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THE KENYA CEREALS ENHANCEMENT PROGRAMME – CLIMATE RESILIENT AGRICULTURAL LIVELIHOODS

(KCEP-CRAL)

PIGEON PEA
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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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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ABBREVIATIONS AND ACRONYMS

°C	Degrees Celsius
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
g	Grammes
ha	Hectare
IFAD	International Fund for Agricultural Development
IPDM	Integrated pest and disease management
IPM	Integrated Pest Management
KALRO	Kenya Agricultural and Livestock Research Organization
KCEP	Kenya Cereals Enhancement Programme
KCEP-CRAL	Kenya Cereals Enhancement Programme - Climate Resilient Agricultural Livelihoods Window
kg	Kilogram
mm	Millimetres
MoALF&C	Ministry of Agriculture, Livestock, Fisheries and Cooperatives
PICS	Purdue Improved Cowpea Storage

1 INTRODUCTION

Pulses, or grain legumes in general, are an essential source of supplementary protein to daily diets based on cereals and starch for those who cannot afford expensive animal protein. Pulses are therefore often regarded as poor man's meat". They also provide energy, 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 many 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.

Pigeon pea is an important crop in Semi-Arid tropical and sub-tropical areas. It is also known as red gram, Congo pea, gungo pea, noeye pea, *mbaazi* in Kenya. It is believed to have originated from India, but may have come from Africa It is a perennial legume that is highly adapted to dry environments. It can grow to 12 feet tall, but it usually reaches 3 to 6 feet. It has very deep roots which enables it to take up nutrients and water from lower subsoil layers.

Pigeon peas is primarily grown for its grain because it has highly nutritious grain. The growth period ranges between 90 to 130 days for annual types and 130 to 365 days for the perenials. The crop is grown for multiple purposes. The foliage and stems can be used as fodder and firewood, respectively. Pigeon pea is also grown as hedgerow for windbreaks and as ground cover. The leaves and immature stems can be cut and used as a green manure for soil fertility enrichment. Its nitrogen fixation properties makes it a useful source of green manure. Most of the fixed nitrogen is transferred to the developing seed after flowering. It is useful in honey production as bees are attracted to the flowers Pigeon pea has a high potential of enhancing food security.

Smallholder grain farmers including those of pigeon peas in the country face two key interrelated challenges after harvesting their crop. Poor grain handling and management, which leads to up to 30% of post-harvest losses. Losses are among the major reasons why Kenya continues to be insufficient in food supply even when crop yields and land under cultivation have been increasing. Furthermore, marketing of grain at low prices at harvest forces households to buy grains for family consumption later when prices are high. This is partly due to lack of knowledge on appropriate handling and storage methods. This compels them to sell the pigeon peas during the off season at higher prices.

Kenya was ranked the third largest world's pigeon pea producer in 2014, with over 200,000 hactares cultivated annually. The crop is second only to field beans (*Phaseolus vulgaris*) as pulse and as a food legume in acreage and production. Although it is reported to have wide adaptability to different climates and soils, 98.7% of its production in Kenya is concentrated mainly in four counties (Machakos, Kitui, Makueni and Embu (Mbeere) but it is also grown in parts of coastal regions. The average yield of 544 $Kgha^{-1}$ currently achieved by farmers is far below its potential yield (1500–2500 Kg/ha) under research conditions.

This manual will help address some of these challenges by providing information on improved varieties and appropriate crop management practices aimed at increasing production and productivity in the country. The manual is intended to assist farmers, extension personnel, researchers and other stakeholders in Kenya profitably and sustainably grow green gram.

1.1 Ecological requirements

1.1.1 Altitude

Pigeon pea is drought resistant and grows at altitudes between 0-1800 meters above sea level (masl) but may also be found at altitudes of up to 2000 masl.

1.1.2 Rainfall

Pigeon pea is largely cultivated as dry land or rain fed crop, and is fairly drought tolerant. It performs optimally in areas where rainfall is between 400 and 750 mm per annum. The crop prefers moist conditions in the first two growing months, and drier conditions during flowering and harvesting. However, early and short duration cultivars do not perform well in high rainfall areas. Cloudy weather or rains at flowering and fruiting result in poor pod setting and seed filling and may lead to increased damage by pod borers (*Helicoverpa armigera*).

1.1.3 Soil Types

The crop grows well in all types of soils, varying from sandy to heavy loams, with well-drained, medium heavy loams being best. It requires a pH ranging from 5.0 to 7.0, but can tolerate pH 4.5–8.4. Pigeon pea is sensitive to high salinity and water logging. It grows well in soils with low phosphorus levels. In deep well-structured soil it is more tolerant to lower moisture levels.

1.1.4 Temperature

Pigeon pea is tolerant to hot conditions and grows in temperatures greater than 35ºC when soil moisture and fertility are adequate, but it is generally grown in temperatures of 18-30ºC. It does not tolerate low temperatures and frost. Day length of 12-14 hours is required for optimum growth and development. For late maturing types high temperatures (greater than 20°C) delay maturity whereas in early maturing types higher temperatures (20°C-28°C) hasten maturity.

2 KEY OPERATIONS

Several operations are necessary in order to achieve the desired crop yields. The operations can be divided into pre-field or preparatory activities, on field operations, post-harvest handling and utilization. These different operations are discussed here.

2.1 Pre- Field Operations

2.1.1 Varietal Selection

Pigeon pea varieties differ not only in form of seeds, colour and taste, but also in growth habit, time of flowering, maturity period and susceptibility towards pests and diseases (Table 1 and Figures 1, 2 and 3).

Table 1: Pigeon peas varieties and their characteristics

Variety	Maturity (Days)	Potential yield 90 Kg bag/Acre)	Description
Mbaazi 1 (ICPL 87091)	105 - 120	4.4 bags for one season 8.8 bags for two seasons	• Flowers in 55-70 days • Pods are green with purple streaks • It is a determinate that grow to 80-120 cm high depending on the season and altitude. • It is compact and is grown as sole crop. • Highly susceptible to insect pests mainly pod sucking bugs and pod borers
KAT 60/8	135 - 150	4.4-6.6 bags for one season. 8.8-13.2 bags for two seasons	• Yellow Flowers (standard and wing) • Flowers in 95-120 days • Has indeterminate growth habit and grow to 85-130 cm depending on the altitude and season • Grains are white in colour with brown spots and smaller than long duration local landraces • Susceptible to insect pests mainly pod sucking bugs and pod borers • Tolerant to wilt and leaf spot diseases
Mbaazi 2 (ICEAP 00040)	150 - 180	5.7 bags	• Has yellow flowers while the pod are green with dark stripes • Flowers in 60-90 days • Has indeterminate growth habit and plant height ranges from 120 to 240 cm depending on season and altitude • Normally planted in the short rain season (October-November) – mainly two season variety • The plant is taller and stronger at lower altitudes (less than 1000 m) than at higher altitudes • Grain colour is greyish

Figure 1: Mbaazi 1 (ICPL 87091)

Figure 2: White brown spotted grains of Mbaazi 2 (ICEAP 00040)

Figure 3: Grey colured grains of Mbaazi 2 (ICEAP 00040)

2.1.2 Seed treatment

Seed treatment plays an important role in protecting the seeds and seedlings from seed and soil borne diseases and insect pests affecting crop emergence and its growth. Seed-borne diseases result in poor germination, poor plant vigour, low yield and poor quality seed.

Germination test

The results of the test informs the farmers, how much seed they need to plant in a given acreage to get good yields. To calculate the germination percentage, a random sample of about a hundred seeds are taken from the seed lot. They are placed on moist newspaper and covered with another piece of moist newspaper. The seeds should be kept moist, but not wet. Seedlings should begin to emerge 7-11 days after planting. The germination percentage is calculated by counting the number of seeds that have germinated and dividing this by the intial number of seeds. Then multiply this number by 100.

2.1.3 Land Preparation

To ensure high pigeon pea yields, select a fertile land that is not sloping or swampy. The soil should not be very sandy or shallow. Land preparation should be done as early as possible to ensure early planting. Pigeon peas require a medium tilth as in other grain legumes and soils with huge soil clods should be avoided. Pigeon pea thrives best in seedbeds prepared by deep ploughing and cultivation.

2.1.4 Improving soil fertility

If planted on poor soils, pigeon peas can suffer from nutrient deficiencies. Such plants will show deficiency symptoms.

Although pigeon peas are a nitrogen fixing species, compound fertilizer is recommended at 20 kg P/ha and 8 kg N/ha (DAP 50 kg-bag/ha). Phosphorus is the most limiting factor for pigeon pea. Pigeon peas can fix up to 35kg/ha N by symbiosis by the mid pod filling stage. To enhance nitrogen fixation the seeds can be inoculated with *Rhizobium* during planting. Pigeon pea can also be used as a green manure.

2.1.5 Planting

Pigeon pea does well when broadcasted and covered or drilled into a well-prepared seedbed at a depth of 2.5–10 cm. Early planting is recommended. Seeds should be sown in rows with spacing of 30-50 cm ×75-150 cm depending on variety, rainfall amount ,soil type and production system. In dry areas, and especially in coarse-textured, infertile soils, a wider spacing between plants should be used to limit competition. Seedlings emerge 2–3 weeks after planting. The initial growth is slow until the taproot develops.

2.1.6 Seed rate

(i) Sole cropping

The seeding rates for pure stand are 12 to 25 kg/ha.

Spacing

The recommended spacing depends on variety as indicated below.

Mbaazi 1 (ICPL 87091)– 50 cm between rows and 10 cm between plants if using plough, skip one furrow.

Kat 60/8 75 cm between rows and 50 cm between plants. When using oxen in ploughing and planting skip two furrows.

Mbaazi 2 (ICEAP 00040) - 100 cm between the rows and 50 cm between plants at lower altitudes where temperature are warmer. At higher altitudes these spacing's should be reduced by 20-30 cm.

Local varieties – Plant at 120 cm between rows and 60 cm between plants.

(ii) Intercropping

Pigeon pea is grown as an intercrop with other legumes or cereal crops such as maize, sorghum and millets, which are harvested before it starts flowering to avoid competition for sunlight. It performs well when intercropped with two rows of cereals (e.g. sorghums or millets), groundnuts or cotton. After the harvest of the intercrop, pigeon peas continues to protect the soil and restore fertility. Kat 60/8 and Mbaazi 2 can be intercropped with maize, sorghum or millet during the first season which is normally the short rains (October-December). If intercropped with maize, one row of pigeon pea is planted between the maize or sorghum rows at a distance of 90 cm between the rows.. Two rows of maize or sorghum can be planted between the pigeon pea rows at a distance of 90 cm. However, Mbaazi 1 should always be planted as a pure stand.

2.1.7 Weeding

Pigeon pea is sensitive to weed competition in the early growth stage and it is important to keep the crop weed free in the first 45 to 60 days of growth. Effective weed control at the early growth stages of the crop is one of the most important factors contributing to high yields. The first weeding of all varieties must be done within the first 2-3 weeks after germination whereas subsequent weeding sesssions will depend on the growth of weeds and amount of rainfall.

3 CROP PROTECTION

3.1 Importance of Pest and Disease Identification

Pests and diseases are a major constraint in pigeon pea production and lead to heavy yield losses and loss of income for farmers and other value chain players. Farmers lave limited access to technical skills and knowledge on how to control most pests and diseases in pigeon pea thereby increasing insurgence. There is need to assist farmers and key stakeholders to correctly identify and manage pests and diseases that affect pigeon pea production. This can be done by continually developing and providing information training manuals and extension materials to stakeholders involved in pigeon pea production. This project envisages that the trained extension staff will in turn train farmers and share expertise and expedite adoption of new pest and disease management strategies.

3.2 Management of Pest and Disease Using Intregrated Pest and Disease Management (IPDM)

Integrated pest and disease management (IPDM) relies on a combination of various practices such as cultural, biological and chemical; as well as development and use of resistant and tolerant crop varieties. It is guided by constant monitoring and identification of crop pests and diseases in order to prevent and control them. Currently most farmers have not embraced this approach in pest and disease prevention and management. Significant yield losses are experienced in pigeon pea production due to pests and diseases.

3.3 Scouting for pigeon pea pests, diseases and weeds

The purpose of scouting is to gain an understanding of insects, diseases, weeds and beneficial insect activity in the pigeon pea crop. Effective monitoring includes assessing their numbers and incidences. Scouting is a critical component of implementing an IPM programme. When scouting, get in the farm and take a close look at the plants. If you have a large block of pigeon pea, walk in a Z, V, W or zigzag pattern through the field. Make sure you turn the leaves over. The protected, damp areas under plants are often favorite homes for pests and diseases. Check in all wet areas or other troubled spots for symptoms as well. Scout in your pigeonpea crop once a week in order to identify problems before they get out of control. Once you find insects, diseases or weeds, control them using the information contained below.

4 PESTS AND DISEASES CONTROL

Pests and diseases have a negative impact on pigeon pea production, leading to poor quality seed and yield in general. Integrated pest and disease management approaches can be used to control and minimize pest and disease occurrences through the combination of various strategies including cultural, biological and chemical and use of resistant varieties.

4.1 Common Insect Pests

Aphids, thrips, pod fly, pod sucking bugs, pod borers and bruchids are major pigeon pea pests. During vegetative stage the flowering of some pigeon pea varieties for instance, Mbaazi-1 and KAT 60/8, coincides with the peak period of pests infestation. To control pests, appropriate management strategies need to be employed as follows:

i) Before flowering - Thrips and aphids

ii) After flowering - Pod fly, pod borers, pod sucking bugs

iii) Before storage - Bruchids

It is generally recommended to spray the pigeon pea crop once before flowering and twice after flowering.

4.1.1 Flower thrips (*Megalarothrips usastus*)

Initial symptoms are seen as large numbers of shiny black insects on the flowers of the crop. Thrips destroy flowers leading to their abortion. In some instances there is failure of the crop to flower (Figure 4).

Figure 4: Thrips on flowers

Control/ Management

Plough in previous crop residues and intercrop with onions, garlic, spider plants and coriander to repel insects in the farm. Sticky traps with different colours may be used. Neem based botanical sprays may be used such as Neeemraj Super and Nimbecidine and Achook

EC 1.5%). Use chemical Lambda Cyhalothrin and deltamethrin based products such as Tata Umeme 2.5 EC, Triger 5%) and alternate with Atom 2.5 EC or Decis 2.5 EC according to manufacturers' recommendations.

4.1.2 Aphids

Aphids suck sap from leaves, stem and pods. They cause distortion of leaves and stunting growth of plants (Figure 5).

Figure 5: Heavy infestation of pigeon pea by aphids

Management: Mixed cropping and use of trap crops is advocated.

Beneficial and natural enemies such as lady bird and hoverfly that predate on aphids should be maintained in the natural environment to maintain the aphid population below economic threshold. Yellow sticky traps are advisable for use. Infested plants can be sprayed with soapy solution at the rate of 10-15 tablespoon liquid soap in 20 litres of water. Use neem based botanical products such as Nimbecidine, Neemraj Super or Achook 0.15% EC.

4.1.3 Pod borers *(Maraca testulallis)*

These are caterpillars that are yellowish-white or greenish-white or reddish-white in colour (Figure 6). They feed on flower buds, pods and seeds in the field.

Figure 6: Yellowish-white or greenish-white or reddish-white caterpillars

Management: Destroy infested plant residues by burying deep or burning. Collect pods by crushing or dipping in hot water. The use of Lamba Cyhalothrin (Pentagon 5% EC), Flubendiamide (Belt) and Diafenthiuron (Pegasus 500 SC) products.

4.1.4 Pod sucking bugs

Young larvae usually attack buds and flowers while older ones bore into maturing pods. The flowers and pods are webbed together by frass produced by the larva (Figure 7). A larva may consume 4-6 flowers before larval development is completed. Seeds in the damaged pods are totally or partially eaten out by the larvae. Adult female moth lays light yellow, translucent eggs in groups on flower buds and flowers, developing pods, leaf axils and shoots.

Figure 7: Larvae and adult bug sucking bugs destroy buds and pods covering them with a whitish web

Management

Larvae can be physically collected and mechanically squashed to death. Botanical based insecticides such Nimbecidine at the rate of 20 ml/20L after flowering may, be applied. In severe infestations chemical sprays may be applied such as imidacloprid and betacyfluthrin based pesticides.

4.1.5 Pod sucking bugs *(Maruca vitrata)*

Adult female flies and lay eggs individually in the developing pods.White maggots bore inside the pod and feed on the developing grains (Figure 8). Pupae stage takes place within the pod itself without leaving external symptoms of damage. Adults and nymphs suck the sap from developing pods causing premature drying of pods and lack of normal seed formation. Adult flies emerge through the pod by making a pin-sized hole. Thus, the concealed feeding habit causes more losses to the crop without the the farmers' notice, to enable timely control.

Figure 8: White maggots bore inside the pods and feed on the developing grains

4.1.6 Pod sucking insects *(Clavigralla spp.)*

Adults and nymphs suck the sap from developing pods causing premature drying of pods and lack of normal seed formation (Figure 9).

Figure 9: Adults and nymphs suck the sap from developing pods

Control/ Management

Bugs can be collected by hand regularly and killed, especially during flowering and pod formation; conserve natural enemies such as the assassin bugs, spiders, praying mantises and ants which are important natural enemies of bugs that kill or deter bugs. Spray Neem products to repel bugs. If necessary, spraying should be done in the morning when the immature stages are exposed.

4.1.7 Root knot nematodes

Nematode are worms that parasitize on pigeon pea. Their hot spots are identified where pigeon pea plants appear stunted or drought-stressed compared to nearby plants. In advanced stages of infection pigeon pea leaves often display symptoms of potassium or nitrogen deficiencies, with high frequencies of interveinal chlorosis and leaf scorching (Figure 10).

Water soaked spots and curling of pods appearance as well as flower abortion is experienced.

Figure 10: Curling of pigeon pea pods and flower abortion

Management

Practise crop rotation with grass crops. Plough the land during hot months and expose the farm to the sun (solarization) to destroy nematodes. Clean farm tools to remove contaminated soil adhering to tools and footwear. Uproot affected plants and burn or bury. Use biopesticide such as Nimbecidine or Achook 0.15% EC to control the nematodes. Maintain high levels of organic matter (manure and compost) in the soil, incorporate neem cake powder into the soil.

4.1.8 Bruchids

These manifest themselves by boring thin tunnels beneath the seed coat and circular holes on the surface of the grain (Figure 11).

Figure 11: Bruchids bore circular holes on grain

Management: Clean stores before storing new grain. Dust grain with Actellic super at 50 gm per 90kg bag, ash or neem leaves at rate of (4-5 kg/ton or 5-10 g/kg).

4.2 Common diseases

There are many pathogens that attack pigeon peas including fungi, bacteria, mycoplasma and nematodes. However, only a few of them cause economic losses in crop production along the pigeon pea value chain.

The crop is susceptible to *Fusarium* wilt especially on wet soils.

4.2.1 Fusariumwilt (*Fusarium udum*)

The fungus survives on infected debris in soil for three years. Symptoms appear on seedlings 4-6 weeks after planting and on the fully grown crop. Infected plants normally occur in patches thus incidences can be easily noted (Figure 12). Leaves of infected plants get limp, wilt, turn yellow and fall, necrotic stem tissue, xylem develops black streak when teased apart. The stems develop brown to dark purple bands around the stem.

Figure 12: Fusarium attack on a pigeon pea crop

Management: A three year crop rotation schedule with non legumes and the planting of resistant varieties is advised. Field sanitation by removing or rouging infected plants and burning them should be done. A soil sample analysis should be done before planting of pigeon peas at each and every season. Suspected infected soils can be drenched with Carbendazim based products like Rodazim SC or Bendazim SC as per the manufacturers' recommendations.

4.2.2 Leaf and pod spot *(Ascochyta pisii*)

Symptoms appear as irregular circular, often sunken necrotic brown spots on leaves and pods. On lower leaves the spots occur under the leaves and coalesces to form dark necrotic black blight appearance on the leaf surfaces and eventual defoliation occur (Figure 13). Sometimes symptoms appear on petioles thus forcing drying of leaf tips and premature defoliation.

Figure 13: Circular, sunken brown spots that coalesce and turn black thus causing necrosis on leaves

Management

Plant certified or clean seeds while practicing crop rotation over seasons with non legume crops for a period of 2 to 3 seasons. Use of tolerant pigeon pea varieties such as KAT60/80 and Mbaazi 2 is advisable. Rouging out and burning of infected plant debris helps in minimizing the spread of the cercospora pathogens in the field. Use of chemical foliar sprays such as Mancozeb based products (Oshothane or Farmcozeb) and Azoxystrobin products such as Ortivasc may be used as preventive or curative approaches in containing the disease spread in the farm.

4.2.3 Powdery Mildew (*Erysiphe polygoni*)

White to greyish mildew patches visible on leaves. Infection by powdery mildew causes crickling and yellowing of the leaves causing premature defoliation (Figure 14).

Figure 14: Powdery mildew patches on leaves

Management

Practise early planting, crop rotation with non-legumes for 2-3 seasons. Observe high field hygiene, uproot and destroy severely infected plants to reduce inoculum in the field. Avoid overhead irrigation to reduce humidity and splash which promotes disease spread. Apply sulphur based protective fungicides at a rate of 30g/10ltrs water, e.g. Jet, Cosavet DF, Flosul Plus, Wetsulf WP or spray with Triadimefon at a rate of 40gm/20ltrs water at 10-14 day intervals, e.g. Bayleton WP25, and Edimefon 25 WP.

4.2.4 Alternaria blight *(Alternaria alternata)*

Appears in the form of light to dark brown small necrotic spots on the leaves and pods(Figure 15). Severe infections cause defoliation and destruction of crop. Disease is mostly confined to older leaves but may infect new leaves after rainy season.

Figure 15: Light to dark brown small necrotic spots on leaves and pods

Management

Crop rotation with non legume crops for a minimum period of 2 to 3 seasons is advised. Working in the farm during wet periods is not advised and if need be its recommended that working should start from non infected areas towards infected areas. All volunteer and infected plants should be uprooted and burned to minimize spread in the farm, use tolerant varieties and if infections are serious spray with copper based fungicides (Cuprocaffaro or isacop 50WP and alternate with Ortiva SC).

4.2.5 Pigeon pea yellow mosaic virus

This disease is transmitted by whiteflies. Infected leaves are chlorotic and eventually turn necrotic. Diseased plants become stunted have late maturity and produce fewer flowers and pods (Figure 16).

Figure 16: Chlorotic infected leaves turn necrotic as the diseased plants become stunted

Management

Use certified or clean seed. Disinfect tools with Jik (50ml/L of water). Rogue out infected plants up to 45 days. Foliar spray with neem based biopesticides such as Nimbecidine or Achook 0.15% EC. Thiamethoxam 75 WS 1g/3 L and repeat after 15 days.

4.2.6 Rust

Dark brown raised spots (pustules) appear on the underside of the leaves and in severe cases the stems and pods get infected and leaves dry off and later fall off (Figure 17).

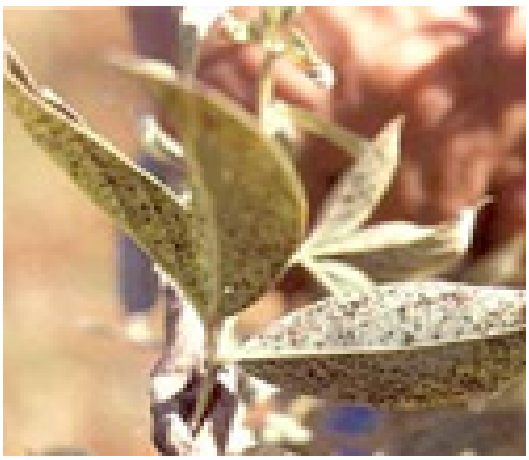


Figure 17: Dark brown raised spots on the underside of the leaves

Management

Use of certified clean seed is recommended for planting. Early planting coupled with crop rotation with non legume for 2-3 seasons is advised. Diseased plants and weeds that act as alternative host should be uprooted. Avoid working in the field during wet weather and spray with copper oxychloride based products such as cuprocaffaro or isocap once initial symptoms are observed in the crop.

4.2.7 Root rots

Infected plants wilt and eventually are necrotic (Figure 18). The diseased plants are stunted with late maturity and production of fewer flowers and pods that turn yellow in colour.

Figure 18: Diseased plant with necrotic symptoms due to infection

Management

Practice crop rotation for 3-4 years with non legume crops. Avoid surface run off by digging trenches, as these spreads the pathogen. Uproot affected plants and burn. Sterilize farm tools with Jik 50 ml/L. Drench affected fields with biopesticides (Trianum -P; Trichotech, Rootguard). Where biopesticides are not available drench affected plants with Carbendazim products such as Rodazim. If Rodazim is not available, drench affected plants with Saat WP, Sherriff 75 WP.

4.3 When to Harvest

- Pigeon peas can be harvested when still green and used as a vegetable or they can be left to dry and harvested as dry grain.
- Harvesting of green beans is done when the pods and seed are developed. Since bright green seed is preferred, the pods should be harvested just before they start losing their green colour (Figure 19). The appearance of pods at this stage varies between cultivars.

Figure 19: Hand picking of pigeon peas

4.4 Harvesting

Harvesting of dry grain can begin about five months after sowing and may continue for a further six months or several years. Pigeon peas are usually grown for only one year owing to the high incidences of fusarium wilt and mealy bugs in old crops.

- Start harvesting when pods have reached 95% physiological maturity.
- Green pods are commonly picked by hand and the seed removed from the pods also by hand. Green pods are picked over a long period.
- Harvest dry grains when most of the pods are fully ripe and have turned yellow but before the pods start to shatter.
- Nearly mature pods continue to ripen even after plants are cut, but very dry pods shatter and heavy losses occur when plants are cut or during transportation.

  Harvesting is done by hand picking individual pods or cutting the bearing branches. Harvested material is dried in the sun in the field or in the homestead for about a week, depending on the weather conditions.
- Harvesting ground should be covered with canvas so as not to allow the grains to collect a lot of dust and dirt or get mixed up with other impurities.
- After harvest, the stems are cut back to facilitate re-growth and a second (ratoon) crop is harvested in the subsequent season.
- Farmers can use human labour, bicycles or domestic animals to transport the harvest to the homestead (Figure 20).

Figure 20: Means of transportation from the field

Source: http://ianandterri.blogspot.co.ke

5 POST HARVESTING MANAGEMENT

5.1 Threshing/Shelling

Threshing can be done using mechanical or manual methods (Figure 21). Entire air-dried plants or pods are threshed, usually by hand and seeds cleaned. For mechanical method, a thresher can be used which makes work efficient and faster but for manual threshing sticks are used to hit the pods either placed on a tarpaulin or inside a bag. To avoid dirt and impurities, the threshed seeds should be spread on polythene sheets. The grains are then winnowed and sorted.

Figure 21: Threshing and shelling of pigeon peas

https://en.wikipedia.org/wiki/Pigeon pea

5.2 Winnowing and Sorting

Winnowing is the process of removing impurities from the threshed grain and this is achieved through use of winnowing trays ('*uteo*') or by scooping the grain and subjecting it to wind action (Figure 22). The grain drops to the ground while the chaff or foreign material is blown away. Sorting is also done to remove stones (Figure 22).

Figure 22: Winnowing and sorting of pigeon peas

(Source: https://www.oneacrefund.org/

Figure 23: Drying of pigeon peas

Source: Hodges and Stathers, 2012

5.3 Specific requirements for pigeon peas

Unclassified pigeon peas shall be classified as reject pigeon peas, and shall be regarded as unfit for human consumption. Table 2 shows the Specific requirements for pigeon peas.

Table 2: Specific requirements for pigeon peas

Parameter		Requirements			Method of test
		Grade 1	Grade 2	Grade 3	
Physical characteristics	The Pigeon Peas (*Cajanus cajan* Linn.) shall be sound, dry, fresh and light to medium brown in colour. They shall be sweet, clean, wholesome, uniform in size, shape, colour and in sound merchantable conditions.				ISO 605
Purity Whole Pigeon Peas, defective Pigeon Peas and seed coats.		99.0% Min by weight	97.0% Min by weight	97% Min by weight	ISO 605
Moisture, % max by wt		10.0	12.0	14.0	ISO 711/712
Damage, % by mass, *max, unless otherwise stated*	Heated or rotten	Nil	3K	1.0	
Mouldy	Nil	6K	2.0		
Split and broken	2.0	3.0	4.0		
Immature seeds	1.0	2.0	3.0		
Defective Pigeon Peas not of the specified variety. Pigeon Peas that are bin burnt, broken, caked, chipped, frost damaged, heat damaged, insect damaged, sappy, shrivelled, split, sprouted, weather damaged, wrinkled and affected by mould (field or storage). Includes pods that contain pigeon peas, whether broken or unbroken, and loose seed coat.		3.0% Max by weight, includes nil mould (field or storage)	5.0% Max by weight, includes nil mould (field or storage)	8.0% Max by weight, includes nil mould (field or storage)	
Poor colour Pigeon Peas whose seed coat or kernels are distinctly off colour from the characteristic colour of the predominating class.		1 % Max by weight	1 % Max by weight	1 % Max by weight	
Weevilled grains, % by count		0.5	1.0	2.0	
Foreign matter, % by mass, *max.*	Excreta	0.01	0.01	0.01	
	Ergot	Nil	0.05	0.05	
	Insect parts	0.02	0.02	0.02	
	Sclerotinia	0.05	0.05	0.05	
	Stones or shale	0.10	0.20	0.50	

Foreign material Unmillable material and all vegetable matter other than Pigeon Pea seed material.	0.5 % max by weight, includes 0.1 % max by weight unmillable material	1.0% max by weight, includes max 0.5% max by weight unmillable material	2.0% max by wt, includes 1% max by wt field peas and 0.7% max by wt unmillable material	4.2.2

5.4 Grain dressing and storage drying (knowing when the grain is dry enough)

Grains should be stored when thoroughly dried (< 13% Moisture content) and can be determined using a moisture metre, dressed in Actellic Super (50 g per 90 kg bag), or with Neem leaves or treated with wood ash (4-6 kg per 90 kg bag) if stored for longer period. The grains can also be kept in airtight drums or in hermetic bags. Clean bins prevent insect attack, which can be considerable. Storage as split peas reduces bruchid attacks. However, if seeds are to be used for planting, they should not be stored in airtight containers to maintain viability, gunny bags are recommended.

5.4.1 How to check grain moisture content in pigeon peas

The approach is to use the salt method, which is simple and quick. Dry salt will absorb moisture from grain. Materials required: A clean dry glass bottle of about 750 ml capacity, with a cap that makes it airtight and some common salt.

How to do it

It is important to ensure the salt is dry. Place the salt in a thin layer on some plastic sheeting in hot sun for at least 3 or 4 hours, until the salt is hard. Turn the salt at intervals during this time. Store the dry salt in a sealed container.

- Fill one third of the dry bottle with the grain sample (250 g to 300 g).
- Add 2 or 3 tablespoons of salt (20 g or 30 g).
- Close the bottle tightly with its cap.
- Shake the mixture vigorously for 1 minute Leave the bottle to settle for 15 minutes.
- Request someone with a moisture meter and who has been trained on its usage to test the grain moisture content.
    - If after 15 minutes the salt sticks to the side of the bottle, then the moisture content of the grain is above 15% and is therefore not safe for storage.
    - If the salt does not stick to the bottle then the moisture content is below 15% and is therefore safe for storage.

The grain gets harder as it gets drier, therefore with experience farmers can tell by biting or pinching it (Figure 23). Before beans are threshed, make sure that they dry in the pod. If you start threshing immediately after harvesting, you will damage the seed because it is too moist to be threshed.

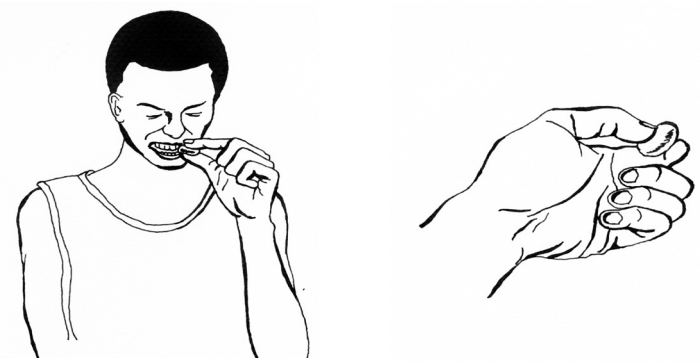


Figure 24: Checking when the grains are dry using teeth or pinching with fingers

Source: Soniia (1998) as described in KALRO-KCEP (2016); APHLIS (2012)

Different sounds when pouring or rattling

These methods are subjective and of no use if the farmer is not experienced.

5.5 Storage of pigeon peas using appropriate methods

Pigeon peas can be stored in jute, sisal or propylene bags, in hermetic bags or plastic drums or in metal silos (Figure 26, 27 and 28).The hermetic grain storage bags have allowed farmers to safely store their grain, so that they can sell them beyond harvest season.

- The hermetic storage technology is linked with the depletion of oxygen in the hermetic container and with the parallel rise in carbon dioxide.
- Low oxygen leads to cessation of larval feeding activity, whereas elevated levels of carbon dioxide have little or no effect on feeding.
- Cessation of feeding arrests the growth of the insects, which do not mature and do not reproduce.
- As a result, population growth ceases and damaging infestations do not develop.
- The cause of death is desiccation, resulting from an inadequate supply of water by blocking the supply of oxygen.

Figure 26**: **Jute bags for storage of grains

https://www.olx.co.ke/ad/agroz-bags-storage-of-grains

5.6 How to store grain in Purdue Improved Crop Storage (PICS) bags

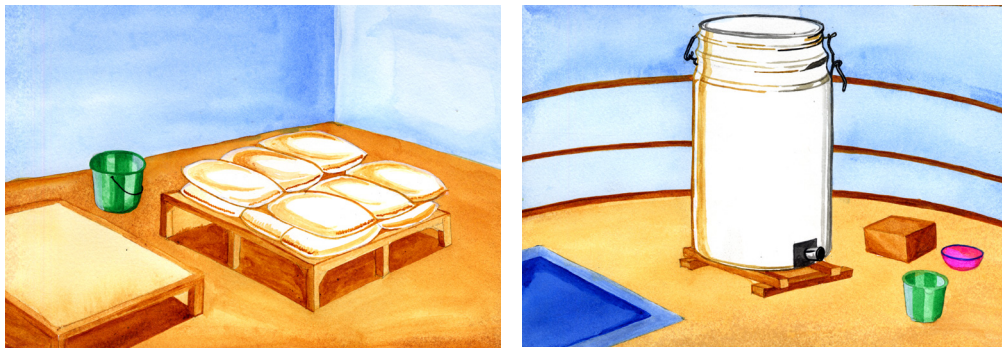
- Buy PICS bags from approved merchants. Separate the three PICS bags and check the two inner bags for holes and tears.
- Do not use bags that have holes or tears. Gently pour 2-3 kg of grain into the inner bag. Drop the partially filled inner bag into the middle plastic bag (one inside the other).
- Put the two plastic bags into the woven bag. Fold the tops of the bags inside-out. Fill the inner bag with more grain. Make sure no grain gets between the bags.
- Fill the inner bag far enough so that a lip remains for tying. Pack the grain tightly to remove air. Twist the lip of the first bag tightly shut. Fold it over and tie firmly with string at the base of the twist and over the folded twist.
- Pull the middle bag up over the first one so that it completely surrounds it. Twist the lip shut, fold over and tie, as before. Follow the same steps for the outer/woven bag. It is easy, simple and effective. Clean grain with no insecticides.

Figure 27: Examples of hermetic bags used by farmers (PICS bags)

Purdue Agricultural Communication photo/Beksoubo Damienne

Pre-cautions during storage

- Use of hermetic bags does not guarantee long term storage since it is permeable to storage pests.
- Do not mix the newly harvested grain with stocks from previous harvests. Store the bags at least one 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 pigeon peas seed should be placed out in the sun occasionally (once every month) in order to reduce moisture content and to kill off pests.
- Pigeon peas 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.



A B

Figure 28: (A) Sacks in a house placed on a pallet made of Insect-proof and (B) hermetic stores and metal silo rassed of ground

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

6 MARKETING OF PIGEON PEAS (Transportation to the market)

The grains 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. The major drawback for producer price is lack of grading and standards. Prices are usually set by buyers who collect all grades (including varietal mixtures and high levels of foreign materials) and pay the same price for all. The farmers have no incentive to bring to the market purified grains as there is no premium for quality. The export market is projected to grow at 15.9% per annum over the period from 2010 to 2020.

Market service providers include

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

Pigeon peas marketers include

- Peas traders (retail)
- Peas traders (wholesale)
- Pigeon vendors (collectors, assemblers)
- Super markets
- Farmer associations/groups
- Make sure the scales are working and that they have a recent calibration (according to 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 pigeon peas is a strategy that can be adapted by farmers to fetch higher prices. Grading of pigeon pea is mostly achieved by physical inspection of visible attributes based on sorting, cleaning and packaging. Measuring using conventional weighing scales, and usually in kilograms is another common practice for standardization.

6.1.2 Ungraded and rejected pigeon peas

Ungraded pigeon peas are the ones which do not fall within the quality standard groups while rejected beans are those dusty and materially weathered. Quality grains fetch better markets and returns. (Figure 29).

Figure 29: Quality grains fetch better markets

7 PACKAGING, LABELLING AND BULKING

Graded pigeon peas should be weighed and packaged in small bags and delivered to a central place for collection. This can be under cooperative societies and farmer groups.

- Pigeon peas shall be packed in gunny bags/jute bags, poly woven bags, poly pouches, cloth bags or other suitable packages which shall be clean, sound, and free from insect, fungal infestation and the packing material shall be of food grade quality.
- Pigeon peas shall be packed in containers which will safeguard the hygienic, nutritional, technological and organoleptic qualities of the products.
- The containers, including packaging material, shall be made of substances which are safe and suitable for their intended use. They shall not impart any toxic substance or undesirable odour or flavour to the product.
- The net weight of the pigeon peas in a package shall comply with OIML R87.
- Each package shall contain pigeon peas of the same type and of the same grade designation.
- Each package shall be securely closed and sealed.

8 VALUE ADDITION AND UTILISATION OF PIGEON PEAS HOUSEHOLD LEVEL

Pigeon peas provide human food contain 25% protein and can also be used as livestock feed. It is an excellent source of dietary protein. It can be consumed in form of whole grain or split dried peas (Figure 30). It is also consumed as a vegetable (immature pods or green pea) or a dried grain (cooked and eaten as dhal (dry split cotyledons). The dry peas may be sprouted briefly, and then cooked, for a flavour different from the green or dry peas. Sprouting enhances digestibility of dried pigeon peas via the reduction of indigestible sugars that would otherwise remain in the cooked dried peas. Pigeon peas leaves and husks provide livestock feed. It is also useful as tall hedges on dry soils and on the bunds of paddy fields. The branches and stems can be used for baskets and firewood. It is often grown as shade crop, cover crop or windbreak. The grains are utilised in variable ways; the utilisation of pigeon peas in Kenya can be in form of:

- Fresh peas
- Dry peas
- Industrial use
- Export market

(a) Fresh peas for consumption

(b) Figure: Pigeon peas with coconut

(c) Split grain

(d)Whole grain

Figure 30: Excellent source of dietary protein, It can be consumed in form of whole grain or split

8.1 Industrial level processing

Labelling each package shall be legibly and indelibly marked with the product name as pigeon peas, variety and grade

- Canning (Figure 31)
- Packaging and grading
- Boiling peas with or without testa; marsh or not and served with *ugali* or rice.
- Pre-cooking plus tomato sauce and canned

Examples of pigeon peas key processors include Kenya Millers Ltd, Spice World Limited and Pisu & Company Limited, which are located in the main urban centres, with Nairobi and Mombasa having the highest concentration. Constraints faced by processors:

- Poor quality beans
- Mixed varieties hence affecting cook ability, non-uniformity

Figure 31: Canned pigeon peas products in Kenya

(Shiferaw et al. 2008)

9 TAKE HOME MESSAGES

The main points to remember in pigeon pea postharvest management are:

- Timely land preparation enables one to prepare for early planting.
- Keeping the field weed free helps reduce competition of the crop and weeds.
- Regualr scounting arrests development of pests and diseases and allow their control before they cause much damage.
- Timely harvesting of pigeon peas to ensure they are dry.
- Ensure the moisture content is the recommended levels.
- Thresh pigeon peas 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 peas 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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