, or insect damaged
- Not rotten or mouldy, discolored; may be diseased.

2.1.3 Seed dressing

Selected seeds must be dressed with appropraite insecticides such as Thiram or Poncho at the rate of 3g per kg of seed or Apronstar at the rate of 5 g/kg of seed. This protects them against pests and fungal diseases. Treated seed is unfit for human consumption and should be planted immediately. Do not inhale or allow contact with the skin, wash hands with soap immediately after handling treated seeds.

2.1.4 Rhizobial inoculation

The legume crops have a unique capacity of utilizing atmospheric nitrogen through nitrogen fixing bacteria in the root nodules. However, the naturally occurring (local) strains of *Rhizobium* may not be efficient. It is therefore, recommended to artificially inoculate the seeds with a commercial strain of *Rhizobium*. The artificial inoculation is cheap and increases the efficiency of the plant to fix nitrogen.

In inoculating seeds, about 60 g of molasses is dissolved thoroughly in half-litre of water. To this solution, an inoculum culture is mixed so as to form slurry. Some 10 kg seed (free from

dust) is mixed thoroughly with the slurry of the culture with clean hands taking care that all the seeds are equally coated with the product. The treated seed is spread on a polythene sheet or a clean cloth and placed in the shade to dry. The coated seeds are sown the same day and immediately covered with soil so as to avoid direct exposure of the coated seeds to sunlight.

Rhizobium Inoculum contains bacteria that must be kept alive in all handling. The inoculum have an expiration date, after which, the bacteria may not be alive and the inoculum should not be bought or used. Heat and direct sunlight kill bacteria in stored inoculum, even while packaged. Since a short period of heat can reduce the number of live Rhizobia, the package should be kept in a cool place and out of direct sunlight - even when taking it home from the Agrovet store (keep it off the dashboard of a car). The preferred storage place for inoculum is the refrigerator (without freezing). Inoculant should not be mixed with either pesticide or fertilizer.

2.1.5 Testing for germination

While the germination rate of seeds is on every packet, farmers often get non-germinating seeds and this result in disappointment after planting. It is therefore advisable to conduct a simple germination test before planting the purchased batch of seeds. This is done through taking a few bean seeds (e.g. a table spoonful) and soaking in water overnight. The soaked seeds are then wrapped in polythene bag and on the third day, the seeds are examined to assess the number of sprouted seeds. Based on the number of seeds that sprout, the farmer will make a decision on whether to use the seeds or not. If the seed has 60% germination rate compared to one with 90% germination rate, you will need to plant more seed of the former than the latter.

2.1.6 Site selection

To ensure high bean yields, select highly productive land that is not steeply sloping land, swampy land, very sandy soil or areas with shallow surface soil. Look out for signs that indicate high or very low soil fertility.

3 FIELD OPERATIONS

3.1 Land preparation

Beans can develop deep roots, provided that the soil is well structured. Land preparation should be done early enough so that the field is free of weeds and ready for planting at the onset of rains. The seedbed should have fine soil spread. In addition, the soils of the seedbed must be deep, level and firm because this ensures better surface contact between the seed and the soil, increasing the absorption of moisture. A level seedbed also facilitates planting to a uniform depth. The soil should be loosened and any noxious weeds like couch grass *(Cynodon dactylon)* should be removed. If the plot was previously covered with weeds like *Amaranthus* spp, which produce a lot of seeds, then the land needs to be prepared early in the season. This will encourage most of the weed seeds to germinate as soon as the soil gets any moisture. They can then be lightly removed before beans are planted. Compost or manure should be applied early to allow for any weed seeds carried along in it to also germinate and be removed before planting.

3.2 Soil fertility

Well drained sandy loam soils with high fertility are ideal for bean production. However unproductive soils can be improved by preventing soil organic matter loss or incorporating organic material (e.g. green manures, compost or animal manure), which will increase organic matter and nutrient levels in the soil. Soil conservation measures such as proper terracing, contour farming, cover crops among others, are needed to prevent soil and organic matter loss.

In poor soils, a small amount of nitrogen from a nitrogen rich source should be supplied before sowing to benefit the initial growing phase when the rhizobia are not yet active. Rhizobia develops better and faster in soils where compost manure has been added.

3.2.1 Organic fertilizers

Beans require modest amounts of nitrogen because the *Rhizobium* bacteria in their root nodules that change atmospheric nitrogen into a nitrogen form accessible to the plants. In poor soils, a small amount of nitrogen should be supplied before sowing to benefit the initial growing phase when the rhizobia are not yet active. Manure or compost should be applied and well incorporated into the soil during land preparation since it encourages Rhizobia to develop better and faster. This also assist in maintaining and increasing soil fertility. Crop residues should be composted fully before being added into the soils in order to benefit the beans. Use of fresh manure should be avoided because it attracts bean fly. The use of 15-20 tons ha^{-1} of farmyard manure is highly recommended especially in areas where soils are low in organic matter content. Well-decomposed animal manure or compost should be applied under dry conditions, and then mixed with the topsoil. This should be done about one week prior to planting. It is advisable to apply animal manure or compost to the previous crop in the rotation, then the beans will not need any additional applications. Soil fertility may also be improved by growing green manure crops and ploughing them into the soil.

3.2.2 Inorganic fertilizers

Apply about 200kg DAP or NPK (23:23:0), or Mavuno per ha. The fertilizer should be thoroughly mixed with soil before covering the seed.

3.3 Planting

3.3.1 Planting time

The most suitable planting date is determined by the following factors:

- Correct soil temperature.
- Probability of heavy rain which may lead to soil crusting and restrict seedling emergence.
- Possibility of high temperatures later in the season, which may cause blossom drop.
- Length of the growing season (high temperatures during flowering, rain during harvest and frost damage should be avoided).

Beans should be planted at the onset of rains. Delay in planting may result in reduced yields or crop failure. Early planting leads to early crop development and hence skips disease and injury. Late planting leads to more disease and pest incidences in the crop.

3.3.2 Spacing

Beans in mono cropping should be planted in rows at 50 cm×10 cm (one seed per hill). The soil texture and its moisture content determine planting depth. Generally, the seeds are placed 2.5 to 5.0 cm below the soil surface. Where animal drawn implements are used in weeding, then rows should be spaced at least 60 cm apart. In intercropping, plant maize at the recommended spacing for the agro-ecological zone. Interplant two equidistant bean rows between the maize rows at 15 cm within the row, one seed per hill. The other alternative is to have one bean row between maize rows, two seeds per hill.

3.3.3 Seed rates

The amount of seed required for a given area vary from variety to variety depending on the size of the seed. The bigger the size of the seed the more the quantity of the seed required but generally ranges between 25-50 kg/ha.

3.4 Weeding

Beans should be kept free from weeds. Timely and thorough weeding is absolutely essential. This is achieved by a first weeding session 2-3 weeks after emergence followed by a second weeding session 3 weeks later (just before flowering) in mono-cropping. In intercropping, one weeding 3 weeks after planting may be sufficient except in high rainfall areas where a second selective weeding 3 weeks later may be necessary. Care should be taken to avoid damaging the shallow roots especially during the first weeding. Cultivation during flowering time is discouraged to avoid mechanically damaging bean flowers and to prevent spread of

diseases and soil compaction. If heavy animals such as oxen are used to till the soil, care must be taken to work the land only when it is dry. Selective herbicides maybe used to control weeds e.g. Dual Gold, Basagran or Beansclean herbicide.

3.4.1 Soil compaction

Soil compaction occurs as a result of poor tillage methods such as ploughing and hoeing which result in the degradation of soil, water, and air qualities. The corrective measures include; sub soiling and ripping to break the impermeable plough-pan, avoid ploughing when the soil is very wet. In addition, mulching and addition of manures improve soil structure in a compacted soil.

Intercropping

Beans can be grown either as a monocrop, or intercropped with other crops. Although a bean monocrop is prefered for large scale production; for efficient crop management and harvest, intercropping presents more benefits especially for small scale farmers:

- Higher production per land unit.
- Crop biodiversity contributes to natural pest regulation.
- Food security; if one of the intercrops fails, the farmer will get a harvest from the other crop.

Intercropping beans with other crops such as maize, bananas or tubers (yams, cassava, and sweet potatoes) is widely practised and brings good results. Beans are delicate plants and susceptible to breakage by wind or running water from uphill, even in gently sloping areas. It is therefore highly advisable to grow beans as an intercrop within taller and stronger plants such as maize and cassava.

3.5 Crop rotation

Beans in a mono cropping system must be grown in rotation with other crops. This practice is recommended to avoid pest and disease build up. It is not advisable to grow beans for two consecutive seasons on the same field. Beans leave a nitrogen-rich soil allowing subsequent crops to therefore benefit and grow successfully. Rotation is mainly done with root crops (cassava, sweet potatoes), cereals (maize, rice, sorghum) and vegetables (cabbage, tomatoes, onions) or any other non leguminaceae crop.

3.6 Crop protection

Diseases and pests contribute greatly to reduced productivity in beans. Incidences and severity of diseases and pests vary between seasons because of differences in environmental conditions and management practices. Integrated pest and disease management using appropriate control measures is recommended.

3.6.1 Pests

Bean fly

Causes economic losses on germinating seedlings, up to 4 weeks at two to three leaf stage (Figure 1). The bean fly maggot inside the stem causes thickening of the stem at the soil level and upon cutting and splitting the stem, a brown or dark feeding area and larva or pupae can be seen. Young seedlings wilt and die within a short time. Older plants become stunted. Adult flies are small shiny black flies with clear wings. When observed on the bean crop they serve as early signs of attack. Additional damages caused by bean fly include punctures on the primary leaves around the base; thickening of the stem and cracking of the stem at the soil level.

Figure 1: Damages primary leaves and basal stem of beans caused by bean fly

Source: Alamy stock photos

Management: Use mulch around the bench rows to promote root development and enhance tolerance to maggots. Ridge up the soil around the plant rows to cover up the roots 2 to 3 weeks after germination. Avoid relay planting of beans in the same farm. Frequently irrigate to reduce water stress in the beans. Uproot the wilted or withered beans and destroy by burning the crop debris to avoid emergence of the bean fly adults. Spray with acetamiprid based products such as “Acetak 200 SL” to manage bean fly. Plant certified seed dressed with Cruiser, imidacloprid and thiamethoxam based products or apply Apron star 42 WS as seed dress at 20 g in 20 litres of water.

Cutworm (*Agrotis* species)

These are brown to black caterpillar like pest that are found in the soil and feed on plants at night. The cut worms destroy young seedling near the ground. Black larvae are found in the soil near the cut plant. The larvae curls up into C- shaped when disturbed (Figure 2).

Figure 2: Cutworm larvae on the base of the bean after feeding

Source: Ochieng, KALRO

Management: Prepare the fields to be planted early and remove weeds and plant debris to reduce infestation after planting. Plough deep to expose the larvae to predators and sunlight to be destroyed. Dig out around the damaged seedlings to kill the larvae mechanically. Spray with biological pesticides such as *Bacillus thuringensis* or use baited traps to monitor and forecast infestation. Seed dress with Thiamethoxam, imidacloprid and thiram based products. In case of high infestation, spray with Lamda cyhalothrin based products e.g Duduthrin 1.75 EC or Battalion 2.5 EC as per the manufacturer's recommendations.

African Bollworm

The caterpillar feeds on leaves, flowers, terminal buds and pods causing round holes (Figure 3) . The Presence of faeces are evident on the surface of the infested plants.

Figure 3: Bollworm larvae feeding on bean flower

Source: Infonet Biovision

Management: Avoid planting susceptible crops adjacent to each other. Deep plough the soils after harvesting to expose the pupae to predators. Crop rotate legumes with cereal crops such as maize and wheat. Spray Deltamethrin and Bifenthrin based products such as "Decis" and "Atom" respectively.

Bean aphid (*Aphis cracivora*)

Black to grey soft bodied insects found clustered around the stem, young shoots pods and underside of the leaf (Figure 4). They suck plant sap and causes stunting and in severe cases plants wilt and die. A black sooty mould grows on excrete on the surface of the leaves and plants and sometimes block photosynthesis of the plant. Aphid infestation can be identified by presence of attendant ants climbing up and down the bean crop.

Figure 4: Bean leaves infested by aphids

Source: Crop Life

Management: Practise early planting in the season and destroy volunteer crops and weeds that act as alternate host in the farm. Crop rotate with non-legume family crops to avoid high pest build up; under heavy infestation, spray with neem based biospesticides e.g Nimbecidrine (50 ml per 20 L of water), Achook 0.15% EC (30 ml per 20 L of water), insecticides such as Acephate, Lambda-cyhalothrin, Chlorypirifos and Acetamiprid based products.

Thrips

Small slender yellow, brown to black insects found concealed in flowers and underside of the leaves (Figure 5). They jump when disturbed. Water soaked spots on pods may result in curling of the pods while the leaves appear silvery. Thrips infestation may cause flower abortion, flower and fruit deformation.

Figure 5: Thrips on bean leaves

Source: Infonet Biovision

Management: Destroy alternate hosts and weeds around the bean field to reduce the population. Intercrop beans with repellant crops such as garlic and onions to keep aphids away. Use blue sticky traps to trap thrips in the bean plantation.

3.6.2 Diseases

Halo blight (*Pseudomonas syringae*)

Small water soaked brown spots on the underside of the leaves which later increase in size and surrounded by yellow ring; the whole leave may turn yellow (Figure 6). Small greasy spots may also be observed on the pods.

Figure 6: Halo blight on the bean leaves

Source: CIAT

Management: Plant resistant bean varieties such as KAT X56, KAT X69. Practise crop rotation with non-leguminous family crops such as maize and millet for 2 to 3 seasons. Avoid field operations when the leaves are wet. Rouge out and destroy by burning all the infected plants and crops. Spray copper based fungicide e.g Champflo (50 g/20 L) or Colonizer 440 WP (50 g/20 L).

Bacterial blight

Water soaked spots appear on leaves and pods. The spots are much larger than those for halo blight and occur on the leaf margins in an angular orientation (Figure 7).

Figure 7: Bacterial blight symptoms on common bean leaves

Source: https://r.search.yahoo.com

Management: Plough deep and burry crop residue to allow to decompose. Use drip and furrow irrigation to avoid spread of the disease on the leaves through splash. Avoid field operations when the leaves are wet. Disinfect farm tools when moving from one part to another. Plant certified seed; rogue and destroy infected plants and plant debris by burning. Crop rotate with cabbage and maize. Spray with copper based fungicide e.g Champflo (50 g/20 L) or Colonizer 440 WP (50 g/20 L).

Bean Anthracnose

Brick red to dark brown sunken spots on the pods; spots have black orange powder; on the other side of the leaf reddish brown spots that may appear on the leaf veins (Figure 8).

Figure 8: Bean pods infected with anthracnose

Photo source: https://r.search.yahoo.com

Management

Use certified seed and crop rotate beans with cereals for a period of 3 to 4 seasons. Remove and destroy by burning all infected plants. Use seed treatment (Apron star 42 WS). When not using certified seed, follow recommended guidelines. Spray with carbendazim based products such as Rodazim 50 SC or azoxystrobin based products e.g Target Top as per manufacturers recomendations.

Bean rust

Raised orange to yellow powdery pustules mainly on leaves. In severe cases stems and pods are affected and leaves may fall off prematurely (Figure 9).

Figure 9: Rust spots on the leaves of the beans

Source: https://r.search.yahoo.com

Management: Maintain weed free fields and remove alternate hosts such as oxalis to minimize infection. Avoid relay planting of leguminous family crops. Practice crop rotation with non legumes. Avoid working in the farm when the conditions are wet. Plant resistant varieties such as GLP-X1127. Spray with copper or azoxystrobin chlorothanil based products, according to the manufacturers recommendations.

Bean root rot

Occur as discoloration of tap root which later turns brown after germination. Rotting of the tap roots occurs, which become hollow and dry thus causing yellowing and death of plants (Figure 10).

Figure 10: Hollow brown rotting tap root

Source: CABI Plantwise

Angular leaf spot

Grey spots appear on the leaves and later turn brown. The spots are enclosed by leaf veins, giving the spot a typical angular shape (Figure 11). On the stem and pods, round spots may appear but in severe cases the leaves fall.

Figure 11: Angular black spots on the bean leaf

Source: https://r.search.yahoo.com

Bean mosaic virus

Results into distorted and stunted growth of the bean crop. The leaves appear dark green along the main veins and light green yellow in between (Figure 12). The leaves later curl and roll downwards on the blade. The infected plants hardly form the pods.

Figure 12: Distorted bean leaves infected with mosaic virus

Source; Howard Schwartz, University of Colorado

Management: Plant certified seed. Establish fields in isolated areas not near bean infected fields. Uproot infected beans and destroy by burning to prevent spread.

3.6.3 Bean weeds

Weeds affect bean productivity through competition for nutrients, space, water and sunlight. Weeds harbor vectors that transmit diseases. Early emergence of weeds affects bean quality and quantity at harvest. Common weeds of beans include: black jack, couch grass, wandering jew and mexican marigold.

Black Jack

An annual weed that grows vigorously up to 1.8 meters tall in cultivated and disturbed land. Black jack competes for water, nutrients and space when left to grow amongst main crop in the field (Figure 13).

Figure 13: Flowering Biden pilosa

Source; Piter Kehoma Boll

Management: Practise hand weeding to remove the black jack plant before flowering. Spray with Beansclean 480 SL which is an early post emergence herbicide for control of grasses and broad leaved weeds in common beans.

Couch grass or Bermuda grass (*Cynodon dactylon*)

It is a spreading perennial grass with vigorous mat-forming stolons, it reproduces and spreads

by rhizomes but is also propagated by seed (Figure 14). Couch grass and other species of *Cynodon* are common in East Africa.

Figure 14: Couch grass

Source: Charles T. Bryson, USDA

Management: Control before planting beans. Use a tooth harrow during the dry season to uproot the rhizomes and expose to the sun so as to dry completely on top of the soil. Introduce shade producing cover crops within a crop rotational system to suppress the grass. It may also be controlled using post emergence herbicides before planting beans in previously non cropped lands.

3.6.4 Integrated Pest Management (IPM)

Pests and diseases can be effectively managed in the bean field by using he following approaches:

3.6.4.1 Improved varieties

Use of improved varieties with resistance to common diseases or tolerance to major pests will not be destroyed by the pests and diseases. Seeds should be obtained from approved seed suppliers or carefully selected to avoid introduction of seed-borne disease like viruses, fungal and bacterial diseases.

3.6.4.2 Proper field management

Vigorously growing plants are more resilient and can tolerate pest and disease infections. Growing a healthy crop begins by choosing a suitable growing location that has loose, fertile soil, which helps quick emergence to avoid pests such as the bean fly. Fresh manure should not be applied in order to avoid the bean fly and chafer grabs.

3.6.4.3 Early planting

Early planting is recommended to avoid water stress in the critical stages of growth. Early planting will also enhance quick growth of the bean plants before pests and diseases build up. Early planting facilitates pest and disease escape and avoidance during the season.

3.6.4.4 Natural pests

Pests can be controlled by encouraging functional biodiversity. This is where natural enemies of pests are encouraged to develop and propagate unhindered. Beneficial insects will build up

their population and prey on plant pests, for example the Syrphid fly (hover fly), a common predator of aphids, can prey also on the bean aphid.

3.6.4.5 Field hygiene

Remove any plants with virus symptoms from the field and burn or bury them. Disease infested plant material should not be left in the field, but made into compost. Beans should be rotated with other crops. Beans or other legumes should not be grown on the same plots for 2 consecutive seasons.

3.6.4.6 Proper drying and clean storage

The most damaging storage pest in dry bean is the bean bruchid (bean weevil) *Acanthoscelides obtectus.* Proper drying and clean storage is the best control for bean weevils.

3.7 Harvesting

Dry beans should be harvested when all the pods have turned yellow, but before they have become so dry that the pods begin to shatter or rot away especially in mixed stands. Dry beans have a moisture content of about 50% at physiological maturity. The beans, however, are only ready for harvesting when the moisture content drops to 16%, the ideal being 15%. For instance, Mwitemania rots easily if not harvested at the right time. Seeds may split during threshing when the moisture content is less than 12%. It is also difficult to clean without further seed split or broken seed coats. Average yield of 20 bags /acre is expected under good agronomic, pest and disease management.

4 POSTHARVEST SYSTEM FOR BEANS IN KENYA

4.1 When to harvest

One can tell when the beans are dry by the loud, sharp noise they make when dropped on the ground. Seeds may split during threshing when the moisture content is less than 12%.

Figure 15: Bean crop ready for harvest in a farmer's field

Beans do not mature at the same time, therefore harvesting should be done selectively on mature ones at any given time (Figure 15 and 16). Harvesting is done by uprooting the mature crop. These are then transported to the homestead for drying. They are then transported on backs, ox-drawn carts, bicycles, pick-ups among others.

Figure 16: Movement of newly harvested crop from the field to the homestead either by head load or on oxen

4.2 Drying. The harvested crop is dried by spreading on the ground or left on a grill. In some cases, the bean plants are tied up under shade/shelter to dry (Figure 17).

Figure 17: Methods of drying beans either under a shade (left) or spread on a tarpaulin (right)

4.3 Knowing when the grain is dry enough

Use of fingers or teeth

One should test the moisture of the seed before threshing using teeth or pinching the seed with fingers (Figure 18). Dry beans should crack with a loud sound when bitten and not brittle. Brittle beans should be dried further.

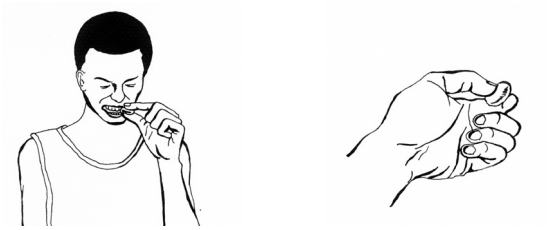

Figure 18: Simple methods of testing moisture

Testing moisture content of grains before storage

a) Salt method

Dry salt will absorb moisture from grain. This principle can be used to help determine whether a grain sample has a moisture content of above or below 15%.

The salt must first be dried by spreading it out on some plastic sheeting in the hot sun and leaving it for at least 3-4 hours until it is hard. It should be turned at intervals during this time. It can also be dried in an oven. The dry salt should be placed in a sealed container until it is ready for use.

The salt test is also a good way to determine the moisture of threshed seed: For this test you will need a clean, dry jar with a lid, some salt and a sample of bean seed.

1. Take one sample (a handful is enough) from the middle of each bag of beans. It is best to remove a sample using a special instrument called a sampling spear or spike across the spectrum of a storage bag to get a representative, sample.

2. Make sure that the jar you are using is clean and completely dry.

3. Put the salt in the jar (enough salt to fill up a quarter of the jar) and add a sample of seed (enough to fill half of the jar). Put the lid on the jar and tighten.

4. Shake the jar well and then allow the seed to settle for about 10 minutes.

5. If after 10 minutes you can see damp salt stuck to the sides of the jar, the seed is too moist. This means that the moisture is above the required 13-15%. If the jar is dry and there is no salt stuck to the sides of the jar, the seed is dry.

Figure 19: The 'salt method' of checking grain moisture content

b) Use of moisture meter

These are electronic meters that operate on dry cells or electricity to check for moisture (Figure 20). The meters are quick, portable, simple to use and fairly accurate. The meters are expensive for smallholder farmers, and would normally be used at warehouses and by

farmers' groups that handle large amounts of grain. However, the extension staff have been provided with the meters to help farmers determine if safe moisture content (≤ 13%) is achieved before storage. A sample of about 150 grams of the grains is scooped with a hand and poured into the moisture meter which is then closed. The device then takes a short while to detect the moisture and temperature of the sample. Digital electronic machines display the readings on the screen once the detection is over. The recommended grain moisture content is 13% or below. The beans intended for longer storage should have at least 12.5% moisture or lower.

Figure 20: Dickey-John multi-grain tester to detect moisture content in grains

4.4 Shelling / Threshing

Dried beans can be piled inside plastic sheets or jute bags and hit with sticks slowly to split them open without damaging the seeds. For purposes of using the bean for seed, these can be threshed by hand (if quantities are small) to avoid minimal damage (Figure 21).

Note: Threshing on the ground or in a gunny bag can easily damage the seed. Broken or cracked grain is more likely to be attacked by insects and fungal moulds.

Figure 21: Threshing of dry beans by hitting them with sticks gently

The dry pods can also be threshed on a threshing rack. This protects the seed from damage (broken or cracked grain) and dirt and prevents it from scattering (Fig. 9). A threshing rack consists of strips of wood arranged on a platform with a wire mesh tray on the bottom to hold the threshed grain (Figure 22).

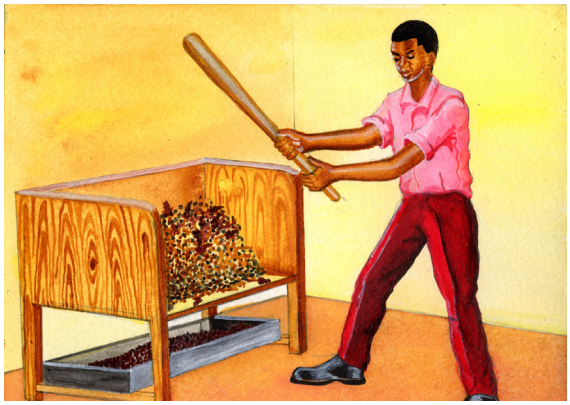

Figure 22: Threshing of dry beans on a threshing rack

4.5 Drying after threshing

After the grain has been threshed, it must be dried to about 13% moisture content. Threshed grain should be dried on mats, plastic sheets or wire mesh trays raised on a platform (Figure 23).

Spread the grain thinly on the drying surface to allow air to pass through it. Turn the grain regularly to avoid overheating. Protect the grain from rain, insects, animals and dirt. The moisture content can be tested as described earlier.

Figure 23: Drying of threshed beans in the sun

4.6 Winnowing and sorting

Dry grains are winnowed to remove chaff, dust, foreign matter such as stones, broken grains, shrivelled, mouldy, insect damaged, rotten discoloured or faded, and any remaining plant parts grains (Figure 24).

Broken and deformed beans should be consumed fast because they do not store well.

The beans should also be separated according to variety in order to increase their market value. Sorting of the dried grains improves the quality and the market value of the produce.


Figure 24: Sorting of dry beans

Figure 25: Winnowing of dry beans

4.7 Storage of beans

4.7.1 Storage structures

Bean weavils (bruchids) are major storage pests. Before storage, dust beans with Actellic at the rate of 50 g per 90 kg bag. Store beans as dry as possible in air-tight bins, drums or well secured gunny bags.

Store the seeds in clean or disinfected bags. Do not mix the newly harvested grain with old stocks from previous harvests. Store the bags at least 1 meter away from the walls and on a raised platform. Store the bags in a non-leaking storehouse to avoid contact with moisture. The grains can also be kept in airtight drums or in hermetic bags. However, if seeds are to be used for planting, they should not be stored in airtight containers to maintain viability, gunny bags are recommended. The store should be clean and well ventilated. Grain should be checked occasionally to prevent infestation of bean weevils. Stored bean seed should be placed out in the sun occasionally (once every month) in order to reduce moisture content and to kill off pests. Bean seeds for next season's planting can be mixed with dried leaves of marigold, tephrosia, neem or any other locally tried plant, in order to keep storage pests away (Figure 26 and 27). Traditional storage of dry beans is shown in Figure 28.

Figure 26: Storage of dry beans in air tight storage containers and hermetic bags

Figure 27: Gunny sack for the storage of dry beans

Figure 28: Traditional storage of dry beans

4.7.2 Precautions during storage

- Use of hermetic bags does not guarantee long term storage since it is vulnerable to penetration by storage pests and hence requires complementary treatment of the grains.
- Beans in hermetic bags should be kept in rat proof stores.
- Do not mix the newly harvested grain with stocks from previous harvests. Store the bags at least 1 meter away from the walls and on a raised platform.
- Store the bags in a non-leaking storehouse to avoid contact with moisture.
- The store should be clean and well ventilated.
- Stored bean grains should be placed out in the sun occasionally (once every month) in order to reduce moisture content and to kill pests. Bean seeds for next season's planting can be mixed with dried leaves of marigold, tephrosia, neem or any other locally tried plant-based pesticide, in order to keep storage pests away.

5 BEAN POSTHARVEST MANAGEMENT

This component on postharvest management and marketing will support farmers in securing high returns from investments on grain productivity enhancement through:

i) Adoption of improved on-farm grain handling practices to minimize post-harvest losses.

ii) Enhance access to profitable grain markets enabling marketing of produce at more favourable terms. Activities here will include investment in community storage facilities to allow target farmers to stock their produce to attract wholesale buyers, for favourable terms of trade, and/or to leverage their stock to access credit.

The expected outcomes of this component are that target groups will be supported in:

i) Reducing post-harvest losses from the current estimated 30% to industry accepted levels of below 5%.

ii) Using certified warehouses to bulk and sell their produce at a price 30% higher than prevailing farm gate price.

iii) Management strategies for controlling postharvest losses are recommended to lower losses.

5.1 Postharvest losses and management

Post-harvest period is the duration between physiological maturity of a crop and the time for its final consumption. Post-harvest loses refer to the degradation of quantity and quality of a food product from harvest to consumption (figure 29). Food losses occurs when edible dry matter or nutritional value that was originally intended for human consumption is reduced (FAO, 2013). It is estimated that food losses of up to 30 % are attributed to poor post-harvest management, translating to more than US$4 billion loses per annum (Hodges *et al*., 2011). Postharvest loses are attributed to improper handling, biological spoilage, insects, birds and rodents (Kiaya, 2014). These loses are common in developed countries and are a concern to farmers and those involved in the selling of food products. In cereals and pulses, deterioration occurs with increase in moisture levels and improper storage. To address these, management strategies for controlling postharvest losses are recommended.

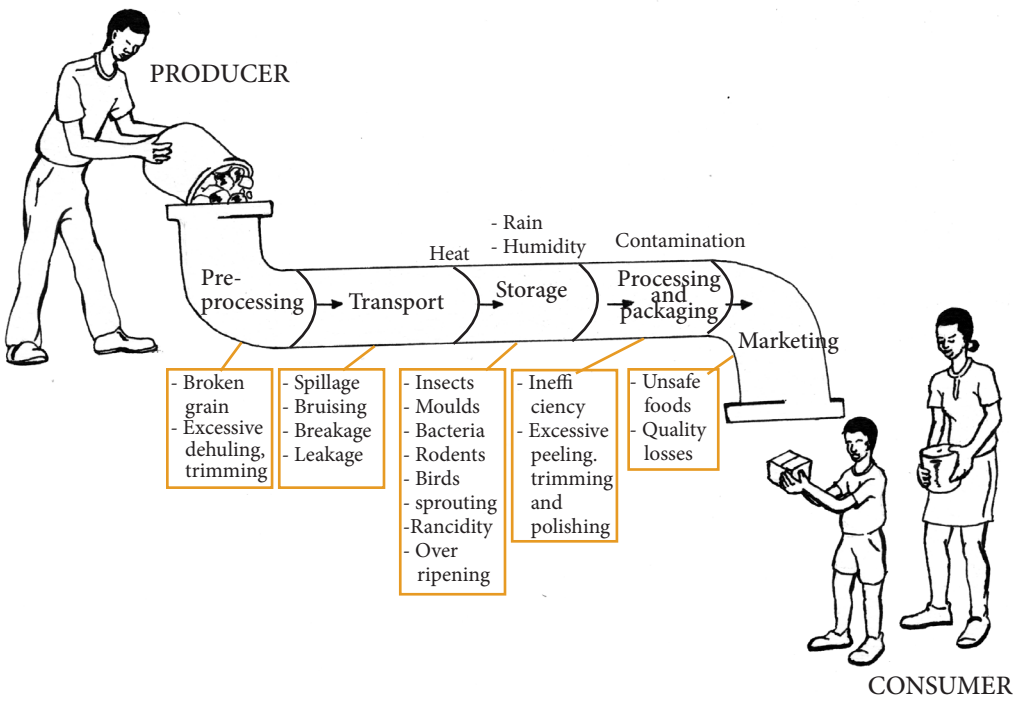

Figure 29: The Food pipeline

Source: http://www.fao.org

6 MARKETING OF BEANS

Transportation to the market

The harvest can be transported on head loads if the homestead is not far from the market, while larger quantities are transported by pick-ups, bicycle, motor bikes, wheel burrow and oxen or donkey carts (Figure 30) to all the varied markets listed (Figure 31 and 32).

Figure 30: Transportation of bean harvest to the market using various modes

Market service providers include:

- Financiers (banks, micro-financiers and SACCOs)
- Market information services
- Warehouse services
- Transporters

Bean marketers include:

- Retailers
- Wholesalers
- Exporters
- Vendors (collectors, assemblers)
- Supermarkets
- Farmer associations / groups

Figure 31: Marketing of beans

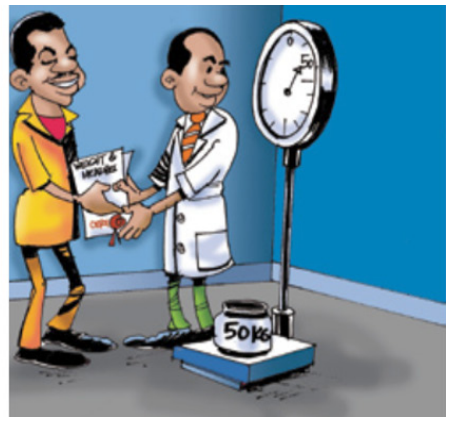

Figure 32: Development of inclusive markets in Agriculture

- Make sure the scales are working and that they have a recent calibration (according to government regulations).

6.1 Marketing Strategy

6.1.1 Grading

This enables farmers to get quality produce that translates to higher demand for their produce. The grading of beans is a strategy that can be adapted by farmers to fetch higher prices (Table 2). The quality standards for beans in Kenya is shown in Table 2.

Table 2: Kenya standard specification for dry beans for human consumption

	Grade Limits (% max. by weight)			
Defect	**Grade 1**	**Grade 2**	**Grade 3**	**Grade 4**
Foreign matter (%)	1.0	1.0	1.0	1.0
Split and broken grain (%)	1.0	2.0	3.0	4.0
Insect-damaged grains (%)	2.0	4.0	6.0	8.0
Other defective grains	2.0	3.0	5.0	8.0
Aflatoxin (ppb, max)	10	10	10	10
Other varieties (%)	1.0	2.0	3.0	4.0

Source: NCPB, 2016

6.2 Ungraded and rejected beans

Ungraded beans are the ones which do not fall within the quality standard groups while rejected beans are those dusty and materially weathered (refer to Table 2).

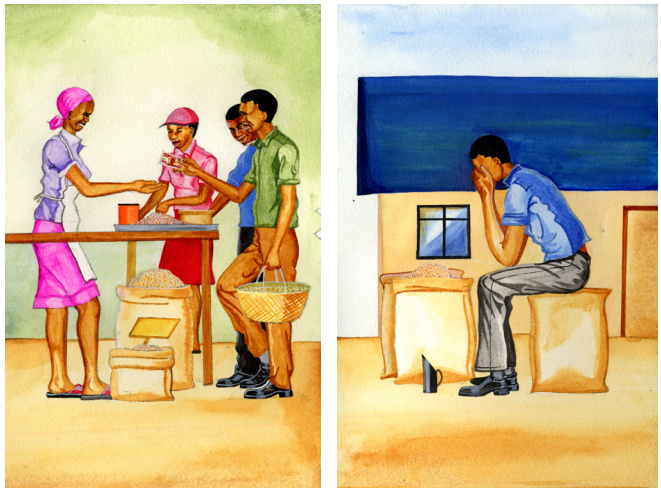

Figure 33: High quality grain fetch better markets

Source: Hodges and Stathers, 2012

6.3 Packaging and bulking

Graded beans should be weighed and packaged in 90 kg bags and delivered to a central place for collection. This can be under cooperative societies and farmer groups.

7 VALUE ADDITION AND UTILISATION OF BEANS

The utilisation of beans in Kenya is in form of:

- Fresh beans
- Dry beans
- Industrial use (canning)

Figure 34: Preparation of fresh beans for boiling

(Source: Kilimo Trust, 2012)

7.1 Consumption/Utilization at household level

The grains are utilised in variable ways as illustrated in figures 34 and 35

- Boiling beans-maize mixture to soft (*Githeri*).
- Boiling beans-maize mashing with potato and greens (*mukimo*).
- Bean sprouts are utilized as salads. Once beans are pre-germinated, they are mixed with other vegetables because of they are good source of vitamins.
- Boiling beans alone with testa or without, mashed or not mashed and consumed along with Ugali, cooked rice and/or substitute animal proteins.
- Bean flour can be used as protein supplement in porridge and baked products like bread, doughnuts, cakes and pizza.

Figure 35: Vegetable samosas made from beans, a Githeri dish made from a mixture of maize and beans and, baked cake enriched with bean flour

Source: Mulei et al. (2011)

Figure 36: Mash beans and porridge, and mandazi comprising bean flour

Source: KALRO Kakamega, 2016

7.2 Industrial level processing

- Canning
- Packaging and grading
- Boiling beans with or without testa; marsh or not (and served with *ugali* or rice).
- Pre-cooking plus tomato sauce and canned (bean variety Mexican 142).

Examples of bean processors in Kenya include Tru-Food Ltd. and Njoro Canners Ltd. Processors sell their canned bean products (baked beans and githeri) to local supermarkets, distributors and the disciplined forces (Kenya Defence Forces, Kenya Police, Kenya Wildlife Service), see figure 37.

Constraints faced by processors:

- Poor quality beans
- Mixed varieties hence affecting cookability, non-uniformity

Figure 37: Canned bean products in Kenya

Source: Wambua et al. 2016

8 TAKE HOME MESSAGES

The main points to remember in bean production and postharvest management are;

- Plant clean seeds for high germination, uniform growth and maturity.
- Do timely land preparation and timely planting to take advantage of rain and control diseases.
- Keep proper population for optimal yield and reduced disease incidence.
- Maintain a weed free field to reduce competition and disease build up.
- Timely harvesting and proper post-harvest handling for long shelf life.
- Prevent and control of pest and diseases in all bean stages to minimize loss (quantity and quality).
- Timely harvesting of beans to ensure they are dry.
- Ensure the moisture content is below the recommended levels during harvesting and drying for storage.
- Thresh dry beans carefully to avoid grain damage (cracked grain) thus preventing insect and mould attack.
- Prevent and control pests and diseases in all stages to minimize loss (quantity and quality) by storing dry beans in insect- and rodent-proof bags to avoid infestation.
- For long shelf-life, storage areas should be kept clean and well-ventilated.

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KCEP-CRAL Extension Manuals are well-written and up-to-date publications with basic information that Extension Officers and service providers need in each value chain. The comprehensive manuals cover all areas of the value chain.

Available extension manuals cover basic cereals (maize, millet and sorghum), pulses (beans, cow peas, pigeon peas and green grams), soil climate smart agriculture and Farming as a Business as listed:

1. Common Dry Bean Extension Manual
2. Cow Pea Extension Manual
3. Green Gram Extension Manual
4. Pigeon Pea Extension Manual
5. Maize Extension Manual
6. Millet Extension Manual
7. Sorghum Extension Manual
8. Climate Smart Agriculture Extension Manual
9. Farming as a Business Extension Manual
10. Integrated Soil Fertility and Water Management Extension Manual
11. Farm Level Agricultural Resilience and Adaptation to Climate Change Extension Manual

KALRO
Kenya Agricultural & Livestock Research Organization

Kenya Agricultural and Livestock Research Organization
P.O Box 57811-00200 Nairobi, Kenya
Tel. +254 709 104 000
www.kalro.org