BEAN PRODUCTION CONSTRAINTS, BEAN SEED QUALITY AND EFFECT OF INTERCROPPING ON FLOURY LEAF SPOT DISEASE AND YIELDS IN TAITA TAVETA DISTRICT, KENYA

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

To my husband,
Mr Shem Ajowi Odhiambo;

my parents,
Mr. Francis Wachenje Ngetti
and
Mrs. Teckla Wawasi Wachenje;

and my sister and her husband,
Mrs. Esther Walowe Mwasaru
and
Mr. Aloysius Mwasaru Mkirema

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ABSTRACT

The study was undertaken to document bean production constraints in Taita-Taveta district, to evaluate the incidence and severity of floury leaf spot (*Mycovellosiella phaseoli* (Drummond) Deighton) on different bean lines and the resulting yields when grown in monoculture and as an intercrop with maize and to assess the effect of storage period on bean seed quality. A Participatory Rural Appraisal was conducted in the area followed by administration of a semi-structured questionnaire. Four and five bean lines in farmer-managed and researcher-managed trials respectively were planted as monocrop (at two varying spacing) and intercrops (at two varying spacing) with maize. Bean seeds produced from the farmer-managed trials were assessed for quality after 2 and 5 months of storage.

The key bean production constraints in order of importance were insect pests, high cost of chemicals, diseases, high cost of certified seed, lack of high quality seed at farm level for planting and poor soil fertility.

In farmer-managed trials, intercropping beans with maize increased the incidence of floury leaf spot during the short rains of 1999. The highest (82.1%) incidence was observed on bean line M22 planted with maize and sown at a spacing of 15 cm x 40 cm whereas the lowest (8.9%) incidence was observed on bean line E8 planted alone at a spacing of 15 cm x 80 cm.

Seed quality tests revealed a significant (P=0.05) decrease in germination percentage in all seed lots after 5 months of storage. There was an increase in the electrical conductivity in all seed lots, a decrease in the Tetrazolium chloride staining in all seed lots and an increase in the moisture content in some seed lots following 5 months of storage.

In researcher-managed trials, intercropping beans with maize had no effect on the incidence but increased floury leaf spot severity. During the long and the residual rains of 2000, the highest severity levels of 14.8% and 1.9% were observed at 10 weeks after planting on bean line M22 planted with maize and sown at a spacing of 15 cm x 40 cm. Bean yields were higher in the monocrop system than in the intercrop system. The best (1517.5 kg/ha) yields during the long rains were produced by bean line E8 planted as a monocrop at a spacing of 15 cm x 50 cm whereas the lowest (410.7 kg/ha) yields were observed on bean line No.B planted with maize and sown at a spacing of 15 cm x 80 cm.

The results indicated that intercropping maize with beans had no effect on incidence but increased the severity of floury leaf spot. Additionally, intercropping resulted in reduction of bean yields probably due to reduced bean plant population and competition from maize. It was also evident that the quality of bean seeds decreased with increased time in storage but the decrease varied among seed lots.

1.0 INTRODUCTION

1.1 Bean production in Kenya

Legumes are among the most important food crops in Kenya. Common beans (*Phaseolus vulgaris* L.) in Kenya are grown mainly in the small holder sector, widely as intercrop with other crops such as maize, sorghum, cowpeas, pigeon peas, potatoes, cotton, and cassava (Acland, 1971; Mukunya and Keya, 1975). As a food crop, common beans rank second to maize in Kenya (MOA, 1986) and it is the main legume cultivated in the country (Anon., 1994). In 1993 over 638,000 hectares of beans were planted giving an estimated yield of 442,000 tonnes (Anon., 1994). The main bean producing areas are Eastern, Central, Rift valley and Western provinces of Kenya (MOAMLD, 1994). At the Coast province, the crop is mainly grown in the medium to high potential areas mainly in Taita-Taveta district (MOA, 1997). In this area, beans are grown at altitudes varying from 700 to 1960m above sea level (Njambere, 1995). They are continuously cropped in Taita hills starting from mid-March up to December with a bean crop free period of 1 to 2 months each year. Pure bean crops are grown from mid-March to May during the long rains. From June onwards beans are grown as intercrops with mainly maize (Njambere, 1995). Average bean yields in the district is 0.6 t/ha (MOA, 1997).

The common varieties grown in Kenya are Rose Coco (GLP-2, commonly known as Nyayo), Canadian Wonder (GLP-24), Red Harricot (GLP-585), Mwitemania (GLPX-92), Mwezi Moja (GLP-1004), and Zebra bean (GLP-806), which were released by Grain Legume Project (GLP) of the National Horticultural Research Station, Thika for different agro-ecological zones of Kenya (Origa, 1992). However, in Kenya the most widely grown bean cultivar is cv. Rose coco-GLP-2 as confirmed during various bean seed surveys (Origa, 1992; Isanda, 1994; Mwang'ombe *et al.*, 1994). Bean yields are generally low with a national average below 0.7 t/ha (Songa *et al.*, 1995) against a potential of 2 t/ha (Mwang'ombe *et al.*, 1994).

1.2 Bean production constraints in Kenya

The major constraints to bean production in many areas include poor agronomic practices, soil infertility, lack of improved cultivars/use of low potential genotypes, moisture stress, weed competition, low plant population at planting, and pests and diseases (Allen *et al.*, 1989; Allen and Edje, 1990).

In Kenya, bean production constraints include land scarcity due to competition with crops such as tea, maize, coffee and potatoes; seedborne pathogens in bean seeds, which provide initial/primary inoculum for specific diseases (Origa, 1992; Isanda, 1994); lack of disease resistant and high yielding cultivars adapted to a range of environments (Mwang'ombe *et al.*, 1994; Njambere, 1995; Songa *et al.*, 1995; Wagara, 1996); uneven rainfall; poor cultural practices; unavailability of good quality planting seed (Origa, 1992; Isanda, 1994); destruction by pests (Schönherr and Mbugua, 1976; Makini and Danial, 1995); and diseases (Origa, 1992; Isanda, 1994; Makini and Danial, 1995; Songa *et al.*, 1995).

Diseases are probably the major factor limiting bean production in Kenya (Origa, 1992; Isanda, 1994; Mwang'ombe *et al.*, 1994). The bean plant is subject to attack by more than 100 pathogens (Harter and Zaumeyer, 1944). The major diseases and the losses that they cause include: halo blight (*Pseudomonas savastanoi* pv. *phaseolicola;* 23-43%) (Origa, 1992; Mwang'ombe *et al.*, 1994), anthracnose (*Colletotrichum lindemuthianum;*

38-95%) (Isanda, 1994), angular leaf spot (*Phaeoisariopsis griseola;* 40-80%) (Wagara, 1996), common bacterial blight (*Xanthomonas campestris* pv. *phaseoli;* 10-75%), rust (*Uromyces appendiculatus;* 18-100%), root rots (10-100%), bean common mosaic potyvirus (35-98%) (Buruchara, 1979; Makini and Danial, 1995) and bean yellow mosaic virus (Allen, 1987; Allen *et al.*, 1989). Floury leaf spot is endemic in Taita Taveta district (Njambere, *et al.*, 1997) and yield losses of 28% have been reported (Allen *et al.*, 1996).

1.3 Floury leaf spot of beans

Floury leaf spot of beans (*Phaseolus vulgaris* L.) is caused by *Mycovellosiella phaseoli* (Drummond) Deighton (Weber, 1973; Deighton, 1974). It is widespread in eastern Africa at mid to high altitudes (1200-1700 metres (m) above the sea level) under cool temperature and high relative humidity (Njambere, 1995; Allen *et al.*, 1996). In Kenya, the disease was reported for the first time in 1965 in Nairobi (Deighton, 1967). It was later observed to be infecting beans in Taita hills in 1992 (Mwang'ombe *et al.*, 1994). The disease, which was later identified as floury leaf spot, was widely distributed in many fields in Taita hills (Njambere *et al.*, 1997). Survey results of 1994 revealed the absence of the disease in Kiambu district, which is located near Nairobi (Njambere, 1995).

Floury leaf spot disease causes serious yield losses on beans. Yield losses of up to 28% have been reported (Allen *et al.*, 1996) and this is attributed to the fact that the disease becomes serious at early and mid-podding causing heavy defoliation (Njambere, 1995). Due to such yield losses control is inevitable. Much work on control of this disease has been carried out in countries such as Uganda (Simbwa, 1972) and India (Singh and

Sharma, 1976; Sharma and Kaushal, 1994). In Kenya, apart from the use of disease resistant bean lines (Njambere, 1995), no other research work on the control of this disease has been carried out. Njambere *et al.* (1997) evaluated 56 bean lines for resistance to floury leaf spot disease under monocropping in Taita hills and at Kabete in the field and greenhouse, respectively. Among these bean lines were No.B, GLP-2, E2, E8 and M22. Bean line No.B was found to be highly resistant; GLP-2 was resistant while the remaining three bean lines were moderately resistant. Earlier, Mwang'ombe *et al.*, (1994) had evaluated these five bean lines among others under monocropping, for resistance to six major diseases, floury leaf spot inclusive, in 11 sites in Kenya. GLP-2 was found to be highly resistant, E2 was resistant, No.B, E8 and M22 were moderately resistant. The five bean lines mentioned above were used in this study.

1.4 Bean seed sources

Due to the high cost of commercial seeds, small-scale farmers tend to use their own seeds, kept from the previous harvest, for planting (Schönner and Mbugua, 1976; Origa, 1992; Isanda, 1994). In some cases, they either buy seeds from other farmers or from the local market. These seeds tend to be highly infected by seedborne pathogens, which serve as the primary inoculum foci for the development and spread of disease epidemics (Origa, 1992; Isanda, 1994; Wakahiu, 2000). The use of clean healthy seeds is therefore seen as a potentially powerful control measure (Fernandez *et al.*, 1987). Considering the above facts, it is essential that small-scale farmers be trained on high quality seed production techniques.

1.5 Seed quality

Seed is the basic and crucial input in agriculture. There are two major aspects to seed in farmers' view: quality and availability. In relation to quality, farmers' primary concern is to grow vigorous and healthy crops. Apart from other agronomic concerns, this means that he or she needs seeds that germinate and produce vigorous seedlings (Almekinders and Louwaars, 1999).

The establishment of healthy seedlings is important for the successful production of any crop. This can only be achieved through the production of high quality seeds. High quality seed production begins with planting of high quality seeds, which ensures a high percentage of field crop emergence and a healthy crop. This is followed by proper management of this crop in the field including disease and insect pest control; proper harvesting and finally proper storage in terms of storage of produce in required conditions and control of storage pests.

Although the causes of poor seed quality in grain legumes appear diverse, from handling damage (Green *et al.*, 1966), seedborne pathogens (Origa, 1992; Isanda, 1994; Wakahiu, 2000) to inappropriate storage conditions (Justice and Bass, 1978), research has revealed the importance of some physiological process, such as deterioration (Roberts, 1972) and imbibition damage (Powell and Matthews, 1978a), in determining seed quality in these crops. Other physiological factors that influence seed quality are aging (Powell *et al.*, 1984), storage period (Powell and Matthews, 1978b) and storage atmosphere (Powell and Matthews, 1977). Imbibition damage resulting from the rapid uptake of water during early imbibition has been identified as the major cause of low vigour in grain legumes because it affects seed germination and vigour during the process of imbibition after sowing (Powell *et al.*, 1984).

Seed health testing methods for seedborne pathogens have been established and widely used in Kenya (Origa, 1992; Isanda, 1994; Wakahiu, 2000) to ensure release of pathogen free seeds to farmers hence preventing early establishment of seedborne diseases in the field thus avoiding disease epidemics. However, seed quality-testing methods for seed vigour such as the conductivity tests, tetrazolium chloride staining and germination tests have not been widely used in the country. Such methods are important in establishing high vigour and low vigour seeds before they are planted in the field. Seed vigour differences determine the performance of the crop in the field in terms of germination, field emergence and crop stand. To ensure high quality seed production, seed quality testing should therefore be included as routine measures.

1.6 General and specific goals of the study

The overall goal was to improve bean production in Taita hills through integration of improved bean lines at small scale farming level.

The specific goals were:

1. To determine the major bean production constraints in Kidaya-Ngerenyi location of Taita-Taveta district using Participatory Rural Appraisal (PRA).

2. To determine the incidence, development and severity of floury leaf spot on new bean lines under bean monocropping and bean/maize intercropping systems.
3. To compare the performance of new bean lines under bean monocropping and bean/maize intercropping systems.
4. To determine the physiological effect of storage period on bean seed quality at the farm level.

2.0 LITERATURE REVIEW

2.1 Beans (*Phaseolus vulgaris* L.)

2.1.1 History of beans

Based on archaelogical remains observed in Peru and South Western United States, Wittmark (1880, 1888a, 1888b), concluded that the common bean (*Phaseolus vulgaris* L.), originated in the Americas. They are thought to have originated in Mexico between 2300 and 4000 BC. Beans have been grown in the Mexican region for the last 4300-6000 years (Wilsie, 1962). The Spaniards and Portuguese sailors and traders then took beans to Europe in the 16th century, reaching England in 1594 (Purseglove, 1968). It is postulated that the Spaniards and the Portuguese sailors and traders introduced the species to Africa (Purseglove, 1968; Nwokolo, 1996). Beans seem to have been grown in Kenya for over 300 years (Mukunya and Keya, 1975). The wealth of common names given to distinctive cultivars is indicative of the long establishment of beans as a food crop in East Africa (Greenway, 1945; Leakey, 1970). The common bean has at least 20 well known and generally accepted names. This multiplicity of names is because the common beans are cultivated in many countries and ecological zones worldwide (Nwokolo, 1996).

2.1.2 Taxonomy of beans

Beans belong to the class Dicotyledonae, sub-class Rosidae, order Fabales, family Fabaceae or Papilionidae (leguminosae) and the genus *Phaseolus* (Holmes, 1986). *Phaseolus* genus includes 150-200 species of plants many of which are cultivated as food or garden ornamentals (Nwokolo, 1996). The specific name *Phaseolus vulgaris* refers to hundreds of varieties and cultivars of the common bean which have been in cultivation for thousands of years (Nwokolo, 1996).

2.1.3 Importance of beans

Common beans are important in providing relatively inexpensive plant proteins. Dry beans contain about 20-30 % protein and are a good source of most essential amino acids (Nwokolo, 1996). They are also rich in carbohydrates (60-65% of the dry weight of beans), are a good source of vitamin B1, nicotinic acid, calcium and iron (Purseglove, 1968). They are a good source of minerals especially potassium, phosphorus and magnesium but a poor source of sodium, zinc, manganese and copper (Nwokolo, 1996).

The common bean including French bean is a popular vegetable and a component of many dishes (Buruchara, 1979; Nwokolo, 1996). The French beans are grown for their immature edible pods while the common bean are grown for dry ripe seeds and, to a lesser extent, for green shelled beans (Purseglove, 1968). Dry beans provide a major fraction of the daily protein intake of millions of low and moderate-income families in Africa and Asia (Duke, 1981). The straw is used as forage (Purseglove, 1968).

Apart from their nutritional importance, beans play an important role in enriching the soil with nitrogen, through fixation of inorganic nitrogen, thus raising the soils fertility status. This is especially important in nitrogen poor soils and has been shown to benefit associated cereals under bean cereal intercropping conditions (Chemining'wa and Nyabundi, 1994). Biologically fixed nitrogen may also benefit alternating crops in a rotation involving legumes.

French beans are also important as a source of foreign exchange to the country and a source of income to the small-scale farmers (Songa *et al.*, 1995).

2.1.4 Ecological requirements for bean production

The common bean is a very common crop of most temperate, subtropical and dry tropical climates (Nwokolo, 1996). It is the main pulse crop grown in all agricultural regions of Kenya (Anon., 1994).

Beans are adapted to temperate and cool tropical climates (Allen *et al.*, 1989). Altitude ranges for bean growing are between 500-2700 metres above sea level (Acland, 1971). Preferred soil types vary considerably between regions of production but in general fertile and well-drained soils are required. Optimum temperatures range between 16-24°c. Annual precipitation is in the range of 500-2000mm with a bimodal distribution in East Africa (between latitudes 6°N and S).

Seasonal lengths from sowing to harvest vary from about 70 days in drier lowlands to about 150 days in humid lands although this depends also on the altitude and growth habit of the bean cultivar (Allen *et al.*, 1989; Mwang'ombe *et al.*, 1994).

2.2 Floury leaf spot of beans

The disease caused by *Mycovellosiella phaseoli* is also known as flowery leaf spot of beans.

2.2.1 History and geographical distribution

Floury leaf spot of beans occurs in the medium to high altitude areas under conditions of moderately low temperatures and high humidity (Njambere, 1995; Njambere *et al.*, 1997). Drummond first described the fungus on French bean from Minas Gerais, Brazil in 1945. In 1950, Petrak reported the disease in Ecuador, Latin America. It was later reported in Nicaragua (Stevenson, 1957), Colombia (Cardona Alvarez and Skiles, 1958), North-West India (Sohi, *et al.*, 1965), Guatemala and Dominican Republic (Schieber, 1969), and in Sikkim, India (Srivastava *et al.*, 1992).

In Cauca valley, Colombia, at an altitude of 1000m the disease was reported to be practically unknown (Cardona Alvares and Skiles, 1958). In the same country, in the savannah of Bogota, at 2600m, floury leaf spot disease was reported to be rare if ever seen (Cardona Alvares and Skiles, 1958). Thus, temperature plays an important role in the distribution of *M. phaseoli* since temperature differential between 1000m and 2600m is considerable in Colombia whereas the annual precipitation from one region to another is fairly uniform (Cardona Alvares and Skiles, 1958).

In East Africa, the disease was first reported by the Commonwealth Mycological Institute from collections made in Uganda as early as 1930, Tanzania (1939) and Kenya in 1965. It has been reported in Kampala, PortHall, Ankole, Kukalusa in Uganda; Moshi, Arusha, Tengen and Oljore near Arusha in Tanzania; Nairobi (Deighton, 1967) and in Taita hills, mainly Wundanyi and higher parts of Mwatate divisions in Kenya (Njambere, 1995;

Njambere *et al.*, 1997). The disease has also been reported in Ethiopia, Malaysia, New Guinea (Deighton, 1967) and Burundi (Perreaux *et al.*, 1985). Inspite of the numerous collections, the disease has never been reported in Western Africa, Zimbabwe and South Africa (Deighton, 1967).

2.2.2 Economic importance of floury leaf spot

Comprehensive studies on the effects of floury leaf spot on yields have not yet been conducted, but it is generally accepted that the disease is potentially serious. During some of the more humid growing seasons, at altitudes of 1800-2200m, the disease ranked with, or higher than anthracnose (*Colletotrichum lindemuthianum* [Sacc. and Magn.] Scrib.), gray blotch (*Cercospora vanderyisti,* P. Henn.), and angular leaf spot (*Phaeoisariopsis griseola* Sacc.) in prevalence and severity in commercial plantings (Cardona - Alvarez and Skiles, 1958). It was considerably more important than rust (*Uromyces appendiculatus*), powdery mildew (*Erysiphe polygoni*) and bacterial blight (*Xanthomonas campestris* pv *phaseoli* (E. F. Smith) Dows.) (Cardona-Alvarez and Skiles, 1958). The disease has been reported to be the most serious on French beans in areas where it occurred (Deighton, 1967). In Burundi, it was the most prevalent disease in Murongwe and Gatega at 1450 and 1600 metres above sea level, respectively (Perreaux *et al.*, 1985). In Rwanda, annual dry bean losses from floury leaf spot were estimated at 30,264 tonnes (Trutmann and Graf, 1993). Yield losses resulting from the disease can be as much as 28% (Allen *et al.*, 1996). This is attributed to the fact that the disease becomes serious at early and mid-podding stage, causing heavy defoliation (Njambere, 1995).

2.2.3 Etiology

2.2.3.1 Nomenclature and classification

Mycovellosiella phaseoli (Drummond) Deighton is the causal agent of floury leaf spot of beans. Other synonyms that have been used are: *Ovularia phaseoli* (Drummond, 1945), *Ramularia phaseolina* (Petrak, 1950) and *Ramularia phaseoli* {(Drummond) Deighton, 1967}.

The form-genus *Mycovellosiella* together with the form - genus *Cercospora* are placed in the form-family Dematiaceae and in the form-order Moniliaceae of the form - class Deuteromycetes and sub-division Deuteromycotina (Alexopoulos and Mims, 1979).

2.2.3.2 Morphological characteristics of the pathogen

Morphological characteristics of conidia and conidiophores provide the main taxonomic criteria for species delimitation (Hughes, 1953). The colourless conidiophores emerge in tufts from the stomata and intertwine in clusters around the leaf hairs (Sohi *et al.*, 1965). After they emerge from the stomata, they grow along the lower epidermis of the leaf and down the leaf trichomes (Cardona- Alvarez and Skiles, 1958). When several to many hyaline conidiophores grow around a trichome, they produce what appears upon cursory examination to be a synnema. This growth gives the tufty appearance to the lower surface of an infected leaf. Conidiophores are borne as terminal and lateral branches ranging from 2.5-7.0 μm long. They are septate, colourless, smooth, branched, flexuous, and slightly or strongly geniculate, sometimes zigzag. One or two conidial scars occur at the apex of the conidiophore (Njambere, 1995).

Conidia vary in shape and size (Sohi *et al*, 1965). They are mostly ellipsoid or ovoid, with acute or obtuse tips, and papillate base at the point of attachment. They are straight, hyaline, commonly aseptate, rarely one septate and measure 8.0 - 19.0 x 3.5 - 5.5 µm (Njambere, 1995). However, conidia from sporulating lesion on the leaf surface are smaller and more regular in shape when compared with conidia obtained from culture plates (Njambere, 1995).

2.2.3.3 Host range

The primary host of the pathogen is the *Phaseolus* (beans) species mainly *Phaseolus vulgaris* (common bean) (Drummond, 1945) and *Phaseolus pubescens* (rice bean) (Srivastava *et al.*, 1992).

2.2.4 Symptomatology

Symptoms caused by floury leaf spot can be observed any time after the emergence of the first trifoliolate leaves (Cardona-Alvarez and Skiles, 1958). They first appear on the lower leaves and progress upwards in the plant (Cardona-Alvarez and Skiles, 1958). The disease is characterised by white floury spots that are conspicuous on the lower surface of the leaves. At first these spots are angular, as is characteristic of angular leaf spot but they are more round or oval and sometimes, delimited by the veins of the leaves. These lesions, which later coalesce to become irregularly shaped, bear white tufty mycelia, conidiophores, and conidia of the pathogen (Allen, 1987), which give leaves the appearance of having been sprinkled with coarse flour (Cardona-Alvarez and Skiles, 1958; Deighton, 1967; Njambere, 1995). Spots appear water soaked at first, but later become grey brown in colour (Schieber and Zentmyer, 1971). These spots are usually brown in colour on the upper side of the leaves and greyish blue on the lower side (Schieber and Zentmyer, 1971). Spots on mature leaves in the advanced stage of disease show a deep brown necrosis, which give a burned appearance. No symptom has been observed on any other plant part except the leaves (Cardona Alvarez and Skiles, 1958; Njambere, 1995).

2.3 Control of floury leaf spot

2.3.1 Chemical control

Various studies (Simbwa, 1972; Singh and Sharma, 1976; Sharma and Kaushal, 1994; Allen *et al.* 1996) have revealed that chemicals can effectively control the disease. However, they are too expensive for the majority of the bean growers in Kenya who are small-scale farmers. Besides, use of chemicals usually poses a health hazard to human beings.

2.3.2 Host resistance

Use of resistant varieties is the cheapest and the most environmental friendliest means of controlling plant diseases (French *et al.*, 1996). Resistant cultivars are particularly convenient and practical especially for countries with underdeveloped or developing agriculture (Prior *et al.*, 1994). Aggarwal *et al.* (1974) evaluated 36 cultivars for resistance to the disease in India. Cultivars such as PLB 326 and EC 30020 showed resistance to the disease as the number and size of spots were much less compared to EC 57714 and Parvati, which were highly susceptible. None of the 36 cultivars tested were immune. In addition, of the 54 cultivars tested by Kapoor *et al.* (1988), 4 were resistant, 15 moderately resistant, 10 moderately susceptible and 25 were highly susceptible.

Eighty-nine *Phaseolus vulgaris* L genotypes consisting of local and exotic collections were tested in India for components of resistance including lesion number, lesion size and halo size over a period of 2 years (Sharma *et al.*, 1996). The two parameters, lesion size and halo size, were strongly correlated. Lesions were always larger than halos; however, accession EC285577 designated as highly susceptible on the basis of number of lesions, had restricted lesions with exceptionally large halos. Only EC 285550 and EC285556 were resistant to floury leaf spot and EC 285549 and EC 285572 were moderately resistant. The disease appeared late in resistant as well as in moderately resistant lines in comparison with the highly susceptible line EC 285578 (Sharma *et al.*, 1996).

Njambere *et al.* (1997) evaluated 56 genotypes under monocropping for resistance to floury leaf spot disease in the field in Taita hills. Of the 56 genotypes evaluated, 6 were highly resistant, 5 resistant, 30 moderately resistant while the remaining 15 were susceptible. The most resistant bean genotypes were Mwitemania-GLPX-92, E5, No.B, E9, Red haricot-GLP-585 and M25.

The main disadvantage with the use of resistant cultivars however is that the pathogen may develop mechanisms of overcoming this resistance.

2.3.3 Intercropping

In Kenya, like many developing countries, traditional agricultural systems are based on the growing of crops in mixtures (Maina and Drennan, 1998). A common practice is that of row intercropping whereby, maize and beans are planted in rows that are close to each other (Ndakidemi *et al.*, 1988). Intercropping is considered beneficial for the farmers because it reduces the risk of total crop failure from drought, pests or diseases (Jonathan and Jeremy, 1991; Maina and Drennan, 1998). It ensures greater yield stability over seasons, higher yields per unit area of land (Ndakidemi *et al.*, 1996; Maina and Drennan, 1998), better use of resources (Nekesa *et al.* 1998) and environmentally, it reduces soil erosion (Jonathan and Jeremy, 1991) while maintaining soil fertility (Chemining'wa and Nyabundi, 1994).

One additional outcome of a multiple cropping strategy may be improved disease control suggested both theoretically (Burdon, 1978) and empirically (Burdon and Chilvers, 1976; Rheenan *et al.*, 1981; Igbokwe *et al.*, 1983) for a range of crop combinations. However, disease increase under multiple cropping has also been reported (Moreno, 1977). Most workers have only speculated on the mechanisms of disease alteration which could be brought about by microclimatic changes, inoculum trapping by non-host plants and induced resistance (Johnson and Allen, 1975; Mukiibi, 1976; Trenbath, 1977).

Kikoka *et al.* (1989) reported reduced severity of common bacterial blight (*Xanthomonas campestris* pv *phaseoli*), bean common mosaic (bean common mosaic potyvirus) and angular leaf spot (*Phaeoisariopsis griseola*) when beans were intercropped with maize.

Boudreau (1993) reported that intercropping reduced the area under disease progress curve (AUDPC) of angular leaf spot disease in the short rains at Kabete and at Thika, Kenya in the long rains by 23-33% at bean:maize proportion of 2:1 for some leaf positions, but did not reduce AUDPC significantly at Kabete in the long rains. Lanter (1990) observed that maize intercrop could increase or decrease angular leaf spot severity, depending on seasons. In Ethiopia, mixed and row intercropping of maize and beans have been reported to significantly decrease the incidence and severity levels of bean common bacterial blight and rust (*Uromyces appendiculatus*) (Fininsa, 1996). Mixed intercropping reduced common bacterial blight on average by 23% and 5% compared with sole cropping and row intercropping, respectively. It reduced rust incidence levels on average by 51% and 25% compared with sole cropping and row intercropping, respectively.

Gallotti *et al.* (1992) reported that intercropping with maize hardly influenced rust incidence but reduced the severity of rust attacks in experiments conducted in Brazil. A study (Reeves, 1990) carried out in Costa Rica to investigate the effect of planting density of beans (*Phaseolus vulgaris* cv. Huetar) in polyculture with maize (cv. Los Diamantes) revealed an increase in the incidence of bean golden mosaic bigeminvirus (BGMV) with an increase in density between plants. Anthracnose (*Colletotrichum lindemuthianum)* is reported to be increased by association with maize (Diaz, 1981) and web blight is increased by association but decreased by relay in relation to its incidence in sole crops (Mora and Galávez, 1987). Intercropping is reported to have reduced halo blight severity (Vermeulen, 1982), reduced rust incidence (Diaz, 1981), and reduced angular leaf spot severity in a susceptible cultivar, although it apparently increased it in a more tolerant cultivar (Lanter *et al.*, 1987). In view of the above, it can be concluded that intercropping as a practice may increase or decrease the incidence and/or severity of bean diseases. However, its effect on floury leaf spot incidence and/or severity has not been investigated. There is therefore need to carry out research to determine how floury leaf spot disease behaves when beans are intercropped with maize.

Intercropping has been associated with low bean yields (Jonathan and Jeremy, 1991; Ndakidemi, *et al.*, 1996), reduced potato tuber yields, and reduced growth and grain yield of maize (Maina and Drennan, 1998) when compared with monocropped beans, potatoes and maize, respectively. This could result from competition for light, nutrients and water (CIAT, 1978). Nevertheless, land equivalent ratio data shows that at the same management level, intercropping yields are better than monocropping of both crops per unit area of land (Ndakidemi *et al.*, 1996; Maina and Drennan, 1998). This is possibly due to better utilization of environmental resources and differences in plant characteristics in demand for growth factors in intercrops than in monocrops (Ndakidemi *et al.*, 1996). Higher productivity could also be due to the fact that the optimum total plant density of intercrops is usually higher than that of the individual sole crops (Jonathan and Jeremy, 1991). Similar work on increased production per unit area with intercrops has been reported in Kenya when several varieties of *Phaseolus* beans were intercropped with maize (Kimani, 1987; Ssebuliba and Itulya, 1994; Itulya, 1996).

2.4 Seedborne pathogens

The major seedborne diseases affecting common beans include anthracnose (*Colletotrichum lindemuthianum*) (Isanda, 1994), halo blight (*Pseudomonus savastanoi* pv *phaseolicola*) (Origa, 1992), common bacteriai blight (*Xanthomonas campestris* pv *phaseoli*) (Mukunya and Keya, 1975), angular leaf spot (*Phaeoisariopsis griseola*) (Wagara, 1996), charcoal rot (*Macrophomina phaseolina*) (Songa *et al.*, 1995) and bean common mosaic virus (Buruchara, 1979). These diseases cause considerable yield losses. Control of seedborne pathogens should therefore target the crop before harvest especially in the case of small-scale farmers who do not seed-dress planting seeds with fungicides, a common practice by commercial seed producers.

2.5 Physiological factors affecting seed quality

The major causes of reduced seed quality in grain legumes are imbibition damage (Powell and Matthews, 1978a) and seed aging (Roberts, 1973). Imbibition damage affects seed germination and vigour during the process of imbibition after sowing whereas, aging can occur at any time from maturity until the seed is sown (Powell, *et al.*, 1984).

2.5.1 Imbibition damage

Imbibition damage resulting from the rapid uptake of water during early imbibition has been identified as a major cause of low vigour in grain legumes (Powell *et al.*, 1984). This was first observed when pea embryos (seeds with the testa removed) failed to stain with tetrazolium chloride following imbibition in water (Powell and Matthews, 1978a).

This apparent cell death occurred as a result of rapid water uptake since damage was reduced when embryos imbibed slowly in a polyethylene glycol solution (Powell and Matthews, 1978a). Damage occurred only in the outer layers of cells of the cotyledons within the first 2 minutes of imbibition and was interpreted as the result of the physical disruption of cell membranes during the rapid inrush of water, causing cell death (Powell and Matthews, 1978a). Powell and Matthews (1981), illustrated that failure to stain actually resulted from the loss of the substrate for the dehydrogenase enzymes that reduce the tetrazolium chloride to the red formazan, which indicates living tissue (Cottrell, 1948; Roberts, 1951). Although imbibition damage did not cause death of the surface cells, it was, however, clearly damaging, allowing loss of solutes which impaired cell function and resulted in the failure to stain with tetrazolium chloride. This loss of solutes was reflected in the high conductivity of seed soak water (Powell and Matthews, 1978a). Embryos also showed reduced respiration and germination, a decline in the rate of food reserve transfer from the cotyledons to the growing axis, and a lower growth rate in the seedlings produced (Powell and Matthews, 1978a).

Imbibition damage occurs in intact pea seeds where cracks in the seed coat (testa) allow rapid water uptake (Powell and Matthews, 1978a). Seed lots, which show damage during seed imbibition, have high levels of electrolyte leakage and poor field emergence characteristic of low vigour seed (Powell and Matthews, 1980). It has been suggested that in pea seeds the incidence of cracks in the testa may result from mechanical threshing during harvest (Biddle, 1980) or from harsh handling during seed processing. Threshing produces breaks, cracks, bruises, and abrasions in seeds, which in turn result in abnormal seedlings of questionable value (Justice and Bass, 1978). Seed lots with high rates of water uptake which contained a large proportion of seeds with at least one crack in the testa, were low in vigour, as indicated by electrolyte leakage and poor field emergence (Powell and Matthews, 1979).

2.5.2 Seed aging

Aging involves the process of deterioration, the accumulation of irreversible degenerative changes in the physiological quality of the seed, until the ability to germinate is finally lost (Powell *et al.*, 1984). This occurs during storage. In a seed lot, the pattern of loss of viability over a period of time follows a sigmoid curve (Justice and Bass, 1978). The survival curve for dry seeds stored under favourable environmental conditions can be divided into three distinct parts. The first represents the period when the seed is vigorous and the decline in the life functions proceeds slowly (few seeds die and germination remains high). Eventually, this stage ends at a survival level of 90-75%, and deterioration then proceeds very rapidly (a rapid fall in germination as many seeds lose their viability). After deterioration has proceeded to a survival level of 25-10%, it slows again and continues as a few seeds retain viability for a longer time. Seed ageing or deterioration during seed storage, where high seed moisture contents and high temperatures favour rapid deterioration, has been implicated in the loss of seed quality (Roberts, 1972).

3.0 MATERIALS AND METHODS

3.1 Site selection

Taita hills of Taita-Taveta district were selected for the Participatory Rural Appraisal (PRA) and the field experiments because floury leaf spot disease is endemic in this area (Mwang'ombe *et al.*, 1994).

The PRA was conducted at Kidaya-Ngerenyi location of Mwatate division, Taita-Taveta district. The location is located at 03°25'31.3" S latitude and 38°20'51.5" E longitude at a mean altitude of 1600 m above sea level. Rainfall is bimodal with the long rains starting in March and ending in June while the short rains begin in October and end in December (Jaetzold and Schmidt, 1983). The mean annual precipitation is 1415 mm (Jaetzold and Schmidt, 1983). Average monthly temperature ranges from a minimum of 9.3-13.5° C to a maximum of 17.9-24.4° C (Jaetzold and Schmidt, 1983). The soils are classified as humic cambisols (Jaetzold and Schmidt, 1983).

3.2 Participatory Rural Appraisal (PRA)

A Participatory Rural Appraisal (PRA) was conducted in Kidaya-Ngerenyi location of Mwatate division in Taita-Taveta district in June 1999. The aim of the PRA was to capture the current bean production practices and document major constraints to bean production in the area. The PRA was conducted with the assistance of researchers from the University of Nairobi and the extension staff from the Ministry of Agriculture, Taita-Taveta district. The PRA involved group discussions followed by a survey conducted in November 1999. The PRA tools used included a community sketch map, time lines, trend lines, seasonal calendars, livelihood mapping, venn diagrams, problem listing and ranking, problem-causes analysis and community action plan as described by Lelo *et al.* (1995). Only women farmers were invited to participate in the PRA exercise and all follow up exercises because in most cases, they are the ones who carry out bean production in Kenya. A total of 43 women farmers participated in the exercise.

The community members using sticks, chalks and bottle tops drew the community sketch map on the floor. The map was used as a guideline in defining boundaries and to document available resources and opportunities within the area. A time line was used to identify past trends, events, problems, and achievements in the life of the community (Lelo *et al.*, 1995). Analysis of the trend lines was used to help the community and the PRA team to learn how the community viewed changes over time. A seasonal calendar was used to establish the regular cycles or patterns of activities and occurrences within a community over 12 months (Lelo *et al.*, 1995). The venn diagrams were used to obtain information on land use/allocation among the different enterprises (crops), bean utilization and bean seed sources. This information was presented in form of pie charts. Livelihood mapping was used in identifying the basic resources used by the community (Lelo *et al.*, 1995). Community members listed their basic resources and through discussion, these resources were categorized according to availability within the community. Therefore those resources available within the community and in sufficient quantities were placed within the community circle; those partially available in insufficient quantities were placed on the border of the community circle; whereas those completely unavailable within the community and have to be acquired from outside were placed outside the community circle.

Problem listing was used to organize the disintegrated information into a manageable structure for the community to assess and rank (Lelo *et al.*, 1995). Ranking provided insight into whether or not development programs were addressing the needs of the community. The team prepared a pairwise ranking matrix. The chart paired the problems and the problems were weighted in pairs, each at a time and discussed to come up with a consensus on each pair. The problems were ranked on the basis of the magnitude of total sum of scores for each problem. During the problem-cause analysis, the farmers identified bean production problems and possible solutions with the help of the PRA team. Later the farmers analyzed the problems in terms of causes, farmers' coping strategies and opportunities available to the community for development. The most concrete output of the entire PRA is the community action plan (CAPs) (Lelo *et al.*, 1995). The tool helped the team to determine whether the community development goals were in line with the project's goals in relation to bean production. Constraints that were related to bean production were identified and these were used for the preparation of CAPs.

3.2.1 House holds interviews

This was carried out in order to provide an in depth study of the problems related to bean production at an individual family level that were not captured in the PRA. It was also meant to provide quantitative data. During the survey, 37 farmers, from 5 villages in Kidaya-Ngerenyi location and 1 village from Wundanyi location, were interviewed using a semi-structured questionnaire. Some of the highlights of the questionnaire included; bean varieties grown and reasons for growing them, period of planting, harvesting, planting method, cropping systems, weed control, bean storage and purchase and major bean production constraints (Appendix 1). Data was analyzed using the Statistical Package for Social Sciences (SPSS).

3.3 Farmer-managed trials

3.3.1 Experimental site

Trials were conducted during the short (October-December 1999) and the long rains (March-May 2000) in Kidaya-Ngerenyi and Wesu locations in Mwatate and Wundanyi divisions, respectively, in Taita-Taveta district.

3.3.2 Treatment combinations

Four improved bean lines (E2, E8, No.B and M22) were evaluated on four treatments combining cropping systems and spacings. It is important to note that cropping systems and spacings had 2 levels each. These were; monocrop and intercrop for cropping systems while spacing had 15 cm x 50 cm or 15 cm x 40 cm (for monocrop and intercrop respectively) and 15 cm x 80 cm (for both monocrop and intercrop). These factors were combined to form four treatments which were; monocrop beans planted at a spacing of 15 cm x 50 cm (134,201 plants/ha), monocrop beans planted at a spacing 15 cm x 80 cm (84,126 plants/ha), intercrop of maize and beans planted at a spacing of 15 cm x 40 cm (166,916 plants/ha) and intercrop of maize and beans planted at a spacing of 15 cm x 80 cm (83,458 plants/ha). In total there were 16 treatments (Table 1). Maize was planted at a spacing of 30 cm x 80 cm giving a plant population of 42,126 plants/ha.

3.3.3 Experimental design

The experiment was arranged in a nested design. A single farmer received two treatments as outlined in table 2. For each treatment, there were five farmers doing the same, hence the experiment was replicated 5 times.

3.3.4 Bean and maize germplasm

The bean germplasm used included bean lines code named as E2, E8, No.B and M22 that were developed at the University of Nairobi and kindly supplied by Prof. A.W. Mwang'ombe. They were produced at Kabete and Wundanyi. Hybrid maize, 513 and 511 were purchased from Kenya Seed Company and were used for the intercropping treatments during the October 1999 and March 2000 experiments, respectively.

3.3.5 Training of farmers

There were 40 farmers who participated in the farmer-managed trials. They were provided with planting bean seeds (E2, E8, M22 and No.B), fertilizer (DAP) and chemicals {benomyl (methyl [1-[(butylamino) carbonyl]-1H-benzimidazol-=2-yl]carbamate) and copper oxychloride (copper (II) chloride oxide hydrate) (for seed dressing) and diazinon (2-iso-propyl-6 methyl 1-4 carbamoylmethyl 1-4 pyrimidimyl phosphorothioate) (for the control of bean stem maggots; *Ophyomyia* spp.)}.

These farmers were divided into 8 different groups of 5 according to the treatments outlined in table 1. Farmers who carried out intercropping trials were additionally

Table 1: Treatments for the farmer-managed trials and their distribution amongst farmers

Grp	No. of farmers/grp	Trt	Bean lines	Cropping system and spacing (cm)	Bean plant population/ha	Maize plant population/ha
1	5	1	E2	Monocrop at 15 x 50	134,201	Nil
		2	E8	Monocrop at 15 x 50	134,201	Nil
2	5	3	E2	Monocrop at 15 x 80	84,126	Nil
		4	E8	Monocrop at 15 x 80	84,126	Nil
3	5	5	E2	Intercrop at 15 x 40	166,916	42,126
		6	E8	Intercrop at 15 x 40	166,916	42,126
4	5	7	E2	Intercrop at 15 x 80	83,458	42,126
		8	E8	Intercrop at 15 x 80	83,458	42,126
5	5	9	No.B	Monocrop at 15 x 50	134,201	Nil
		10	M22	Monocrop at 15 x 50	134,201	Nil
6	5	11	No.B	Monocrop at 15 x 80	84,126	Nil
		12	M22	Monocrop at 15 x 80	84,126	Nil
7	5	13	No.B	Intercrop at 15 x 40	166,916	42,126
		14	M22	Intercrop at 15 x 40	166,916	42,126
8	5	15	No.B	Intercrop at 15 x 80	83,458	42,126
		16	M22	Intercrop at 15 x 80	83,458	42,126

KEY:

Grp - Group

Trt - Treatment

provided with maize seeds (hybrid 513 and 511) and fertilizer (CAN). Each group was trained separately on how to plant and manage the trials (Appendix 2). To minimise variations due to planting dates, the same planting date was set for all the farmers.

3.3.6 Planting, fertilizer application, weed and pest control

During planting, bean seeds were dressed using a mixture of copper oxychloride and benomyl at the rate of 3g/kg of bean seeds. They were then inoculated with bean *Rhizobium* strain, a bean seed inoculant (UON-Soil Science Laboratory) at the rate of 6.7 g/kg of bean seeds. Furrows were opened manually and bean seeds planted at different spacings depending on the treatments.

During planting diammonium phosphate (DAP) fertilizer at the rate of 200 kg/ha was added before placing maize seed. Beans received DAP fertilizer at the rate of 100 kg/ha 14 days after planting. At the knee-high stage, maize was top dressed with calcium ammonium nitrate (CAN) fertilizer at the rate of 200 kg/ha. Liquid diazinon (40% W/W W.P) was applied at a rate of 80ml/20 litres 12 days after planting for the control of bean stem maggot (*Ophyomyia* spp.). This was repeated two weeks after the first spray application. For the control of aphids, dimethoate (dimethyl s (N-methylcarbamoylmethyl) phosphorothiolothione) at a rate of 60ml/20 litres was applied at flowering. This is because the number of aphids found attacking bean plants at this stage was high warranting control. On maize, beta-cyfluthrin (cyano(phenoxyphenyl) methyl 3-(2,2-=dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate) granules were applied to the funnel for the control of maize stalk borer six weeks after planting. Plots were kept weed free by hand cultivation, which was done twice per cropping season.

3.4 Data collection

3.4.1 Floury leaf spot incidence

Floury leaf spot incidence was assessed at the flowering (R6) to mid-podding stage (R8) from 3 plots of 2 m x 2 m each chosen at random. Individual plants from two inner rows in each plot were assessed for infection. A total of 28 plants/plot were used to determine the incidence of floury leaf spot disease for all the treatments except intercropping maize and beans at a spacing of 15 cm x 80 cm where 14 plants/plot were used. Healthy and diseased plants were counted using a hand counter. Disease incidence was determined as the number of plants infected in each plot expressed as a percentage of the total number of plants observed (James, 1974).

3.4.2 Yield data

The plants were left to dry in the field before harvesting. During harvesting, plants at the outer rows were discarded. The total yield per plot in each treatment was converted to yield per hectare.

3.5 Seed quality determination

3.5.1 Seed sampling

Seed sampling was carried out at the second and fifth months after storage. Initially, seeds were to be sampled from 40 farmers. Despite the fact that these farmers were asked to spare seed for research, majority consumed their seed and thus sampling was carried out from 10 farmers only. Due to a limitation in seed supply, germination, conductivity and moisture contents tests had different numbers of replicates during the first and the second analyses. A maximum number of 400 seeds were sampled per seed lot during each sampling period (i.e. March and July 2000). The seeds were assessed for quality using the following evaluation methods:

3.5.2 Germination test

Twenty-five seeds were placed along the long edge of a damp paper towel, covered with another damp paper towel, and then rolled with the seeds into a tube. This was replicated 2 and 4 times during the first and the second analyses, respectively. The replicates were put into a tray along with a little water (10mls) then covered with a polythene bag, which was tied at the end. The tray was kept on a bench in the laboratory. The level of germination was determined after 9 days.

3.5.3 Conductivity test

This test measures the extent of leakage of electrolytes (particularly K^+) from the dry seeds into the water (Powell *et al.*, 1984). Four and 3 replicates of 50 seeds during the first and second analyses were placed in clean beakers with 250-ml sterile distilled water. They were soaked for 24 hours at 23°C after which conductivity was assessed. A conductivity meter was placed in the soak water. Readings were obtained directly from the conductivity meter.

3.5.4 Tetrazolium chloride staining

Seed coats of 50 seeds soaked in water for 24 hours were removed and covered with 1% tetrazolium chloride (TTC) for 3 hours, before assessing the staining on the abaxial (curved) surface of the cotyledons. Staining assessment was carried out on completely stained seeds (completely living). The vital stain, 2, 3, 5 tetrazolium chloride is a straw-coloured solution, which reacts with dehydrogenase enzymes to produce a red substance called formazan. Living tissue therefore stains red; dead tissue remains unstained. Tetrazolium chloride (TTC) is used to determine the viability of the seed by examining which parts of the embryo are living and therefore whether the seed is capable of germinating. It can also be used to assess seed vigour.

3.5.5 Seed moisture content

Seeds were weighed, placed in an oven at 130°C for 1 hour. They were then placed in a desiccator over calcium chloride for cooling purpose and reweighed. The loss in weight was expressed as a percentage of the initial weight. Five and 3 replicates of 5 seeds were used in the first and second analyses, respectively.

3.6 Researcher-managed trials

3.6.1 Experimental site

The trials were conducted in Wundanyi, located in Taita hills of Taita-Taveta District. Wundanyi is located at 3°24' S latitude and 38°22' E longitude at a mean altitude of 1675 m above sea level. Rainfall is bimodal with the long rains starting in March and ending in June (Jaetzold and Schmidt, 1983). The short rains begin in October and end in December. When the country is not experiencing drought, the area receives some form of precipitation throughout the year. The mean annual precipitation is 1415 mm (Jaetzold and Schmidt, 1983). Average monthly temperature ranges from a minimum of 9.3-13.5°

C to a maximum of 17.9-24.4° C (Jaetzold and Schmidt, 1983). The soils are classified as humic cambisols (Jaetzold and Schmidt, 1983).

3.6.2 Treatment combinations

Trials were carried out between March and May (long rains) and between June and September (residual rains) in the year 2000. The factors that were evaluated were similar to those described in 3.3.2. The difference is that there were 5 bean lines (E2, E8, No.B and M22 and Rose Coco-GLP-2) in the first factor. These were evaluated on the 4 treatments combining cropping system and spacing described in 3.3.2. In total there were 20 treatments (Table 2).

3.6.3 Experimental design

Using a split-plot in a randomized complete block design, the five bean lines were planted in the main plots, with the cropping system and spacing treatments as sub-plots, replicated three times. The sub-plot sizes measured 2 m x 3 m. The trials were conducted in a farmer's plot.

3.6.4 Bean and maize germplasm

The source of bean lines (E2, E8, No.B and M22) is similar to that described in 3.3.4. GLP-2 seed was purchased from the Kenya Seed Company. Hybrid maize, 511 and 625 were also purchased from Kenya seed and were used for the intercropping treatments during the March 2000 and June 2000 experiments, respectively.

Table 2: Treatments for the researcher-managed trials

Treatment	Bean lines	Cropping system and spacing (cm)	Bean plant population/ha	Maize plant population/ha
1	E2	Monocrop at 15 x 50	134,201	Nil
2	E2	Monocrop at 15 x 80	84,126	Nil
3	E2	Intercrop at 15 x 40	166,916	42,126
4	E2	Intercrop at 15 x 80	83,458	42,126
5	E8	Monocrop at 15 x 50	134,201	Nil
6	E8	Monocrop at 15 x 80	84,126	Nil
7	E8	Intercrop at 15 x 40	166,916	42,126
8	E8	Intercrop at 15 x 80	83,458	42,126
9	No.B	Monocrop at 15 x 50	134,201	Nil
10	No.B	Monocrop at 15 x 80	84,126	Nil
11	No.B	Intercrop at 15 x 40	166,916	42,126
12	No.B	Intercrop at 15 x 80	83,458	42,126
13	M22	Monocrop at 15 x 50	134,201	Nil
14	M22	Monocrop at 15 x 80	84,126	Nil
15	M22	Intercrop at 15 x 40	166,916	42,126
16	M22	Intercrop at 15 x 80	83,458	42,126
17	GLP-2	Monocrop at 15 x 50	134,201	Nil
18	GLP-2	Monocrop at 15 x 80	84,126	Nil
19	GLP-2	Intercrop at 15 x 40	166,916	42,126
20	GLP-2	Intercrop at 15 x 80	83,458	42,126

3.6.5 Planting, fertilizer application, weed and pest control

These activities were carried out as described under 3.3.6.

3.7 Pathogenecity test

3.7.1 Isolation of *Mycovellosiella phaseoli*

Leaves with typical symptoms of floury leaf spot were obtained from Taita hills. The leaf tissue was placed on a dissecting microscope stage with the lower side of the leaf facing upwards. A well sporulating lesion was located. Using the fine pointed tip of a sterile blade, spores were picked without touching the host tissue and transferred to petri-dish containing potato-dextrose agar medium enriched with the host material (EPDA) (Appendix 3). The petri-dishes were then incubated at room temperature (20-24°C) for 15 days until growth and sporulation occurred.

3.7.2 Conidial preparation and inoculation

A conidial suspension was prepared by flooding 15 day old sporulating colonies of the fungus in culture plates with 10ml of sterile distilled water. Conidia were then scraped off the media surface using a bent sterile glass rod. The conidial concentration was then determined using a Neubauer improved haemocytometer and concentration adjusted to 2 x 10^6 conidia ml^{-1}. Fifteen day old seedlings were inoculated using a modified double inoculation technique of Van der Vossen *et al*, (1976). Conidial suspension was applied on both surfaces of all the trifoliolate leaves using an atomizer held at a distance of 10-15cm away until run-off. A second inoculation was applied after 48 hours. Control plants were sprayed with sterile distilled water. Inoculated plants were covered with transparent plastic bags for 96 hours in order to maintain a high humidity. To increase leaf wetness, plants were sprayed with sterile distilled water at least twice a day. Inoculated plants were incubated in the greenhouse at 20-24°C and daily observations made until the symptoms of floury leaf spot were fully developed (24 days after inoculation). Leaves showing characteristic floury leaf spot symptoms were detached and re-isolation of the pathogen carried out to fulfill Koch's postulates.

3.8 Data collection

3.8.1 Floury leaf spot incidence

Individual plants from two inner rows in each plot were assessed for infection in the field on a weekly basis from flowering stage (R6) (week 6) to the mid-podding stage (R8) (week 10). Assessment was carried out as outlined in section 3.4.1.

3.8.2 Floury leaf spot severity

Floury leaf spot severity was estimated visually as percent leaf area diseased (James, 1974). This was recorded on a weekly basis on ten randomly labeled plants (from the inner rows) beginning from week 6 to week 10. A single leaf in each plant was tagged and assessed throughout the entire assessment period. The assessment was carried out using a modification of the CIAT scale (CIAT, 1987, Table 3).

3.8.3 Yield data

Total yield per hectare in each treatment was collected using the procedure described in 3.4.2. In addition to yield per hectare, the following yield parameters were taken:

Table 3: Floury leaf spot assessment scale (a modification of CIAT scale)

Scale	Percent leaf area	Description of infected leaf
1	0	Healthy, no disease symptoms
2	0.1-5	Small, poorly-sporulating lesions less than 1mm diameter
3	5.1-12	A few isolated (more than five) poorly-sporulating small lesions scattered on the leaf
4	12.1-20	Presence of several, generally small lesions scattered on the leaf lamina
5	20.1-30	Presence of a few small to medium size lesions of limited sporulation of about 1-4mm diameter
6	30.1-40	Presence of many small to medium size lesions of about 1-4mm diameter
7	40.1-50	Few and generally large sporulating lesions often coalescing
8	50.1-60	Presence of many generally large sporulating lesions often coalescing
9	>60	A single large sporulating lesion; tissues are generally chlorotic resulting in severe and premature defoliation

i) Number of pods per plant: Three plants/plot were randomly selected and the number of pods counted.

ii) Number of seeds per pod: From three plants selected randomly, three pods were selected at random, shelled separately and the number of seeds counted.

iii) 100 seed weight: One hundred seeds/plot were counted and weighed.

Total yields and yield components of maize were not taken, as the emphasis was to assess the new bean lines under monocropping and intercropping systems.

3.9 Data analysis

Floury leaf spot incidence, severity, yields and the yield components obtained from the researcher-managed trials were subjected to analysis of variance (ANOVA). Data collected from the farmer-managed trials was subjected to restricted/residual maximum likelihood (REML) analysis.

4.0 RESULTS

4.1 Participatory Rural Appraisal (PRA)

4.1.1 Social and economic issues

a) Land

Kidaya-Ngerenyi location covers an area of 31.63 km^2 and comprises of 10 villages (Appendix 5). It lies within the UM2-UM3 (upper midland) agro-ecological zones. The location is hilly with the main physical features consisting of rocks concentrated mainly in the south western parts and south eastern parts. The total agricultural land is 29.85 km^2, with an average farm holding of 0.4 ha. However, due to increasing population pressure, the land available for agriculture is decreasing. As such, majority of the farmers either own or rent land in the lower parts of Mwatate division for cultivation.

b) Labour

Most of the farm activities (81.9%) are managed by family labour. Other forms of labour utilised are communal (10.8%), hired casuals (6.0%) and hired permanent labour (1.2%). The most labour demanding activities are land preparation, planting, weeding and harvesting.

4.1.2 Crops grown

Crops grown in the area are maize, beans, vegetables, fruits, *Solanum* and sweet potatoes, bananas, coffee, cassava, yams and sorghum. Maize and beans are the most important food crops grown in the area with 59% of the total land allocated to their production (Figure 1). They are mainly intercropped with 67.5% of the farmers using maize as the major intercrop apart from pearl millet and sorghum. During the long rains however, most (40.9%) farmers plant pure stands of beans compared to 20.3% farmers who practise monocropping during the residual rains. During the long rains, maize is planted towards the end of this season that is mainly from June to August to avoid stalk borer attack.

4.1.3 Crop husbandry

The seasonal calendar for the two crops is presented in table 4. Rainfall is bimodal, with the long rains starting in March and ending in June while the short rains begin in October and end in December (Appendix 6). Immediately after the long rains are the residual rains, which are normally used to plant maize-bean intercrop. Under normal circumstances the area receives rainfall throughout the year. Land preparation begins in January to mid-February in preparation for the long rains and in June to September during the residual rains of late June to August. Majority (67.2%) of the farmers indicated that they prepare land before the onset of rains. Some (17.2%) prepare it immediately after harvest while others (15.7%) do it after the onset of rains. Maize planting commences in mid-January to March and between June and September. Beans are planted from mid-February to April mainly in pure stands and between June and September as an intercrop of maize. Planting is mainly done at the onset of rains as was reported by 67.2% farmers. Farmers indicated that they apply farmyard manure (FYM) to maize only during planting. Weeding is carried out 3-4 weeks after planting that is between mid-February and April and between July and November for both crops. Majority (94.9%) of the farmers uses hand-hoeing method of weeding. Maize planted during the long rains is not common but if at all planted, it is harvested green in July to August. That crop planted during the residual rains of late June to

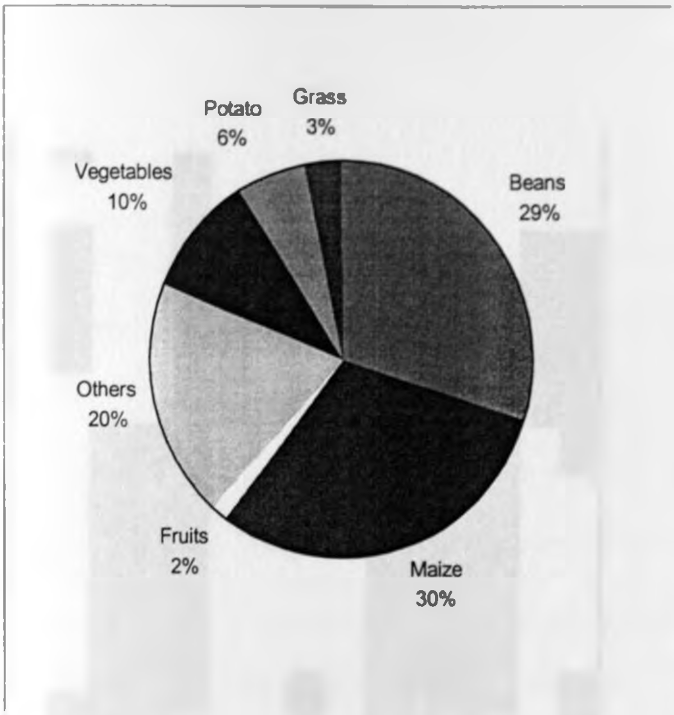


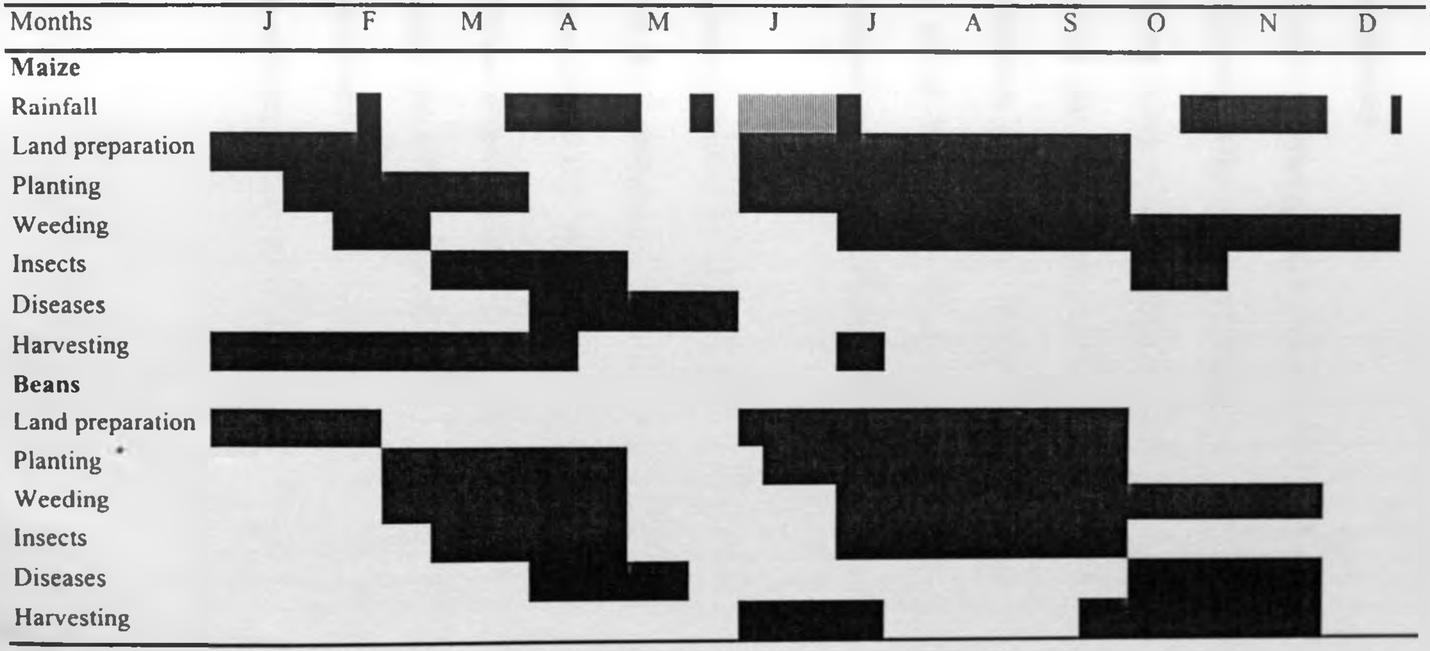
Figure 1: Land allocation per crop

Others include: coffee, bananas, macadamia, cassava, yams, sorghum.

Note:

During the long rains, 59 % of the total land is allocated to bean monocrop whereas during the residual rains, this area is put under bean/maize intercrop.

Table 4: Seasonal calendar for Taita hills (Mwatate and Wundanyi divisions)



Key: Area shaded black- Time of the year when the listed activities take place

Area with stripes- Light rainfall

Maize that is harvested in July is mainly green maize

August is harvested between January to mid-April. Beans are harvested from May to July and between mid-September to November for beans planted in the long and residual rains respectively. Seeds harvested from mid-September to November are usually of poor quality because they are harvested in the rains and cannot therefore be stored for planting in the next season thus accounting for the seed shortage experienced in the area.

4.1.4 Bean production

Beans are the main legumes grown in the area and are therefore the most important source of protein in the diet of this community (Figure 2). Other legumes grown occasionally are cowpeas for green leaves, as the crop does not pod in the cool climate while garden peas are mainly grown for sale. Beans are grown mainly for their dry grain as was reported by 79.2% of the farmers interviewed. Some farmers (20.9%) mainly harvest green pods for consumption. Of all the produce, 75% is utilised as food (of which 25% and 50% is green and dry bean respectively), 25% is used as seed.

The main varieties grown in the area are Rose coco-GLP-2 and traditional varieties. Sixty four percent of the farmers grow both the traditional and Rose coco-GLP-2 beans, 30% grow only Rose coco-GLP-2 while the rest (6%) grow the traditional varieties. Apart from farmers' own seed, other sources of Rose coco-GLP-2 seed in order of importance include the local market (64.3%), neighbours and relatives (32.2%) and researchers (3.5%). Farmers prefer Rose Coco-GLP-2 variety mainly because it is high yielding (48.1%), has good cooking qualities (37.0%) and is early maturing (7.4%).

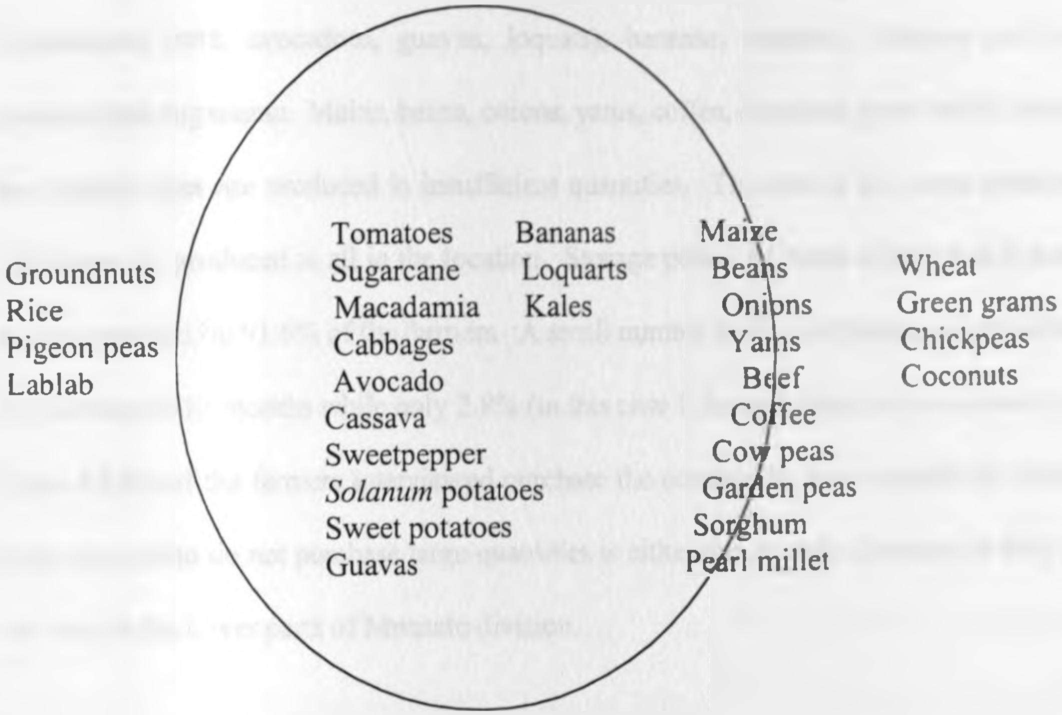


Figure 2: Livelihood map of Kidaya-Ngerenyi community

Bean yields could not be established since none of the farmers keeps records of the quantities of seed planted in a given area. Production however was reported to be in insufficient quantities by 84.1% of the farmers interviewed. According to figure 2, the community is self sufficient in vegetables (kales, tomatoes, sweet pepper), fruits (macadamia nuts, avocadoes, guavas, loquats), bananas, cassava, *Solanum* and sweet potatoes and sugarcane. Maize, beans, onions, yams, coffee, sorghum, pearl millet, cowpeas and garden peas are produced in insufficient quantities. The rest of the crops outside the circle are not produced at all in the location. Storage period of beans is less than 6 months as was reported by 91.6% of the farmers. A small number (5.6%) of farmers store the beans for between 6-12 months while only 2.8% (in this case 1 farmer) store for more than 1 year. Thus, 83.8% of the farmers interviewed purchase the commodity from outside the location. Even those who do not purchase large quantities is either due to lack of money or they grow the crop in the lower parts of Mwatate division.

4.1.5 Farmer identified problems

During the PRA exercise, the farmers identified the major constraints to bean production in their order of importance as insect pests, high cost of chemicals, diseases, high cost of seed, lack of high quality seed for planting, lack of implements, lack of sprayers, too much rain, lack of knowledge on bean production and high cost of fertilizers (Table 5). Household interviews revealed insect pests, diseases, low soil fertility, low yielding varieties, high rainfall and lack of quality seed as the major constraints to increased bean production.

Using a field manual handbook and the PRA team, farmers identified the main bean diseases found in the area as floury leaf spot (*Mycovellosiella phaseoli*), anthracnose (*Colletotrichum lindemuthianum*), bean rust (*Uromyces appendiculatus*), root rots, angular leaf spot (*Phaeoisariopsis griseolu*), sclerotical wilt (*Sclerotinia sclerotium*), bacterial blight (*Xanthomonas campestris* pv *phaseoli*), halo blight (*Pseudomonas syringae* pv *phaseolicola*) and bean common mosaic (bean common mosaic virus). The main bean insect pests identified were bean leaf beetles (*Ootheca* spp.), cutworms (*Spodoptera* spp.), bean flies (bean stem maggots; *Ophiomyia* spp), aphids (*Aphis* spp) and bruchids (*Acanthoscelides obtectus*). Bean root rots and bean flies were identified in this area for the first time by the PRA team. Farmers in this area use soil, ash and green leaves of *Lobelia gibberoa* (msembelele – local name) to control insect pests but do not apply any chemical control measures partly due to high cost of chemicals and partly due to lack of knowledge on appropriate chemicals (Table 6). Although most (75.7%) farmers participate in agricultural related seminars, only a few (5.4%) of them have received information on bean pests and diseases and their control.

Table 5: Problem Ranking Matrix

Problems[a]	Lack of seed	Cost of seed	Cost of chemicals	Diseases	Pests	Lack of sprayers	Too much rain	Lack of labour	Lack of knowledge	Limited land	Lack of implements	Cost of fertilizers	Points	Rank	Survey (%)[b]	Survey (Rank)
Lack of seed SL		CS	SL	D	P	SL	SL	SL	SL	SL	SL	SL	8	5	13.5	6
Cost of seed CS			CC	D	P	CS	CS	CS	CS	CS	CS	CS	8	4	-	-
Cost of chemicals CC				CC	CC	CC	CC	CC	CC	CC	CC	CC	10	2	-	-
Diseases D					P	D	D	D	D	D	D	D	9	3	48.6	2
Pests P						P	P	P	P	P	P	P	10	1	86.5	1
Lack of sprayers LS							LS	LS	LS	LS	LI	LS	5	7	-	-
Too much rain TMR								TMR	TMR	TMR	LI	TMR	4	8	16.2	5
Lack of labour LL									LK	LtdL	LI	CF	0	12	-	-
Limited knowledge LK										LK	LI	LK	3	9	-	-
Limited land LtdL											LI	CF	1	11	-	-
Lack of implements LI												LI	6	6	-	-
Cost of fertilizers CF													2	10	-	-
Low soil fertility													-	-	21.6	4
Low yielding varieties													-	-	27.0	3

[a] - Ranking based on pairwise ranking matrix, 43 farmers participated

[b] - Ranking based on 37 respondents and is expressed in percentages

Table 6: Problem Analysis

Problem	Cause	Coping strategy	Opportunity
1. Insects (pests). Both field and storage pests specifically bruchids	Lack knowledge on insects Chemicals to control the pests are expensive	Do not apply control measures Apply soil or ash on leaves of beans affected by aphids. Use of ash, *Tagetes minuta*, 'Msembelele' (*Lobelia gibberoa*) and tobacco leaves to control storage pests	Training farmers on important pests that attack beans
2. High cost of chemicals	Low purchasing power Pesticide stockists stock pesticides in large containers	Do not apply control measures Apply soil or ash on leaves of beans affected by aphids. Use of ash, *Tagetes minuta*, 'Msembelele' (*Lobelia gibberoa*) and tobacco leaves to control storage pests	Organise seminars on alternative control strategies for pests and diseases Demonstration on how to use indigenous knowledge. Pesticide stockists should stock pesticides in small containers, which farmers can afford.
3. Diseases	Lack of knowledge on bean diseases, cannot identify diseases	Do not apply control measures	Training on bean diseases and the strategies for their control
4. Lack of quality seeds	Low purchasing power Lack of knowledge to produce high quality seeds Low supply of quality seed at planting Lack of information on the performance of new varieties of seed	Use own saved seed for planting Buy from the market and shops Obtain from relatives, friends, or neighbours	Training on quality seed production and storage New varieties of seeds should be planted in demonstration plots so that farmers can see their performance in the field
5. Lack of adequate knowledge on bean production	Failure to attend various seminars and courses related to bean production Lack of understanding on the importance of training programmes Failure to obtain information on bean production from the Agricultural Extension Officers	Plant beans traditionally Seed selection before planting Seed treatment using ash *Tagetes minuta*, Tobbaco and 'Msembelele' (*Lobelia gibberoa*) before planting	Visit the agricultural offices for information on beans Attend seminars offered on beans for the purpose of training Proper care of beans in the field and in storage

4.2 Symptomatology of floury leaf spot in the field

Floury leaf spot occurred from the time the first trifoliolate leaves emerged but it was mainly noticed during the bean flowering stage. Both primary and trifoliolate leaves were affected. Infection began on the lower (older) leaves and progressed upwards. Initially, symptoms appeared as round white spots on the lower surface of the leaves. Later, the spots coalesced to become irregularly shaped, with white tufty outgrowths of the pathogen. This gave the leaf the appearance of having been sprinkled with coarse flour. Symptoms on the upper surface of the leaves appeared as chlorotic spots, which later turned necrotic brown as the disease advanced. At mid-podding, the disease caused heavy defoliation. Symptoms were confined to the leaves (Plates 1 and 2).

4.5 Pathogenecity tests

Round white spots, which are characteristic floury leaf spot symptoms were observed on the lower surface of the leaf 24 days after inoculation of 15 day old seedlings of Rose Coco-GLP-2. The primary and trifoliolate leaves were infected. The lesions covered the whole of the lower surface of the trifoliolate leaves within 2 weeks after initial symptoms were observed. Yellowing on the upper surface of the leaves was observed one week after characteristic floury leaf spot symptoms appeared on the lower surface. This turned brown with yellow margins as the disease progressed. To fulfil Koch's postulate, *Mycovellosiella phaseoli* was re-isolated from the infected leaves and identity confirmed.

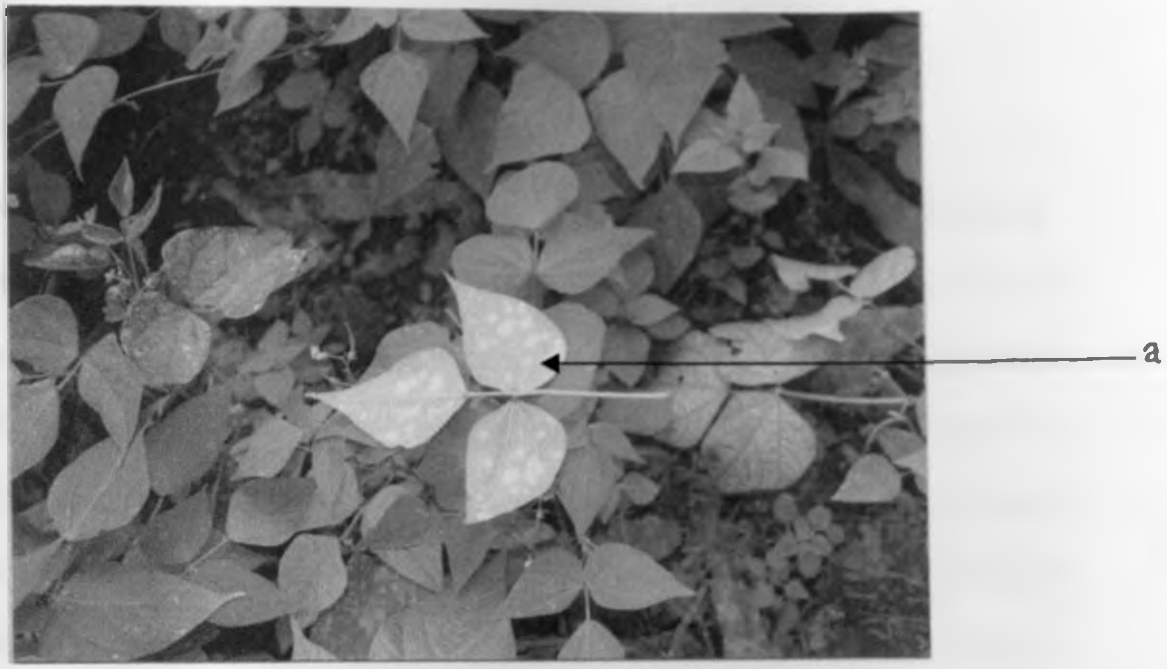


Plate 1: a- Floury leaf spot symptoms on the lower surface of the leaf

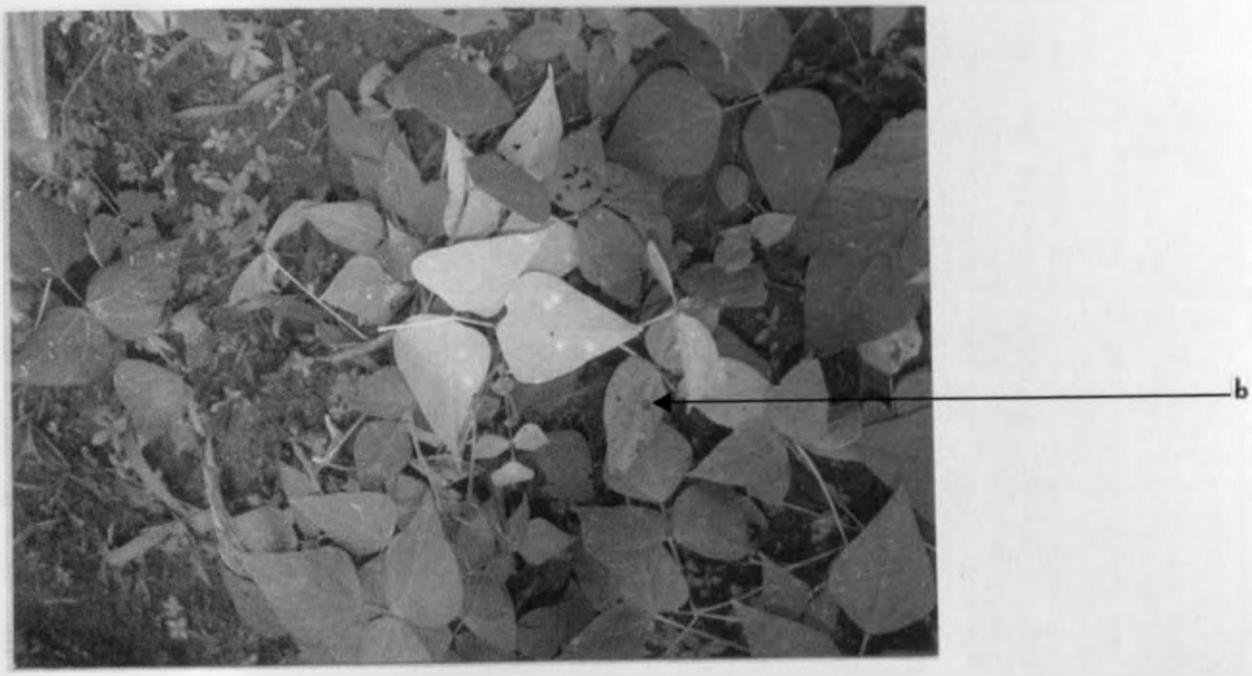


Plate 2: b- Floury leaf spot symptoms on the upper surface of the leaf

4.4 Farmer-managed trials

4.4.1 Incidence of floury leaf spot

This data was taken only once between the flowering stage and the mid-podding stage. There was a significant (P=0.05) interaction in floury leaf spot incidence among the bean lines and cropping system and spacing treatments during both the short (October -December 1999) and long rains (March-May 2000) (Appendices 7 and 8; Tables 7 and 8). Bean line M22 planted with maize at a spacing of 15 cm x 40 cm had the highest (82.1%) floury leaf spot incidence among the 16 treatments during the short rains and was significantly (P=0.05) different from the lowest (8.9%) floury leaf spot incidence recorded on bean line E8 planted alone at a spacing of 15 cm x 80 cm (Table 7). During the long rains, the highest (34.8%) floury leaf spot incidence was recorded on bean genotype E8 planted alone at a spacing of 15 cm x 50 cm (Table 8). The lowest (1.0%) floury leaf spot incidence was recorded on bean genotype No.B planted alone at a spacing of 15 cm x 80 cm.

A significant (P=0.05) difference in floury leaf spot incidence was observed among the cropping system and spacing treatments in both seasons. Beans intercropped with maize at a spacing of 15 cm x 40 cm had the highest (70.8%) floury leaf spot incidence and were significantly (P=0.05) different from the rest of the treatments during the short rains (Table 7). Beans under monocropping at a spacing of 15 cm x 80 cm had the lowest (17.1%) floury leaf spot incidences and were significantly (P=0.05) different from the rest of the treatments. However, there were no significant (P=0.05) differences in floury leaf spot incidences in between beans intercropped with maize at a spacing of 15 cm x 80 cm and those under

Table 7: Floury leaf spot incidences (%) on 4 bean genotypes planted in 4 different cropping systems and spatial arrangement in farmers fields during the short rains (October-December 1999) in Taita hills

	Cropping systems and spacing treatments (B)				
Bean lines (A)	Intercrop at 15cm x 80cm	Intercrop at 15cm x 40cm (±9.5)	Monocrop at 15cm x 80cm	Monocrop at 15cm x 50cm	Means (A) (±4.5)
E2	25.6	62.7	12.4	35.9	31.1
E8	10.4	74.3	8.9	35.1	34.2
M22	54.8	82.1	26.0	56.2	54.8
No.B	33.8	64.1	20.9	40.0	36.7
Means (B)(±5.7)	31.1	70.8	17.1	41.8	

Table 8: Floury leaf spot incidences (%) on 4 bean genotypes planted in 4 different cropping systems and spatial arrangement in farmers fields during the long rains (March-May 2000) in Taita hills

	Cropping systems and spacing treatments (B)				
Bean lines (A)	Intercrop at 15cm x 80cm	Intercrop at 15cm x 40cm (±6.6)	Monocrop at 15cm x 80cm	Monocrop at 15cm x 50cm	Means (A) (±3.1)
E2	4.7	15.1	1.8	25.8	11.8
E8	5.8	6.9	5.0	34.8	13.1
M22	27.4	27.7	11.1	34.3	25.1
No.B	7.1	10.5	1.0	10.8	7.3
Means (B)(±4.1)	11.2	15.0	4.7	26.4	

monocropping at a spacing of 15 cm x 50 cm. During the long rains, a monocrop of beans sown at a spacing of 15 cm x 50 cm had the highest (26.4%) floury leaf spot incidence and differed significantly (P=0.05) from the rest of the treatments (Table 8). Floury leaf spot incidences in beans intercropped with maize and sown at 15 cm x 40 cm and 15 cm x 80 cm were not significantly (P=0.05) different from each other. Monocropping beans at a spacing of 15 cm x 80 cm had the lowest (4.7%) floury leaf spot incidence and differed significantly (P=0.05) from the rest of the treatments.

A significant (P=0.05) difference in floury leaf spot incidence among bean lines was also observed during both seasons. During the short and the long rains, bean line M22 had the highest floury leaf spot incidence of 54.8% and 25.1% respectively while the lowest floury leaf spot incidence of 31.1% and 7.3% was recorded on bean lines E2 and No.B respectively during the short and the long rains. During both seasons however, bean lines No.B, E8 and E2 were not significantly (P=0.05) different from each other.

4.4.2 Bean yields (kg/ha)

Bean yields for the short rains were not obtained since most farmers had eaten the produce while still green. Those who managed to harvest dry grain consumed the produce before weights were taken. There were no significant (P=0.05) interaction in yield between bean lines and cropping systems and spacing during the long rains (Appendix 9, Table 9). Bean line E2 planted at a spacing of 15 cm x 50 cm produced the highest yields of 905.8 kg/ha whereas the lowest yields (330.5 kg/ha) were recorded on bean line No.B when intercropped with maize and planted at a spacing of 15 cm x 80 cm (Table 9). Significant (P=0.05) differences in bean yield were observed among the bean lines and among cropping systems and spacing treatments. The highest mean yields (781.3 kg/ha) were obtained in bean line E2. This was followed in descending order by bean lines E8 (683.0 kg/ha), M22 (677.8 kg/ha) and finally by No.B (469.0 kg/ha). Beans under monocropping at a spacing of 15 cm x 50 cm produced the highest yields (815.2 kg/ha) followed by beans under intercropping at a spacing of 15 cm x 40 cm (733.6 kg/ha), beans under monocropping at a spacing of 15 cm x 80 cm (591.0 kg/ha) and then by beans under intercropping at a spacing of 15 cm x 80 cm (471.3 kg/ha).

4.5 Effect of storage period on the quality of bean seeds

4.5.1 Effect of storage period on germination

After 2 months of storage, all seed lots had a high germination, with the exception of seed lot 7 (M22), and there were no significant (P=0.05) differences among the seed lots (Appendices 10 and 11). Germination percentage of all seed lots declined after 5 months of storage although the decrease in germination varied amongst the seed lots (Table 10). For instance, germination declined by only 2 % in seed lot 3 (No.B), 5% in seed lot 10 (No.B), 7% in seed lot 7 (M22) and by as much as 29% in seed lot 8 (E2). After 5 months of storage, there were significant (P=0.05) differences in germination among the seed lots (Appendices 12 and 13). Seed lot 3 (No.B) had the highest (92%) germination (normal seedlings) but was not significantly (P=0.05) different from seed lots 4 (No.B), 5 (E8) and 10 (No.B) whereas the lowest (65%) germination was recorded in seed lot 8 (E2) but was not significantly (P=0.05) different from that of seed lot 2 (E2). There was a significant (P=0.05) difference in germination after 2 and 5 months of storage by Student's-t test.

Table 9: Bean yield (kg/ha) from 4 bean lines planted in 4 different cropping systems and spatial arrangement in farmers fields in Taita hills during the long rains (March-May 2000)

	Cropping systems and spacing treatments (B)				
Bean lines (A)	Intercrop at 15cm x 80cm	Intercrop at 15cm x 40cm (±331.1)	Monocrop at 15cm x 80cm	Monocrop at 15cm x 50cm	Means (A) (±156.3)
E2	587.6	887.7	744.3	905.8	781.3
E8	420.2	830.3	647.4	834.1	683.0
M22	547.0	713.7	605.3	845.0	677.8
No.B	330.5	502.7	367.1	675.8	469.0
Means (B)(±203.8)	471.3	733.6	591.0	815.2	

Data are means of 3 replicates

Table 10: The effect of storage period on the germination (%normal/abnormal seedlings) of 10 bean seed lots

		Storage time in months		
Seed lot	Bean line	2†	5*	% decrease
1	E8	92/8	79/15	13
2	E2	94/4	71/22	23
3	No.B	94/4	92/7	2
4	No.B	94/2	86/6	8
5	E8	98/2	86/14	12
6	E2	92/6	76/21	16
7	M22	82/14	75/19	7
8	E2	94/4	65/30	29
9	E8	90/10	80/20	10
10	No.B	94/6	89/7	5
Lsd		ns	9.1*/7.6*	
Sed		±7.2/6.6	±4.4/5.7	

Where * is significant and ns is not significantly different at P = 0.05

KEY: †- Data are means of 2 replicates

*- Data are means of 4 replicates

4.5.2 Effect of storage period on electrical conductivity

The electrical conductivity among seed lots fell into 2 groups, with significant (P=0.05) differences within each group (Appendices 14 and 15). Thus, 7 seed lots (group 1) had conductivity in the range 14.13$\mu Scm^{-1}g^{-1}$ to 16.48$\mu Scm^{-1}g^{-1}$ whilst seed lots 3, 4 and 10 (group 2; all bean line No.B) had higher conductivity (>27.00$\mu Scm^{-1}g^{-1}$) after 2 months of storage (Table 11). The same grouping was evident after 5 months of storage. There was a small increase in conductivity following storage with the largest increase in seed lot 8 (E2) from 14.40 $\mu Scm^{-1}g^{-1}$ after 2 months of storage to 17.76$\mu Scm^{-1}g^{-1}$ after 5 months of storage. There was no significant (P=0.05) difference in electrical conductivity after 2 and 5 months of storage by Student's-t test.

4.5.3 Effect of storage period on tetrazolium chloride staining of bean seeds

Tetrazolium chloride staining of bean seeds after 2 months of storage ranged from 66% to 100% while the range was 59% to 92% after 5 months of storage (Table 12). There was a decrease in the proportion of the cotyledons having complete vital staining between the second and the fifth month of storage. This fall was greatest (13%) in seed lots 5 (E8) and 9 (E8) and least (2%) in lot 7 (M22). There was no significant (P=0.05) difference in Tetrazolium chloride staining after 2 and 5 months of storage by Student's-t test. Plate 3 shows complete tetrazolium chloride staining on the seeds of bean line E2.

4.5.4 Effect of storage period on seed moisture content

The seed moisture content differed significantly (P=0.05) among the seed lots after both 2 and 5 months of storage (Appendices 16 and 17). Moisture content was highest (12.6%)

in seed lot 10 (No.B) and lowest (9.8%) in seed lot 4 (No.B) after 2 months of storage (Table 13). After 5 months storage, the moisture content had increased in seed lots 2 (E2), 4 (No.B), 7 (M22) and 8 (E2) and decreased in seed lots 1 (E8), 3 (No.B), 5 (E8), 6 (E2), 9 (E8) and 10 (No.B). The largest increase in moisture content was observed in seed lot 8 (E2) (from 11.55% to 14.64%) while the largest decrease (11.77% to 7.96%) was observed in seed lot 5 (E8). There was no significant (P=0.05) difference in the seed moisture content after 2 and 5 months of storage by Student's-t test.

Table 11: The effect of storage period on electrical conductivity ($\mu Scm^{-1}g^{-1}$) of 10 bean seed lots

Seed lot	Bean line	Storage time in months		
		2†	5•	Increase
1	E8	14.65	14.89	0.24
2	E2	14.95	15.42	0.46
3	No.B	29.92	30.68	0.76
4	No.B	27.51	29.17	1.66
5	E8	14.13	14.55	0.42
6	E2	15.00	15.61	0.61
7	M22	16.48	18.06	1.58
8	E2	14.40	17.76	3.36
9	E8	14.82	15.02	0.20
10	No.B	28.01	28.17	0.16
Lsd		1.6*	1.9*	
Sed		±0.8	±0.9	

Where, * is significant at P=0.05

KEY: †- Data are means of 4 replicates
•- Data are means of 3 replicates

Table 12: The effect of storage period on the vital tetrazolium chloride staining of 10 bean seed lots

Seed lot	Bean line	Storage time in months		
		2	5	% decrease
1	E8	76	70	6
2	E2	100	92	8
3	No.B	94	87	7
4	No.B	70	66	6
5	E8	96	83	13
6	E2	80	76	4
7	M22	78	76	2
8	E2	66	59	7
9	E8	90	77	13
10	No.B	78	74	4

Table 13: The effect of storage period on moisture content of 10 bean seed lots

Seed lot	Bean line	Storage time in months		
		2†	5•	Change
1	E8	12.11	9.75	-2.36
2	E2	11.38	13.56	+2.18
3	No.B	12.48	10.83	-1.65
4	No.B	9.84	11.83	+1.99
5	E8	11.77	7.96	-3.81
6	E2	10.13	7.32	-2.81
7	M22	10.01	12.54	+2.53
8	E2	11.55	14.64	+3.09
9	E8	10.57	8.00	-2.57
10	No.B	12.62	11.25	-1.37
Lsd		0.7*	0.5*	
Sed		±0.3	±0.2	

Where, * is significant at P=0.05

KEY: †- Data are means of 5 replicates
•- Data are means of 3 replicates

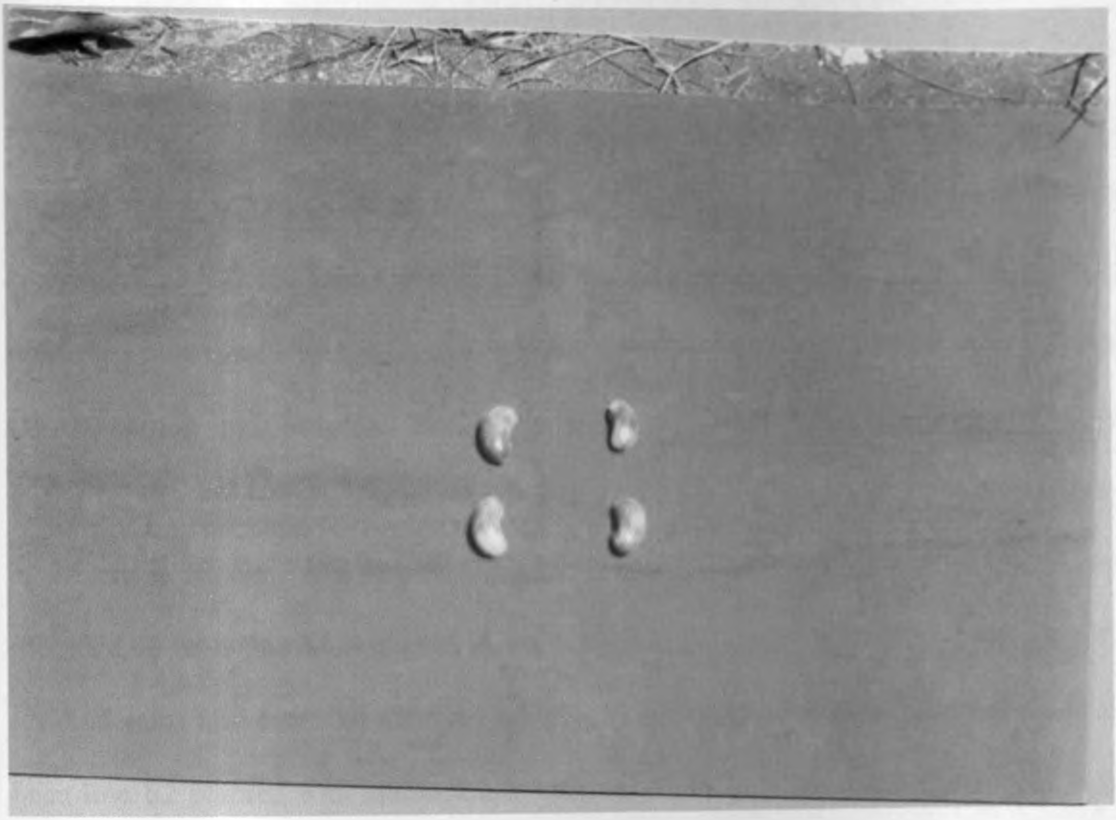


Plate 3: Tetrazolium chloride staining showing completely stained (completely living) seeds of bean line E2

4.6 Researcher-managed trials

4.6.1 Incidence of floury leaf spot

Field inoculation was not done and therefore floury leaf spot infection was as a result of natural field inocula. Analysis of variance revealed an insignificant (P=0.05) interaction in floury leaf spot incidence amongst the bean lines, cropping systems and spacing and time in the long rains (March-May 2000) and residual rains (June-September 2000) (Appendix 18 and 19; Tables 14 and 15). In all the treatments, floury leaf spot incidence increased over time with the highest incidence being recorded at 10 weeks after planting (WAP) during both seasons. During the long rains, at 10 WAP, the highest (97.9%) floury leaf spot incidence was recorded on bean line M22 planted with maize at a spacing of 15 cm x 80 cm. The lowest (33.1%) floury leaf spot incidence at this time was recorded on bean line No.B planted at a spacing of 15 cm x 80 cm (Table 14). During the residual rains however, the highest (34.4%) floury leaf spot incidence was recorded on bean line E2 planted with maize at a spacing of 15 cm x 80 cm while the lowest (6%) floury leaf spot incidence was recorded on bean line No.B planted alone at a spacing of 15 cm x 50 cm at 10 WAP.

The interactions in floury leaf spot incidence between bean lines and cropping systems and spacing treatments irrespective of time of disease assesment was insignificant (P=0.05) in both seasons. During the long rains, the highest (72.1%) floury leaf spot incidence was observed on bean line E8 whereas the lowest (12.4%) was recorded on bean line No.B both planted under monocrop at a spacing of 15 cm x 80 cm (Figure 3). Bean line E2 planted as an intercrop with maize at a spacing of 15 cm x 80 cm had the

Table 14: Mean (%) and standard errors of the difference of means of floury leaf spot incidence recorded in five bean genotypes planted in four different cropping system and spacing treatments during the long rains (March-May 2000) in Taita hills.

				Time (C)				
Bean genotypes (A)	CSSP (B)	Week 6	Week 7	Week 8 (±18.1)	Week 9	Week 10	Means (A x B) (±16.4)	Means (A) (±6.2)
E2	ISR	38.0	46.6	52.7	68.2	77.7	56.7	
	ITR	25.8	35.1	41.2	62.6	72.2	47.4	40.7
	MSR	9.9	17.3	27.2	44.1	45.9	28.8	
	MTR	16.3	19.7	25.7	41.6	46.7	30.0	
	Mean(A x C)	22.5	29.7	36.7	54.1	60.6		
E8	ISR	33.8	50.5	55.8	79.0	87.9	61.4	
	ITR	31.1	39.2	43.2	73.2	88.0	54.9	61.7
	MSR	50.6	63.9	67.8	83.2	94.9	72.1	
	MTR	30.5	40.0	52.6	77.4	92.1	58.5	
	Mean(A x C)	36.5	48.4	54.9	78.2	90.7		
GLP-2	ISR	12.1	24.2	33.3	54.9	75.3	40.0	
	ITR	29.4	44.2	55.6	75.3	82.2	57.4	41.2
	MSR	8.9	18.1	23.3	51.9	62.2	32.9	
	MTR	9.2	16.6	23.6	54.2	68.7	34.4	
	Mean(A x C)	14.9	25.8	34.0	59.1	72.1		
M22	ISR	25.0	41.7	54.2	92.5	97.9	62.3	
	ITR	32.4	61.5	69.2	84.5	90.9	67.7	59.6
	MSR	21.2	40.7	51.5	76.0	84.3	54.7	
	MTR	34.7	41.1	47.3	63.7	81.2	53.6	
	Mean(A x C)	28.3	46.3	55.6	79.2	88.6		
NOB	ISR	3.0	8.8	23.7	68.7	91.4	39.1	
	ITR	11.9	20.6	27.6	58.0	73.3	38.3	35.1
	MSR	1.4	2.8	7.5	17.5	33.1	12.4	
	MTR	21.7	34.1	40.2	67.0	89.5	50.5	
	Mean(A x C±7.2)	9.5	16.6	24.8	52.8	71.8		
							Mean (B)	
				(±8.6)			(±7.9)	
Means (B x C)	ISR	22.4	34.4	44.0	72.7	86.0	51.9	
	ITR	26.1	40.1	47.4	70.7	81.3	53.1	
	MSR	18.4	18.4	28.6	35.5	54.5	40.2	
	MTR	22.5	30.3	37.9	60.8	75.6	45.4	
	Mean(C±1.9)	22.3	33.3	41.2	64.7	76.8		

LSD A	14.2*	LSD A X C	15.4*
LSD B	ns	LSD B X C	ns
LSD C	3.7*	LSD A X B X C	ns
LSD A X B	ns		

Where, *, is significant and ns is not significant at P = 0.05

CSSP is cropping system and spacing treatments which are:

MSR- monocrop at a spacing of 15cm x 80cm

MTR- monocrop at a spacing of 15cm x 50cm

ISR- intercrop at a spacing of 15cm x 80cm

ITR- intercrop at a spacing of 15cm x 40cm

Data are means of 10 plants

Table 15: Means (%) and standard errors of the difference of means of floury leaf spot incidence recorded in five bean genotypes planted in four different cropping system and spacing treatment during the residual rains (June-September 2000) in Taita hills.

			Time (C)					
Bean genotypes (A)	CSSP (B)[1]	Week 6	Week 7	Week 8 (±8.4)	Week 9	Week 10	Means (A x B) (±6.4)	Means (A) (±2.8)
E2	ISR	0	24.2	26.7	29.3	34.4	22.9	
	ITR	0	14.4	15.7	16.9	19.5	13.3	12.5
	MSR	0	2.4	5.2	10.7	16.3	6.9	
	MTR	0	5.4	6.9	10.0	11.5	6.8	
	Mean(A x C)	0	11.6	13.6	16.7	20.4		
E8	ISR	0	2.5	4.9	7.4	8.6	4.7	
	ITR	0	3.7	6.3	11.4	16.5	7.6	6.2
	MSR	0	4.8	7.1	9.5	14.3	7.1	
	MTR	0	2.9	5.8	8.7	10.2	5.5	
	Mean(A x C)	0	3.5	6.0	9.3	12.4		
GLP-2	ISR	0	2.8	5.6	8.3	13.9	6.1	
	ITR	0	5.2	7.7	9.0	10.3	6.5	6.9
	MSR	0	5.3	8.1	10.9	19.2	8.7	
	MTR	0	4.1	6.8	9.4	10.8	6.2	
	Mean(A x C)	0	4.4	7.1	9.4	13.6		
M22	ISR	4.9	21.4	21.4	23.8	26.2	19.5	
	ITR	0	10.8	12.1	13.5	14.9	10.3	16.7
	MSR	0	20.2	22.6	25.0	29.8	19.5	
	MTR	8.0	18.0	19.3	20.7	22.0	17.6	
	Mean(A x C)	3.2	17.6	18.9	20.8	23.2		
NOB	ISR	0	4.8	5.9	8.1	9.2	5.6	
	ITR	0	2.8	8.3	11.1	13.9	7.2	5.3
	MSR	0	2.8	5.6	8.3	11.1	5.6	
	MTR	0	1.2	2.4	3.6	6.0	2.6	
	Mean(A x C±3.9)	0	2.9	5.5	7.8	10.0		
				(±3.8)			Mean (B) (±3.0)	
Means (B x C)	ISR	1.0	11.1	12.9	15.4	18.5	11.8	
	ITR	0	7.4	10.0	12.4	15.0	9.0	
	MSR	0	7.1	9.7	12.9	18.1	9.6	
	MTR	1.6	6.3	8.2	10.5	12.1	7.7	
	Mean(C±1.4)	0.6	8.0	10.2	12.8	15.9		

LSD A	6.5*	LSD A X C	8.0ns
LSD B	6. 0 ns	LSD B X C	7.6 ns
LSD C	2.7*	LSD A X B X C	16.7 ns
LSD A X B	12.9 ns		

Where, *, is significant and ns is not significant at P = 0.05

CSSP is cropping system and spacing treatments which are:

MSR- monocrop at a spacing of 15cm x 80cm

MTR- monocrop at a spacing of 15cm x 50cm

ISR- intercrop at a spacing of 15cm x 80cm

ITR- intercrop at a spacing of 15cm x 40cm

Data are means of 10 plants

Fig. 3: Floury leaf spot incidence on 5 bean lines planted under different cropping systems and spatial arrangement during the long rains (March -May 2000) in Taita hills

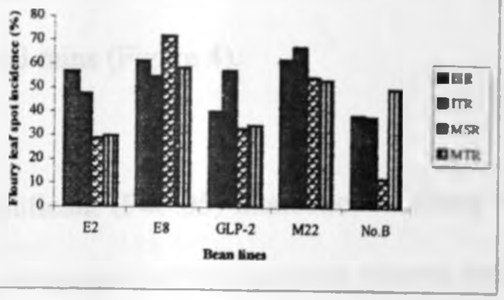


Fig. 4: Floury leaf spot incidence on 5 bean lines planted under different cropping systems and spatial arrangement during the residual long rains (June-September 2000) in Taita hills

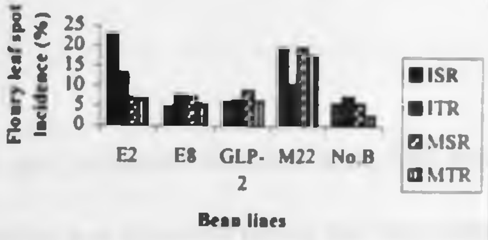


Fig. 5: Floury leaf spot incidence 6-10 weeks after planting during the long (March-May 2000) rains in Taita hills

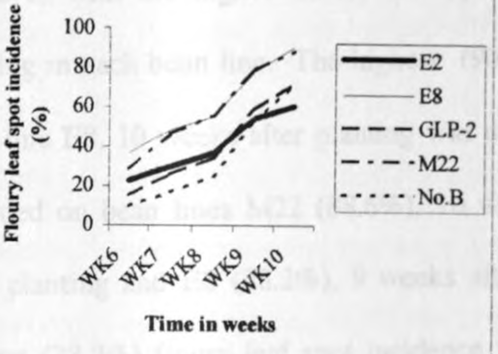


Fig.6: Floury leaf spot incidence on 5 bean lines 6-10 weeks after planting during the residual (June-September 2000) rains in Taita hills

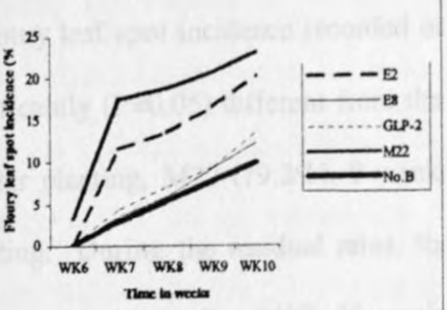


Fig. 7: Floury leaf spot incidence in 4 different cropping systems and spatial arrangement 6-10 weeks after planting during the long (March-May 2000) rains in Taita hills

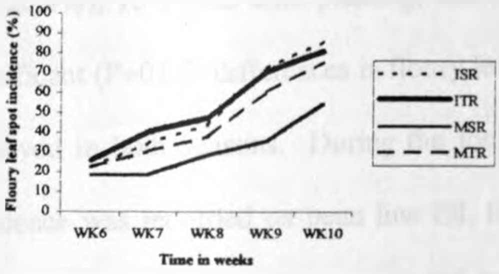
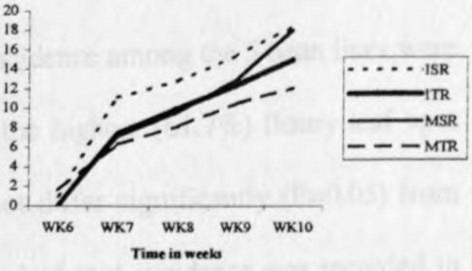


Fig. 8: Foury leaf spot incidence on 4 different cropping systems and spatial arrangement 6-10 weeks after planting during the residual long (June-September 2000) rains in Taita hills



Where, CSSP is cropping system and spacing treatments which are:
MSR- monocrop at a spacing of 15cm x 80cm
MTR- monocrop at a spacing of 15cm x 50cm
ISR- intercrop at a spacing of 15cm x 80cm
ITR- intercrop at a spacing of 15cm x 40cm

highest (22.9%) floury leaf spot incidence while bean line No.B planted alone at a spacing of 15 cm x 50 cm had the least (2.6%) floury leaf spot incidence during the residual rains (Figure 4).

A significant (P=0.05) interaction in floury leaf spot incidence between bean lines and time irrespective of the cropping systems and spacing was observed during the long rains but not during the residual rains. Floury leaf spot incidence increased with time (Figures 5 and 6) with the highest floury leaf spot incidence being recorded 10 weeks after planting in each bean line. The highest (90.7%) floury leaf spot incidence recorded on bean line E8, 10 weeks after planting was not significantly (P=0.05) different from that recorded on bean lines M22 (88.6%), 10 weeks after planting, M22 (79.2%), 9 weeks after planting and E8 (78.2%), 9 weeks after planting. During the residual rains, the highest (23.2%) floury leaf spot incidence was observed on bean line M22, 10 weeks after planting. This was followed by the same bean line (20.8%), 9 weeks after planting, E2 (20.4%), 10 weeks after planting, and finally M22 (18.9%), 8 weeks after planting. Significant (P=0.05) differences in floury leaf spot incidence among the 5 bean lines were observed in both seasons. During the long rains, the highest (61.7%) floury leaf spot incidence was recorded on bean line E8, but did not differ significantly (P=0.05) from bean line M22 (59.6%). The lowest (35.1%) floury leaf spot incidence was recorded in bean line No.B, but was not significantly (P=0.05) different from bean lines E2 (40.7%) and GLP-2 (41.2%). During the residual rains, bean line M22 had the highest (16.7%) floury leaf spot incidence, but was not significantly (P=0.05) different from E2 (12.5%). The lowest (5.3%) floury leaf spot incidence during this season was recorded on bean line No.B. The differences in floury leaf spot incidence among bean lines No.B, E8 (6.2%) and GLP-2 (6.9%) were not significant (P=0.05).

There was no significant (P=0.05) interaction in floury leaf spot incidence between cropping systems and spacing treatments and time irrespective of bean lines in both seasons. However, floury leaf spot incidence increased with time with the highest incidence being recorded at 10 WAP in each of the 4 cropping systems and spacing treatments. During the long rains, the highest (86.0%) floury leaf spot incidence was observed at 10 WAP when beans were intercropped at a spacing of 15 cm x 80 cm (Figure 7). The lowest (54.5%) floury leaf spot incidence observed at 10 weeks after planting, on monocropped beans at a spacing of 15 cm x 80 cm was much lower than that observed under monocropping at a spacing of 15 cm x 80 cm (60.8%), 9 WAP, intercropping at a spacing of 15 cm x 40 cm (70.7%), 9 WAP, and intercropping at a spacing of 15 cm x 80 cm (72.7%), 9 weeks after planting. The highest (18.5%) floury leaf spot incidence during the residual rains was observed 10 weeks after planting at intercropping at a spacing of 15 cm x 80 cm (Figure 8). The least (12.1%) floury leaf spot incidence observed at monocropping at a spacing of 15 cm x 50 cm at 10 weeks after planting was lower than the one recorded under intercropping at a spacing of 15 cm x 40 cm (12.4%) and also monocropping at a spacing of 15 cm x 80 cm (12.9%) at 9 weeks after planting. Similarly, floury leaf spot incidence (15.0%) observed under intercropping at a spacing of 15 cm x 40 cm 10 weeks after planting was even lower than the one recorded (15.4 %) at intercropping at a spacing of 15 cm x 80 cm at 9 weeks after planting. The differences in floury leaf spot incidence among the cropping systems and spacing treatments were not significant (P=0.05) during both seasons. During the long rains, the highest (53.1%) floury leaf spot incidence was recorded on beans planted as intercrops with maize and sown at a spacing of 15 cm x 40 cm while the lowest (40.2%) was recorded on beans planted alone at a spacing of 15 cm x 80 cm. During the residual rains, the highest (11.8%) floury leaf spot incidence was recorded on beans planted as an intercrop of maize at a spacing of 15 cm x 80 cm while the lowest (7.7%) was recorded on beans planted alone at a spacing of 15 cm x 50 cm. There was a highly significant (P=0.05) difference in floury leaf spot incidence among time treatments during both seasons.

Floury leaf spot incidence between the long and the residual rains differed significantly (P=0.05) by Student's-t test (procedure). The incidence was higher during the long than during the residual rains.

4.6.2 Severity of floury leaf spot

A significant (P=0.05) interaction in floury leaf spot severity among bean lines, cropping systems and spacing treatments and time was observed during the long rains but not during the residual rains (Appendices 20 and 21; Tables 16 and 17). Floury leaf spot severity increased over time and at 10 weeks after planting (WAP), the highest floury leaf spot severity of 14.8% and 1.9% were recorded on bean line M22 planted with maize and sown at a spacing of 15 cm x 40 cm during the long and the residual rains respectively. This was followed by bean line E8 (11.5% and 1.8%) also planted with maize and sown at a spacing of 15cm x 40 cm during the long and the residual rains respectively. During the long rains at

Table 16: Means (%) and standard errors of the difference of means of floury leaf spot severity recorded in five bean genotypes planted in four different cropping system and spacing treatments during the long rains (March-May 2000) in Taita hills.

		Time (C)						
Bean genotypes (A)	CSSP (B)	Week 6	Week 7	Week 8 (±0.7)	Week 9	Week 10	Means (A x B) (±0.5)	Means (A) (±0.2)
E2	ISR	0.7	0.7	1.2	2.0	4.0	1.7	
	ITR	1.3	2.0	3.0	3.7	8.7	3.7	2.3
	MSR	0.1	0.5	1.1	1.5	2.8	1.2	
	MTR	0.7	1.4	1.7	3.4	4.5	2.4	
	Mean(A x C)	0.7	1.2	1.8	2.6	5.0		
E8	ISR	0.5	0.8	1.7	2.7	4.3	2.0	
	ITR	1.8	3.8	4.6	5.7	11.5	5.3	2.8
	MSR	0.4	0.8	1.0	1.5	2.7	1.3	
	MTR	0.9	1.4	1.9	3.3	4.7	2.5	
	Mean(A x C)	0.9	1.7	2.3	3.3	5.8		
GLP-2	ISR	0.3	0.6	0.8	1.2	1.7	0.9	
	ITR	1.1	1.7	2.2	3.7	6.7	3.1	1.5
	MSR	0.3	0.5	0.7	1.0	1.4	0.8	
	MTR	0.4	0.8	1.0	1.3	2.2	1.1	
	Mean(A x C)	0.5	0.9	1.2	1.8	3.0		
M22	ISR	0.7	1.2	1.7	2.5	4.7	2.2	
	ITR	1.6	2.1	3.3	5.9	14.8	5.6	3.0
	MSR	0.7	1.1	1.5	2.2	3.0	1.7	
	MTR	1.0	1.4	2.0	3.2	5.5	2.6	
	Mean(A x C)	1.0	1.4	2.1	3.4	7.0		
NOB	ISR	0.4	0.5	0.6	1.3	1.5	1.1	
	ITR	0.6	1.0	1.5	3.3	5.2	2.3	1.2
	MSR	0.0	0.1	0.3	0.5	0.7	0.3	
	MTR	0.4	0.8	1.0	1.2	1.7	1.0	
	Mean(A x C±0.3)	0.4	0.6	0.8	1.8	2.3		
				(±0.3)			Mean (B) (±0.2)	
Means (B x C)	ISR	0.5	0.8	1.2	1.9	3.2	1.5	
	ITR	1.3	2.1	2.9	4.5	9.4	4.0	
	MSR	0.3	0.6	0.9	1.3	2.1	1.1	
	MTR	0.7	1.2	1.5	2.5	3.7	1.9	
	Means (C±0.1)	0.7	1.2	1.6	2.5	4.6		

LSD A	0.5*	LSD A X C	0.7*
LSD B	0.5*	LSD B X C	0.6*
LSD C	0.2*	LSD A X B X C	1.3*
LSD A X B	ns		

Where, *, is significant and ns is not significant at P = 0.05

CSSP is cropping system and spacing treatments which are:

MSR- monocrop at a spacing of 15cm x 80cm

MTR- monocrop at a spacing of 15cm x 50cm

ISR- intercrop at a spacing of 15cm x 80cm

ITR- intercrop at a spacing of 15cm x 40cm

Data are means of 10 plants

Table 17: Means (%)and standard errors of the difference of means of floury leaf spot severity recorded in five bean genotypes planted in four different cropping system and spacing treatments during the residual rains (June-September 2000) in Taita hills.

		Time (C)						
Bean genotypes (A)	CSSP (B)	Week 6	Week 7	Week 8 (±0.3)	Week 9	Week 10	Means (A x B) (±0.2)	Means (A) (±0.2)
E2	ISR	0	0	0.1	0.2	0.4	0.1	
	ITR	0	0.1	0.3	0.8	1.2	0.5	0.2
	MSR	0	0	0	0	0	0	
	MTR	0	0.1	0.2	0.5	0.9	0.3	
	Mean(A x C)	0	0.1	0.2	0.4	0.6		
E8	ISR	0	0.2	0.3	0.6	0.7	0.4	
	ITR	0	0.5	0.8	1.1	1.8	0.8	0.5
	MSR	0	0.1	0.2	0.3	0.4	0.2	
	MTR	0	0.4	0.5	0.7	1.0	0.5	
	Mean(A x C)	0	0.3	0.5	0.7	1.0		
GLP-2	ISR	0	0	0	0.3	0.5	0.2	
	ITR	0	0.3	0.6	0.8	1.2	0.6	0.3
	MSR	0	0	0	0	0	0	
	MTR	0	0.1	0.3	0.5	0.6	0.3	
	Mean(A x C)	0	0.1	0.2	0.4	0.6		
M22	ISR	0.2	0.3	0.4	0.7	1.0	0.5	
	ITR	0	0.7	1.0	1.3	1.9	1.0	0.7
	MSR	0	0.2	0.2	0.3	0.8	0.3	
	MTR	0.4	0.5	0.8	1.2	1.5	0.9	
	Mean(A x C)	0.2	0.4	0.6	0.9	1.3		
NOB	ISR	0	0	0	0.2	0.3	0.1	
	ITR	0	0.2	0.4	0.6	1.0	0.4	0.2
	MSR	0	0	0	0	0	0	
	MTR	0	0.1	0.2	0.3	0.5	0.2	
	Mean(A x C±0.2)	0	0.1	0.2	0.3	0.5		
				(±0.1)			Mean (B) (±0.1)	
Means (B x C)	ISR	0.04	0.1	0.2	0.4	0.6	0.3	
	ITR	0	0.4	0.6	0.9	1.4	0.7	
	MSR	0	0.1	0.1	0.1	0.2	0.1	
	MTR	0.08	0.2	0.6	0.6	0.9	0.4	
	Mean(C±0.04)	0.03	0.2	0.3	0.5	0.8		

LSD A	Ns	LSD A X C	0.4*
LSD B	0.2*	LSD B X C	0.2*
LSD C	0.1*	LSD A X B X C	ns
LSD A X B	Ns		

Where, *, is significant and ns is not significant at P = 0.05

CSSP is cropping system and spacing treatments which are:

MSR- monocrop at a spacing of 15cm x 80cm

MTR- monocrop at a spacing of 15cm x 50cm

ISR- intercrop at a spacing of 15cm x 80cm

ITR- intercrop at a spacing of 15cm x 40cm

Data are means of 10 plants

10 WAP, the lowest (0.7%) floury leaf spot severity was recorded on bean line No.B planted alone at a spacing of 15 cm x 80 cm. During the residual rains, at 10 WAP, bean lines E2, GLP-2, and No.B all sown alone at a spacing of 15 cm x 80 cm had the least (0%) floury leaf spot severity.

The interaction between bean lines and cropping systems and spacing treatments was not significant (P=0.05) during the long and the residual rains irrespective of time of recording. The highest (5.6%) overall mean floury leaf spot severity was recorded on bean line M22 planted with maize and sown at a spacing of 15 cm x 40 cm during the long rains (Figure 9). This was followed by bean line E8 (5.3%) also planted with maize and sown at a spacing of 15 cm x 40 cm. The lowest (0.3%) floury leaf spot severity in this season was recorded on bean line No.B planted alone at a spacing of 15 cm x 80 cm. During the residual rains, the highest (1.0%) floury leaf spot severity was again recorded on bean line M22 planted with maize and sown at a spacing of 15 cm x 40 cm whereas the lowest (0%) floury leaf spot severity was recorded on bean lines E2, GLP-2, and No.B all sown alone at a spacing of 15 cm x 80 cm (Figure 10).

The interaction between bean line and time irrespective of the cropping systems and spacing treatments was significant at P=0.05 at both seasons. In all the bean lines, floury leaf spot severity increased over time. At 10 weeks after planting the highest (7.0% and 1.3%) floury leaf spot severity were recorded on bean line M22 during the long and the residual rains respectively (Figures 11 and 12). Similarly, the lowest (2.3% and 0.5%) floury leaf spot

Fig. 9: Floury leaf spot severity on 5 bean lines planted under different cropping systems and spatial arrangement during the long rains (March-May 2000) in Taita hills

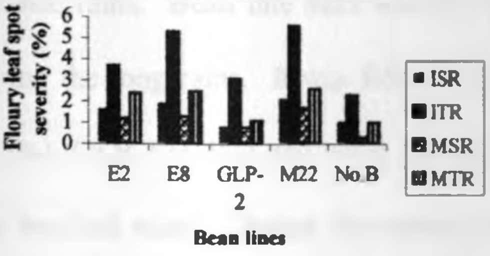


Fig. 10: Floury leaf spot severity on 5 bean lines planted under different cropping systems and spatial arrangement during the residual rains (June-September 2000) in Taita hills

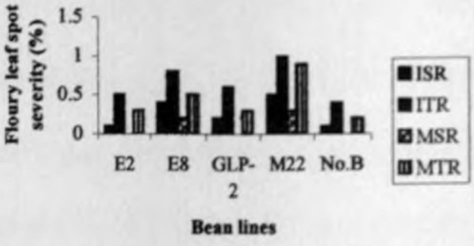


Fig. 11: Floury leaf spot severity 6-10 weeks after planting during the long rains (March-May 2000) in Taita hills

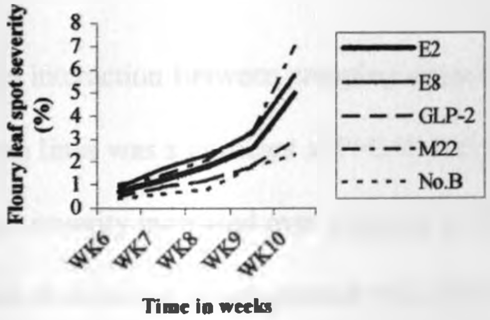


Fig. 12: Floury leaf spot severity on 5 bean lines 6-10 weeks after planting during the residual rains (June-September 2000) in Taita hills

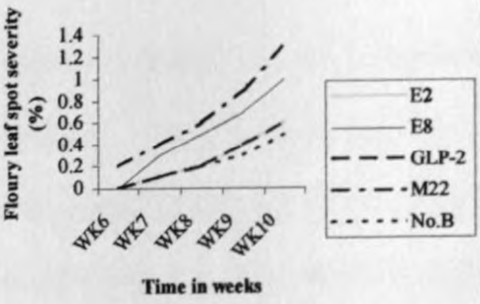


Fig. 13: Floury leaf spot severity in 4 different cropping systems and spatial arrangement 6-10 weeks after planting during the long rains (March-May 2000) in Taita hills

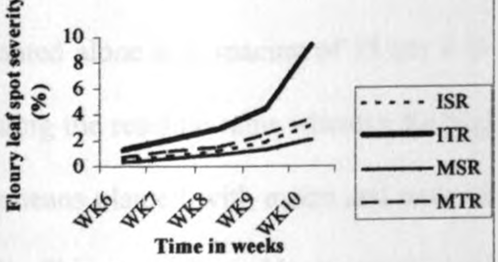
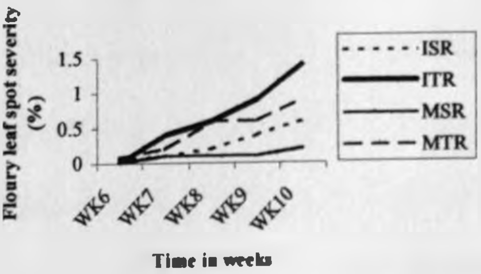


Fig. 14: Floury leaf spot severity in 4 different cropping systems and spatial arrangement 6-10 weeks after planting during the residual rains (June-September 2000) in Taita hills



Where, CSS P is cropping system and spacing treatments which are:

MSR- monocrop at a spacing of 15cm x 80cm
MTR- monocrop at a spacing of 15cm x 50cm
ISR- intercrop at a spacing of 15cm x 80cm
ITR- intercrop at a spacing of 15cm x 40cm

severity at 10 WAP was observed on bean line No.B during the long and the residual rains respectively (Figures 11 and 12). Significant (P=0.05) differences in floury leaf spot severity among the 5 bean lines was observed during the long rains but not during the residual rains. Bean line M22 was the most (3.0%) severely affected by floury leaf spot during the long rains. It was followed in descending order by bean lines E8 (2.8%), E2 (2.3%), GLP-2 (1.5%) and No.B (1.2%). A similar trend of observation was made during the residual rains. During this season, the highest (0.7%) floury leaf spot severity was observed on bean line M22 followed by bean line E8 (0.5%), GLP-2 (0.3%), E2 (0.2) and No.B (0.2%).

The interaction between cropping systems and spacing treatments and time irrespective of bean lines was significant at P=0.05 during both seasons. During the long rains, floury leaf spot severity increased over time and at 10 WAP the highest (9.4%) floury leaf spot severity was observed on beans planted with maize and sown at a spacing of 15 cm x 40 cm (Figure 13). This was followed by beans planted alone at a spacing of 15 cm x 50 cm (3.7%), beans planted with maize and sown at a spacing of 15 cm x 80 cm (3.2%) and finally by beans planted alone at a spacing of 15 cm x 80 cm (2.1%). Similar observations were recorded during the residual rains whereby the highest (1.4%) floury leaf spot severity was observed on beans planted with maize and sown at a spacing of 15 cm x 40 cm at 10 WAP (Figure 14). This was followed by beans planted alone at a spacing of 15 cm x 50 cm (0.9%), beans planted with maize and sown at a spacing of 15 cm x 80 cm (0.6%) and finally by beans planted alone at a spacing of 15 cm x 80 cm (0.2%). Cropping systems and spacing treatments differed significantly (P=0.05) amongst each other irrespective of bean lines and time of recording during both seasons. During both seasons, the highest floury leaf spot severity was observed under intercropping at a spacing of 15 cm x 40 cm. This was followed by monocropping at a spacing of 15 cm x 50 cm, intercropping at a spacing of 15 cm x 80 cm and finally by monocropping at a spacing of 15 cm x 80 cm. There was a significant (P=0.05) difference in floury leaf spot severity amongst time treatments during both seasons.

Floury leaf spot severity between the long and the residual rains differed significantly (P=0.05) by Student's-t test. The severity was higher during the long than during the residual rains.

6.3 Bean yields and yields components

4.6.3.1 Yield (kg/ha)

The interaction between the bean lines and cropping systems and spacing on yield in the long (March – May 2000) and the residual (June – September 2000) rains was not significant (P=0.05) (Appendix 22 and 23, Table 18 and 19). The best yields during the long rains were however produced by bean lines E8 (1517.5 kg/ha) and M22 (1498.9 kg/ha) both planted under monocrop system at a spacing of 15 cm x 50 cm. This was followed by bean line E8 (1423.5 kg) which was planted as an intercrop with maize at a spacing of 15 cm x 40 cm. During the residual rains, the highest yields (1365.1 kg/ha) were produced by bean line M22 planted under monocropping system at a spacing of 15 cm x 50 cm. Highly significant (P=0.05) yield differences were, however, observed

Table 18: Bean yield (kg/ha) from 5 bean lines planted in 4 different cropping systems and spatial arrangement during the long rains (March-May 2000) in Taita hills

	Cropping systems and spacing treatments (B)				
Bean lines (A)	Intercrop at 15cm x 80cm	Intercrop at 15cm x 40cm (±277.6)	Monocrop at 15cm x 80cm	Monocrop at 15cm x 50cm	Means (A) (±147.9)
E2	633.4	932.5	712.5	1337.8	904.1
E8	642.3	1423.5	986.2	1517.5	1142.4
GLP-2	600.1	811.4	730.7	834.4	744.2
M22	578.3	1288.2	802.5	1378.5	1011.9
No.B	410.7	929.9	543.4	1498.9	845.7
Means (B)(±121.3)	573.0	1077.1	755.1	1313.4	
Lsd A	ns				
Lsd B	247.7*				
Lsd A x B	ns				

Where, *, is significant and ns is not significantly different at P = 0.05

Data are means of 3 replicates

Table 19: Bean yield (kg/ha) from 5 bean lines planted in 4 different cropping systems and spatial arrangement during the residual rains (June-September 2000) in Taita hills

	Cropping systems and spacing treatments (B)				
Bean lines (A)	Intercrop at 15cm x 80cm	Intercrop at 15cm x 40cm (±142.3)	Monocrop at 15cm x 80cm	Monocrop at 15cm x 50cm	Means (A) (±83.1)
E2	666.7	941.1	854.4	1080.9	885.8
E8	524.5	1041.4	875.0	1097.5	884.6
GLP-2	497.2	856.5	661.1	1242.5	814.3
M22	607.1	963.8	690.9	1365.1	906.7
No.B	418.6	946.4	827.8	1042.1	808.7
Means (B)(±59.7)	542.8	949.8	781.8	1165.6	
Lsd A	ns				
Lsd B	121.8*				
Lsd A x B	ns				

Where, *, is significant and ns is not significantly different at P = 0.05

Data are means of 3 replicates

among the cropping systems and spacing treatments in both seasons. Beans under monocropping at a spacing of 15 cm x 50 cm resulted in the highest yields of 1313.4 kg/ha and 1165.6 kg/ha during the long and the residual rains respectively. This was followed by beans intercropped with maize at a spacing of 15 cm x 40 cm, which had yields of 1077.1 kg/ha and 949.8 kg/ha in the long and the residual rains respectively. The lowest yields (573.0 kg/ha and 542.8 kg/ha) were recorded in beans intercropped with maize at a spacing of 15 cm x 80 cm in the long and the residual rains respectively.

During the long rains, there was no significant (P=0.05) difference in yields between beans under monocropping at a spacing of 15 cm x 50 cm (1313.4 kg/ha) and beans intercropped with maize at a spacing of 15 cm x 40 cm (1077.1 kg/ha) (Table 18). Yields recorded in beans under monocropping at a spacing of 15 cm x 80 cm (755.1 kg/ha) and those intercropped with maize at a spacing of 15 cm x 80 cm (573.0 kg/ha) did not differ significantly (P=0.05) from each other but significantly (P=0.05) differed from those yields obtained in beans under monocropping at a spacing of 15 cm x 50 cm and beans intercropped with maize at a spacing of 15 cm x 40 cm.

During the residual rains, bean yields obtained from beans under monocropping at a spacing of 15 cm x 50 cm (1165.6 kg/ha) differed significantly (P=0.05) from those obtained from bean crop intercropped with maize at a spacing of 15 cm x 40 cm (949.8 kg/ha). Yields recorded from bean crop intercropped with maize at a spacing of 15 cm x 40 cm (949.8 kg/ha) were significantly (P=0.05) different from those obtained from monocrop beans sown at a spacing of 15 cm x 80 cm (781.8 kg/ha) and beans intercropped with maize at a spacing of 15 cm x 80 cm (542.8 kg/ha). Differences in yields from bean monocrop at a spacing of 15 cm x 80 cm and those intercropped with maize at a spacing of 15 cm x 80 cm were significant at P=0.05. During both seasons, there were no significant (P=0.05) differences in yields among the 5 bean lines. However, the highest yields were obtained on bean line E8 (1142.4 kg/ha) and M22 (906.7 kg/ha) during the long and the residual rains respectively. On the other hand, GLP-2 and No.B produced the lowest yields during the long and the residual rains respectively. Bean yields obtained during the long rains were significantly (P=0.05) higher than the yields obtained during the residual rains by Student's-t procedure (test).

4.6.3.2 Number of pods per plant

From the analysis of variance (Appendix 24 and 25), there was no significant (P=0.05) interaction in the number of pods per plant between bean lines and cropping systems and spacing treatments in both the long (March- May 2000) and the residual long rains (June-September 2000) (Table 20 and 21). A significant (P=0.05) difference in the number of pods per plant was however observed among the bean lines during the long rains but not during the residual rains. During the long rains, the highest (8) number of pods per plant was recorded on bean line No.B while the lowest (5 pods) was recorded in bean line GLP-2 (Table 22). Bean line No.B did not differ significantly (P=0.05) in the number of pods per plant from bean line E2 (7 pods). Similarly, the number of pods per plant recorded on bean lines E2 was not significantly (P=0.05) different from bean lines E8 (6 pods) and M22 (6 pods). The differences in number of pods among bean lines E8, M22 and GLP-2 was not significant (P=0.05).

Table 20: Number of pods per plant on 5 bean lines planted in 4 different cropping systems and spatial arrangement during the long rains (March- May 2000) in Taita hills

Bean lines (A)	Cropping systems and spacing treatments (B)				Means (A)
	Intercrop at 15cm x 80cm	Intercrop at 15cm x 40cm (±1.5)	Monocrop at 15cm x 80cm	Monocrop at 15cm x 50cm	(±0.6)
E2	7	7	7	7	7
E8	6	6	6	6	6
GLP-2	5	5	5	5	5
M22	6	6	6	7	6
No.B	7	8	8	7	8
Means (B)(±0.7)	7	7	7	6	
Lsd A	1.4*				
Lsd B	ns				
Lsd A x B	ns				

Where, *, is significant at P = 0.05 and ns is not significantly different at P = 0.05

Data are means of 3 replicates

Table 21: Number of pods per plant on 5 bean lines planted in 4 different cropping systems and spatial arrangement during the residual rains (June- September 2000) in Taita hills

Bean lines (A)	Cropping systems and spacing treatments (B)				Means (A)
	Intercrop at 15cm x 80cm	Intercrop at 15cm x 40cm (±0.9)	Monocrop at 15cm x 80cm	Monocrop at 15cm x 50cm	(±0.7)
E2	2	2	2	2	2
E8	3	3	3	3	3
GLP-2	4	5	4	4	4
M22	3	3	4	3	4
No.B	3	2	3	3	3
Means (B)(±0.3)	3	3	3	3	
Lsd A	ns				
Lsd B	ns				
Lsd A x B	ns				

Where, ns is not significantly different at P = 0.05

Data are means of 3 replicates

During the residual rains, bean lines M22 and GLP-2 had the highest (4 pods) number of pods per plant followed by No.B and E8 which had 3 pods per plant. The lowest number of pods per plant was observed on bean line E2. There was no significant (P=0.05) difference in the number of pods per plant among cropping systems and spacing treatments in both seasons.

4.6.3.3 Number of seeds per pod

From the analysis of variance (Appendix 26 and 27), the interactions between the bean lines and the cropping systems and spacing treatments on number of seeds per pod was not significant (P=0.05) in both the long (March- May 2000) and the residual (June-September 2000) rains. Significant (P=0.05) differences were similarly not observed among the cropping systems and the spacing treatments in both seasons. However, highly significant (P=0.05) differences in the number of seeds per pod were observed among bean lines in both seasons. During the long rains, bean lines No.B and E8 had the highest (5) number of seeds per pod (Table 22). Bean lines E2, GLP-2 and M22 recorded the least number (4) of seeds per pod which were significantly (P=0.05) lower than that recorded on bean lines E8 and No.B. During the residual rains however, bean line No.B recorded the highest number (4) of seeds per pod which was significantly (P=0.05) higher than 2 seeds recorded in each bean line viz: E2, E8, GLP-2 and M22 (Table 23).

4.6.3.4 100 seed weight

Appendices 28 and 29 present the analysis of variance tables for 100 seed weight for the long (March-May 2000) and the residual (June-September 2000) rains respectively.

Table 22: Number of seeds per pod from 5 different bean lines planted in 4 different cropping systems and spatial arrangement during the long rains (March- May 2000) in Taita hills

Bean lines (A)	Cropping systems and spacing treatments (B)				Means (A)
	Intercrop at 15cm x 80cm	Intercrop at 15cm x 40cm (±0.5)	Monocrop at 15cm x 80cm	Monocrop at 15cm x 50cm	(±0.3)
E2	4	4	4	4	4
E8	5	5	5	5	5
GLP-2	4	4	4	4	4
M22	4	4	4	4	4
No.B	5	5	5	5	5
Means (B)(±0.2)	4	4	4	4	
Lsd A	0.6*				
Lsd B	ns				
Lsd A x B	ns				

Where, *, is significant at P = 0.05 and ns is not significantly different at P = 0.05

Data are means of 3 replicates

Table 23: Number of seeds per pod from 5 different bean lines planted in 4 different cropping systems and spatial arrangement during the residual rains (June-September 2000) in Taita hills

Bean lines (A)	Cropping systems and spacing treatments (B)				Means (A)
	Intercrop at 15cm x 80cm	Intercrop at 15cm x 40cm (±0.4)	Monocrop at 15cm x 80cm	Monocrop at 15cm x 50cm	(±0.3)
E2	2	2	2	2	2
E8	2	2	2	2	2
GLP-2	2	2	2	2	2
M22	3	2	2	2	2
No.B	4	4	4	4	4
Means (B)(±0.1)	3	3	2	3	
Lsd A	0.8*				
Lsd B	ns				
Lsd A x B	ns				

Where, ns is not significantly different at P = 0.05

Data are means of 3 replicates

There were no significant (P=0.05) interaction in 100 seed weight between bean lines and cropping systems and spacing treatments in both seasons. Similarly, insignificant (P=0.05) differences in 100 seed weight were also observed among cropping systems and spacing treatments in both seasons. However, a highly significant (P=0.05) difference in 100 seed weight was observed among bean lines in both seasons. Bean line E2 recorded the highest weight of 56.7g and 51.3g in the long and the residual rains respectively (Table 24 and 25). Bean line No.B on the other hand recorded the least weight of 23.1g and 22.8g during the long and the residual rains respectively.

During the long rains, the highest 100 seed weight recorded in bean line E2 (56.7g) differed significantly (P=0.05) from that of seeds of bean lines M22 (51.8g), E8 (46.1g), GLP-2 (42.5g) and No.B (23.1g). Seeds from bean line M22 were significantly (P=0.05) higher in 100 seed weight when compared to seeds from bean lines E8, GLP-2 and No.B. Bean lines E8 and GLP-2 seed weights were not significantly (P=0.05) different from each other but were significantly (P=0.05) different from that of seeds of bean line No.B. During the residual rains, bean lines E8 (44.7g), GLP-2 (41.5g) and M22 (41.6g) did not differ significantly (P=0.05) in 100 seed weight among each other, but were significantly (P=0.05) different from that of seed weights of bean line No.B (22.8g).

Table 24: Hundred seed weight (g) of seeds of 5 bean lines planted in 4 different cropping systems and spatial arrangement during the long rains (March-May 2000) in Taita hills

Bean lines (A)	Cropping systems and spacing treatments (B)				Means (A)
	Intercrop at 15cm x 80cm	Intercrop at 15cm x 40cm (±3.3)	Monocrop at 15cm x 80cm	Monocrop at 15cm x 50cm	(±1.9)
E2	58.1	57.6	54.9	56.3	56.7
E8	45.6	46.6	47.6	44.7	46.1
GLP-2	41.6	45.9	42.7	39.6	42.5
M22	55.7	49.1	51.0	51.3	51.8
No.B	23.3	23.9	23.1	22.0	23.1
Means (B)(±1.4)	44.9	44.6	43.9	42.8	
Lsd A	4.3*				
Lsd B	2.9ns				
Lsd A x B	6.7ns				

Where, *, is significant at P = 0.05 and ns is not significantly different at P = 0.05

Data are means of 3 replicates

Table 25: Hundred seed weight (g) of seeds of 5 bean lines planted in 4 different cropping systems and spatial arrangement during residual rains (June-September 2000) in Taita hills

Bean lines (A)	Cropping systems and spacing treatments (B)				Means (A)
	Intercrop at 15cm x 80cm	Intercrop at 15cm x 40cm (±2.8)	Monocrop at 15cm x 80cm	Monocrop at 15cm x 50cm	(±2.1)
E2	53.3	51.4	50.0	50.3	51.3
E8	44.5	42.5	46.0	45.6	44.7
GLP-2	41.6	40.7	42.2	41.6	41.5
M22	40.5	40.2	42.6	43.0	41.6
No.B	22.8	22.9	23.2	22.4	22.8
Means (B)(±1.0)	40.6	39.6	40.8	40.6	
Lsd A	4.8*				
Lsd B	ns				
Lsd A x B	ns				

Where, *, is significant at P = 0.05 and ns is not significantly different at P = 0.05

Data are means of 3 replicates

5.0 DISCUSSION

5.1 Introduction

The study was carried out with the overall objective of improving bean production in Taita hills through integration of improved bean lines at small scale farming level. This chapter therefore discusses the major constraints to bean production in the area, the effect of storage period on bean seed quality, the incidence and severity of floury leaf spot and subsequently yield of new bean lines under bean monocropping and bean/maize intercropping systems.

5.2 Participatory Rural Appraisal (PRA) and household interviews

PRA exercise revealed that limited land size in Taita hills is a constraint to increased agricultural production. Limited land size is due to land fragmentation as a result of increased population. As a result, farmers in the area rent or own land in the lower parts of Mwatate division. The most labour demanding activities include land preparation, planting, weeding and harvesting and these are mainly carried out by the family members. Maize and beans are the major food crops grown in the area. During the long rains (mid- February to April), most farmers plant a pure stand of beans whereas during the residual rains (June to September), beans are planted as intercrops with maize. Njambere (1995) made similar observations while working on floury leaf spot of beans in Taita hills. Land preparation begins in January to mid-February during the long rains and in June to September during the residual rains. Maize planting commences in mid-January to March and between June and September whereas beans are planted from mid-February to April mainly in pure stands and between June and September as an intercrop of maize.

Beans are the main legumes grown in the area with the main variety being Rose Coco-GLP-2 (locally referred to as 'Nyayo') apart from traditional varieties. The major source of bean seeds for planting in the area is the farmers' own seed. Other sources include the local market, neighbours, relatives and researchers. Farmers in this area do not seem to purchase certified bean seeds from agrochemical shops mainly due to financial constraints. Bean production is insufficient to meet home consumption due to a number of constraints. The PRA team documented various constraints and in order of importance were identified as insect pests, high cost of chemicals, diseases, high cost of certified seed, and lack of high quality seed at farm level for planting. Household interviews on the other hand revealed insect pests, diseases, low soil fertility, low yielding varieties, high rainfall and lack of high quality seed as the major constraints in the mentioned order. Other researchers have documented diseases unlike insect pests as the major constraints of the bean crop in Africa (Allen *et al.*, 1989; Allen and Edje, 1990; Kimani *et al.*, 1990; Rollin and Robary, 1991; Allen, 1992; Rabakoarihanta and Rakotomalala, 1993). However, farmers ranked diseases second because their conceptual knowledge on diseases was very limited where they equated diseases with 'too much sun' or 'too much rain'. This concurs with Allen (1992) who made similar observations.

To combat the problem of lack of high quality seed, farmers use their own seed from the previous harvest, purchase from the local market, or receive seeds from relatives and neighbours. These seeds have been reported to harbour seedborne pathogens (Mukunya and Keya, 1975; Origa, 1992; Isanda, 1994; Wakahiu, 2000). Seedborne inoculum in beans has been documented to be the most important in disease epidemic development since infected or contaminated seed provide the primary inoculum foci for the secondary spread of diseases when planted in the field (Mukunya and Keya, 1975; Origa, 1992; Isanda, 1994; Wakahiu, 2000).

5.3 Effect of storage period on the quality of bean seeds

This study was carried out to further assist the small scale farmer with proper technical advice so as to be able to produce and maintain high quality bean seeds in storage at the farm level. After 2 months of storage all seed lots had germination greater than 80 %, that is, greater than the minimum standard (80%) which is an indication of good quality seed (Almekinders and Louwaars, 1999). However, after 5 months of storage, the germination of all the seed lots declined and were more variable among bean seed samples. Some seed lots had germination of above 80% while others had germination of below 80%. This decline in the germination may possibly be due to deterioration (ageing) of the seeds leading to a decline in seed quality. Ageing has been implicated in the loss of seed quality (Asiedu and Powell, 1998) which involves seed deterioration, the accumulation of irreversible degenerative changes in the physiological quality of the seed, until finally the ability to germinate is lost (Powell *et al.*, 1984). The fact that some seed lots maintained germination of above the minimum standard (80%) while others had germination below the minimum standard after 5 months of storage implies that deterioration of these seed lots took place at varying rates.

Leachate conductivity was variable among the seed lots at 2 and 5 months of storage. All seed lots showed increased seed leachate conductivity after 5 months of storage. An increase in seed leachate conductivity is as a result of an increase in solute leakage from the seeds (Asiedu and Powell, 1998). The increased leakage observed following storage might be partly explained by cell death resulting from deterioration (Powell and Matthews, 1978). Membrane deterioration is thought to be the initial change during ageing and these weakened membranes may be more susceptible to the physical change imposed during rapid water uptake, that is imbibition damage (Asiedu and Powell, 1998). Leachate conductivity is measured after imbibition in water, and thus, imbibition damage (Powell and Matthews, 1978) may also have contributed to increase in the leakage of electrolytes observed in this study. However, some seed lots (3, 4 and 10) had higher conductivity values (between 27.51 and 30.68 $\mu Scm^{-1}g^{-1}$), but this was not associated with poorer staining than other seed lots. Thus the high leakage could not be attributed to more dead tissues. These seed lots were all bean line No.B and this bean line has smaller seeds. It has been noted in other species, notably peas, that where seed size is very small, solute leakage is greater. This is possibly due to the greater seed surface to weight ratio in small seeds. Thus, a relatively larger area is available for solute leakage from small seeds.

The reduction in vigour indicated by an increase in the leaching of the electrolytes was also reflected in the tetrazolium chloride staining of the abaxial surfaces of the cotyledons. All seed lots showed a decrease in the percentage of seed with complete staining after 5 months of storage, due to the development of dead tissues; a phenomenon also observed in peas seeds (Powell and Matthews, 1978). In their study, they reported an increase in the percentage of seed with incomplete staining that is an increase in the proportion of dead tissue of seed peas after storage.

This study revealed variation in the moisture contents among the seed lots in both sampling times (2 months and 5 months of storage). Additionally, the moisture content at 2 months of storage was above the safe moisture content (8%) for storage of beans (Almekinders and Louwaars, 1999). After 5 months of storage, the moisture content in some seed lots increased while in others it fell, in some cases to below the safe moisture content (8%) of bean seed storage (Almekinders and Louwaars, 1999). The different storage environments under which these seeds were subjected varied from farmer to farmer and this may be the contributing factor to this observation. Seed lots whose moisture content increased might have been stored at high humidity whereas seed lots whose moisture content declined might have been stored at low humidity. Studies (James, 1967; Roberts, 1972; Justice and Bass, 1978) have related the moisture content of seed in storage to the relative humidity of the storage atmosphere. Seeds are hygroscopic and therefore they take up or lose water until their moisture content is in equilibrium with the ambient relative humidity (Powell *et al.*, 1984). Thus, different storage humidities may contribute to the changes in the seed moisture content.

5.4 Floury leaf spot of beans

5.4.1 Effect of intercropping on floury leaf spot incidence (farmer-managed and researcher-managed trials)

The study revealed that intercropping increased floury leaf spot incidence in the farmer-managed trials during the short rains. Under researcher-managed trials however, intercropping had no effect on floury leaf spot incidence during the long and the residual rains.

In the farmer-managed trials, intercropping at a spacing of 15 cm x 40 cm increased the incidence of floury leaf spot in all the 4 bean lines compared with monocropping at a spacing of 15 cm x 50 cm during the short rains. Similarly, intercropping at a spacing of 15 cm x 80 cm significantly increased the incidence of floury leaf spot in all the 4 bean lines compared with monocropping at a spacing of 15 cm x 80 cm. The high floury leaf spot disease incidences in intercropping at a spacing of 15 cm x 40 cm may be attributed to high plant densities, which favoured spread through leaf-to-leaf contact or alteration of the micro-climate. In addition, weed management at farm level was noted to be inadequate thereby increasing the plant population per unit area which in turn might have influenced the microclimate by increasing the humidity which favoured the disease. This is similar to reports by Reeves (1990) which indicated that the incidence of bean golden mosaic bigeminivirus (BGMV) on *Phaseolus vulgaris* cv. Huetar intercropped with maize cv. Diamantes increased with an increase in density between plants.

During the long rains, however, intercropping of beans at a spacing of 15 cm x 40 cm reduced floury leaf spot incidence in all the 4 bean lines compared with monocropping at a spacing of 15 cm x 50 cm. These findings concur with other studies (Diaz, 1981; Fininsa, 1996; Rheenan *et al.*, 1981), which indicate reduction in incidence of bean diseases under intercropping. Rain has been shown to be the major dispersal agent of stem anthracnose (*C. truniutum*) (Chambers, 1969). During this season, more rainfall (175.0mm; an average figure for the March-May (2000) rains; Appendix 6) was recorded than during the short rains (152.1mm; an average figure for the October-December (1999) rains) and dispersal of *M. phaseoli* conidia might have been mainly by the splashing raindrops. The maize intercrop may have served as a barrier to the spores hence limiting spread of the pathogen thus reducing the incidence of floury leaf spot on bean crop. This may explain why floury leaf spot incidence was lower under intercropping than under monocropping. The variations made in the farmer-managed trials, which indicate, increased (during the short rains) and reduced (during the long rains) floury leaf spot incidence on beans grown as an intercrop point to the fact that depending on season, maize intercrops can increase or reduce floury leaf spot incidence.

In the researcher-managed trials, floury leaf spot incidence was higher in the long rains than in the residual rains. During the long (March to May 2000) rains, more rains (175.0mm on average; Appendix 6) were reported than during the residual (June to September 2000) rains (66.7mm on average). Cardona-Alvares and Skiles (1958) reported that the second growing season of 1957, which was much drier and warmer than normal had relatively low incidence of floury leaf spot. This could offer a probable explanation why the disease incidence was lower during the residual rains than during the long rains. Floury leaf spot incidence was higher in the short rains than in the long rains in the farmer-managed trials although the long rains reported more rains (175.0mm) than the short rains (152.1mm). This is contrary to Njambere's (1995) findings that reported higher floury leaf spot incidence in Taita hills in the long rains than in the short rains. During the short rains, all farmers carried out timely planting and at the same date whereas during the long rains they all planted late and at varying dates. Late planting and variations in planting dates might have contributed to this observation. During the long rains, floury leaf spot incidence was high in the researcher-managed trials than in the farmer-managed trials. Floury leaf spot incidence data was recorded over a period of time (flowering to mid podding) and probably higher incidences could have been missed as a result of defoliation Njambere (1995).

5.4.2 Effect of intercropping on floury leaf spot severity (researcher-managed trials)

The study revealed that intercropping maize with beans and sown at a spacing of 15 cm x 40 cm increased the severity of floury leaf spot when compared to monocropped beans at a spacing of 15 cm x 50 cm during both the long and the residual rains. The highest floury leaf spot severity was recorded during the long rains 10 weeks after planting when beans were planted as an intercrop with maize at a spacing of 15 cm x 40 cm. Similarly, beans intercropped at a spacing of 15 cm x 80 cm had higher levels of severity of floury leaf spot when compared to monocropped beans at the same spacing. These findings appear to be at variance with those studies that indicate decreases in severity of most common bean diseases in bean-maize associations (Kikoka *et al.*, 1989; Boudreau and

Mundt, 1992; Galloti *et al.*, 1992; Fininsa, 1996). However, the above findings concur with Moreno (1977), Msuku and Edje (1982) and Sengooba (1990) who reported increased angular leaf spot severity of beans intercropped with maize. The intercrop (maize) may have brought about microclimatic changes, which favoured floury leaf spot disease hence increasing the severity. One of the microclimatic changes due to intercrops might have been increased humidity, which favoured infection by the pathogen. Moreno (1977) speculated that the increased angular leaf spot severity, when beans were grown with maize, was due to prolonged periods of high humidity under a maize canopy, because beans intercropped with sweet potatoes and/or cassava had lower angular leaf spot severity than beans grown alone. Cardona-Alvarez and Walker (1956) found that *P. griseola* required long periods of leaf wetness for infection and sporulation and in Lanters (1990) work; longer periods of leaf wetness correspond to increased angular leaf spot severity. Boudreau (1993) reported increased relative humidity and decreased leaf temperatures for the long rains at Kabete in maize intercrops and this favoured dew formation and so the increase in angular leaf spot severity. Cool temperatures and high relative humidity favours floury leaf spot (Allen *et al.*, 1996) thus the above observations may explain why floury leaf spot severity increased in intercrops. Intercropping has been reported to reduce the relative wind velocity (Boudreau, 1993). Reduced wind velocity may remove spores from a lesion and lower their impaction efficiency, leading to lower severity; but also result in decreased air circulation and prolonged leaf wetness, favouring disease development. This could be another reason why in this study, floury leaf spot severity increased under intercropping.

The severity of floury leaf spot was higher under intercropping at a spacing of 15 cm x 40 cm (2 rows of beans in between 2 rows of maize) than under intercropping at a spacing of 15 cm x 80 cm (1 row of beans in between 2 rows of maize). Likewise, the severity of floury leaf spot was higher under monocropping at a spacing of 15 cm x 50 cm than under monocropping at a spacing of 15 cm x 80 cm. This implies that high plant density in intercropping at a spacing of 15 cm x 40 cm and monocropping at a spacing of 15 cm x 50 cm increased floury leaf spot severity. This observation contradicts Boudreau's (1993) findings of reduced angular leaf spot severity due to high plant density, but concurs with other works for fungal pathogens (Burdon and Chilvers, 1982). A high plant density provides more number of host targets for spore interception and a more favourable microclimate for disease development (Burdon and Chilvers, 1976; Blad *et al.*, 1978), which might have been the case in this study.

The five bean lines differed in their susceptibility to floury leaf spot as is evidenced in the differences in severity levels amongst themselves. The disease was more severe in bean line M22, followed in descending order by bean lines E8, E2, GLP-2 and No.B. Bean line M22 in this study was the most susceptible while bean line No.B was the least susceptible. This is in line with Njambere's (1994) findings who, while evaluating 56 bean genotypes for resistance under monoculture, rated bean lines M22, E8 and E2 in that order to be of intermediate resistance while GLP-2 and No.B were rated resistant and highly resistant respectively. Mwang'ombe *et al.*, (1994) however rated GLP-2 as highly resistant, E2 as resistant, No.B, E8 and M22 as moderately resistant.

The disease was more severe during the long rains than during the residual rains, which is similar to Njambere's (1995) observations. This is probably because of higher (175.0mm) rainfall during the long than during the residual (66.7mm) rains. Kimani *et al*., (1993) recorded higher disease levels during the wetter seasons while evaluating 50 advanced generation bean lines for multiple resistance. Predominantly dry weather during the residual rains may have been responsible for low infection by the floury leaf spot pathogen.

The severity of floury leaf spot increased with time but started declining after the tenth week after crop emergence (mid-podding stage). This is attributed to leaf defoliation, which started off at this time. Njambere (1995) reported heavy defoliation at the mid-podding stage due to this disease. A similar phenomenon has been reported by Fernandez *et al*., (1987) and Isanda (1994). In their findings, they observed that disease rating on bean anthracnose could not be taken after 6 weeks after crop emergence due to premature leaf senescence followed by defoliation.

5.5 Effect of intercropping on bean yield

Monocropping produced higher yields than intercropping in both seasons. Bean yields under monocropping at a spacing of 15 cm x 50 cm were higher than yields under intercropping at a spacing of 15 cm x 40 cm. Similarly, monocropping at a spacing of 15 cm x 80 cm gave higher yields compared to intercropping at a spacing of 15 cm x 80 cm. Kikoka *et al*. (1989) reported similar observations in Morogoro, Tanzania, while evaluating the effect of cropping systems on bean diseases and yield. Similar reports of higher crop yields in monocrops than intercrops have been reported by various workers (Raposo *et al*., 1995). The fact that intercropped beans at a spacing of 15 cm x 40 cm had lower yields than monocropped beans at a spacing of 15 cm x 50 cm despite the fact that the former had higher plant density than the latter suggest some kind of competition in intercrops. In intercrops, there is competition for light, space and nutrients (CIAT, 1987), which finally result in poor yields of both crops. Boudreau (1993) reported reduction in the bean leaf area to approximately 75% of the monocrop value in the high proportion maize intercrop (2:1 bean:maize). This competition-induced reduction in bean leaf area may be responsible for reduced yields in intercrops observed in this study.

Intercropped beans at a spacing of 15 cm x 40 cm (row arrangement was maize, beans, beans, maize) had higher yields than intercropped beans at a spacing of 15 cm x 80 cm (row arrangement was maize, beans, maize, beans), which concurs with Salomon (1990) findings. On the other hand, monocropped beans at a spacing of 15 cm x 50 cm gave higher yields than monocroppped beans at a spacing of 15 cm x 80 cm. This may be attributed to high plant densities in both intercropped beans at a spacing of 15 cm x 40 cm (166,916plants/ha) and monocropped beans at a spacing of 15 cm x 50 cm (134,201plants/ha) compared to their counterparts, which is in agreement with Reeves (1990). In his study on the effect of planting density of beans in polyculture with maize on the incidence of bean golden mosaic virus, he reported increased yields of *Phaseolus vulgaris* with an increase in plant density despite the increase in viral infection. Similar reports of increased yields with increasing density of crops have been made (Candal *et al*., 1993; Robinson, 1997).

Yields during the long rains were generally higher, than those of the residual rains. This observation concurs with Kimani *et al.*, (1993) who reported higher yields in 50 advanced bean lines during the long rains season than the short rains season. Taita hills recorded high rainfall during the long rains than during the residual rains. Thus high moisture supply during this time may have favoured more robust growth of beans resulting in higher yields.

Higher yields were recorded at the researcher-managed trials than at the farmer-managed trials during the long rains. This may be associated with poor weed management practices by the farmers.

6.0 CONCLUSIONS AND RECOMMENDATIONS

From the PRA results, it is clearly evident that maize and beans are the major food crops grown in the area where beans are mainly grown as a pure stand during the long rains and as an intercrop with maize during the residual rains. Dry beans are therefore the major source of protein in the diet of Kidaya-Ngerenyi community. The constraints to bean production in the area include insect pests, high cost of chemicals, diseases, high cost of certified seed, lack of high quality seed for planting and poor soil fertility.

The study revealed that the quality of bean seeds decreases with increased time of storage as is indicated by a decrease in germination, an increase in the leaching of electrolytes and reduced vital staining.

Intercropping maize with beans hardly influenced the incidence of floury leaf spot but increased its severity. Under bean monocrop and maize/bean intercrop systems; the disease was more severe where the inter-row spacing was closer. Floury leaf spot was observed to be more serious during seasons receiving prolonged rainfall and this coincided with March to May long rain season in this study. Intercropping maize with beans on the other hand depressed bean yields with the best yields being recorded from beans planted alone at a spacing of 15 cm x 50 cm. Bean yields produced under farmer-managed trials were lower than those produced under researcher-managed trials. Clearly, this is an indication that with better management of beans, farmers can improve yields and seed quality thereby reducing food insecurity.

Recommendations:

1. The best spacing for adoption under monocropping is 15 cm x 50 cm;
2. The best spacing for adoption under intercropping is 15 cm x 40 cm;
3. The best bean lines are E8, M22 and E2.

Future work:

1. It should focus on training more farmers on identification of important insect pests and diseases that attack beans and their control, quality seed production and proper storage as small scale farmers do use seed for planting from informal sources.
2. Further studies should be carried out to quantify actual yield losses due to floury leaf spot.
3. Need to evaluate the storage potential of seeds after harvesting since farmers will store their own seed.
4. Need to investigate effect of factors such as time of harvesting, post harvest handling, and storage conditions such as temperature and moisture on seed quality.

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8.0 APPENDICES

Appendix 1: Highlights of the questionnaire

1.0 Farmer identification

2.0 Characteristics of the farmer

3.0 Other members of the household staying in the farm

4.0 Farmer awareness

5.0 Bean types grown and why

6.0 Bean varieties, their acreage and production in November rains

7.0 Bean varieties, their acreage and important products in April rains

8.0 Dry grain production, period of planting and harvesting April rains

9.0 Planting time, method and thinning

10.0 Cropping systems

11.0 Weed control

12.a Level of angular leaf spot, (ALS) damage and control

12.b Level of bean rust damage and control

12.c Level of floury leaf spot (FLS) damage and control

12.d Level of root rots damage and control

13.0 Bean storage

14.0 Consumption of home produced bean products

15.0 Consumption of purchased bean

16 .0 Beans consumption

17.0 Bean products sold

18.0 Bean sales and marketing costs

19.0 Other purchased inputs used

20.0 Source and purpose for credit

21.0 Major bean production constraints

Appendix 2: Essential bean production management practices

1. Prepare your land adequately and remove all weeds.
2. Seed dress the seeds with *Rhizobium* spp just before planting.
3. Seed dress the seeds with Copper based fungicides mixed with either Benlate or Antracol at the rate of 3-5g/kg seed for the control of root rots.
4. Plant the beans in rows (spacing varied depending on the treatment combinations outlined in table 2).
5. Twelve (12) days from planting spray the young seedlings with Diazinon at 60-80ml/20 litres water for the control of bean flies/bean stem maggots.
6. Fourteen days (14) from planting apply DAP fertilizer at the seedling base at the rate of 100kg/ha.
7. Two (2) weeks from the first spray application, spray again using Diazinon 80ml/20litres of water for the control of bean flies/bean stem maggots.
8. At flowering, to early podding, apply copper fungicide (30g) mixed with either Antracol (30g) or Benlate (30g) in 20 litres of water for the control of any bean diseases. This treatment can be repeated 2-3 weeks if need be (This applies to the seed producers only).
9. Apply Karate or Dimethoate at mid podding at 80ml in 20 litres of water for the control of pod borers.

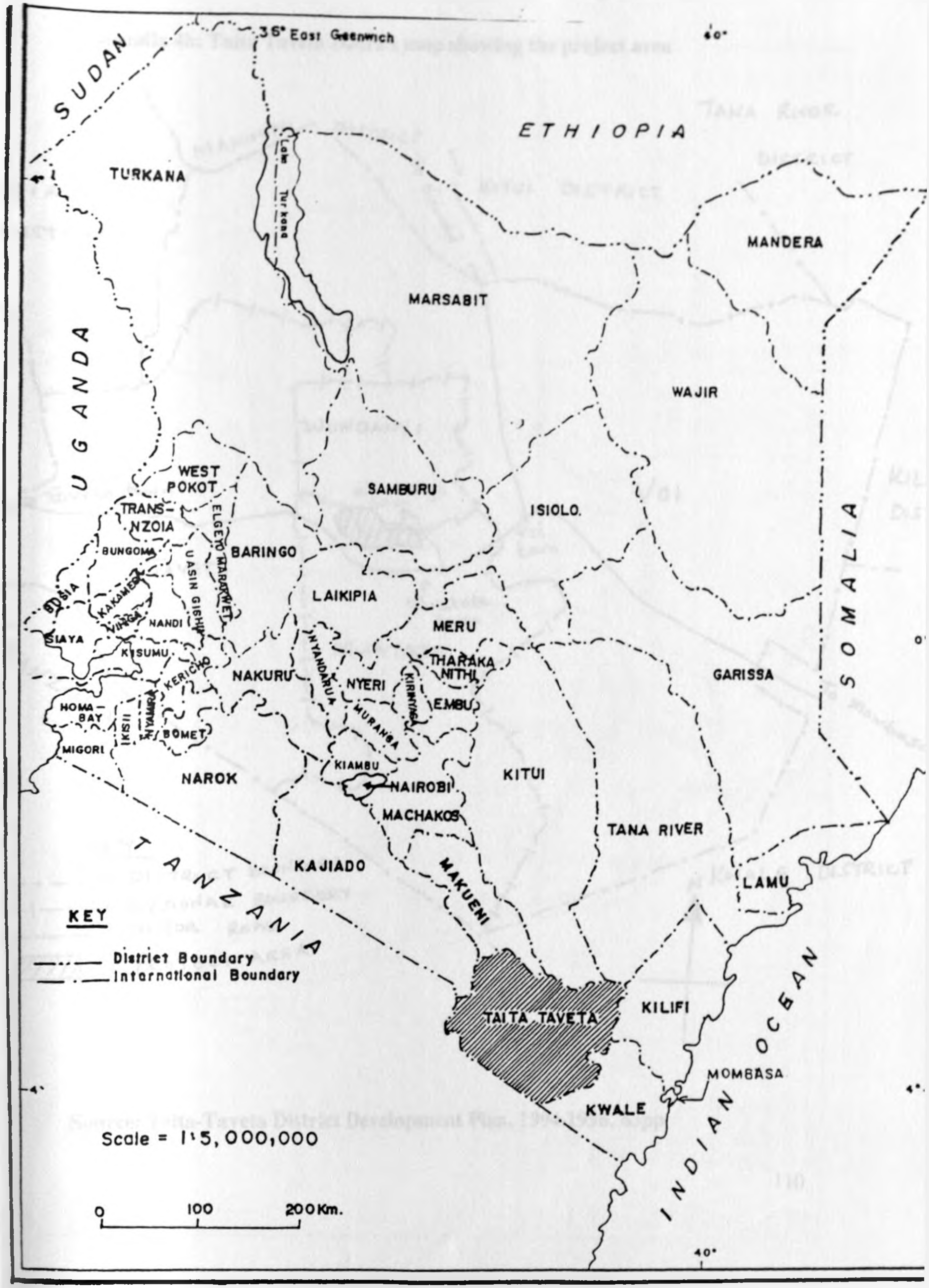
Appendix 3: Enriched potato dextrose agar (EPDA)

Commercial PDA was used

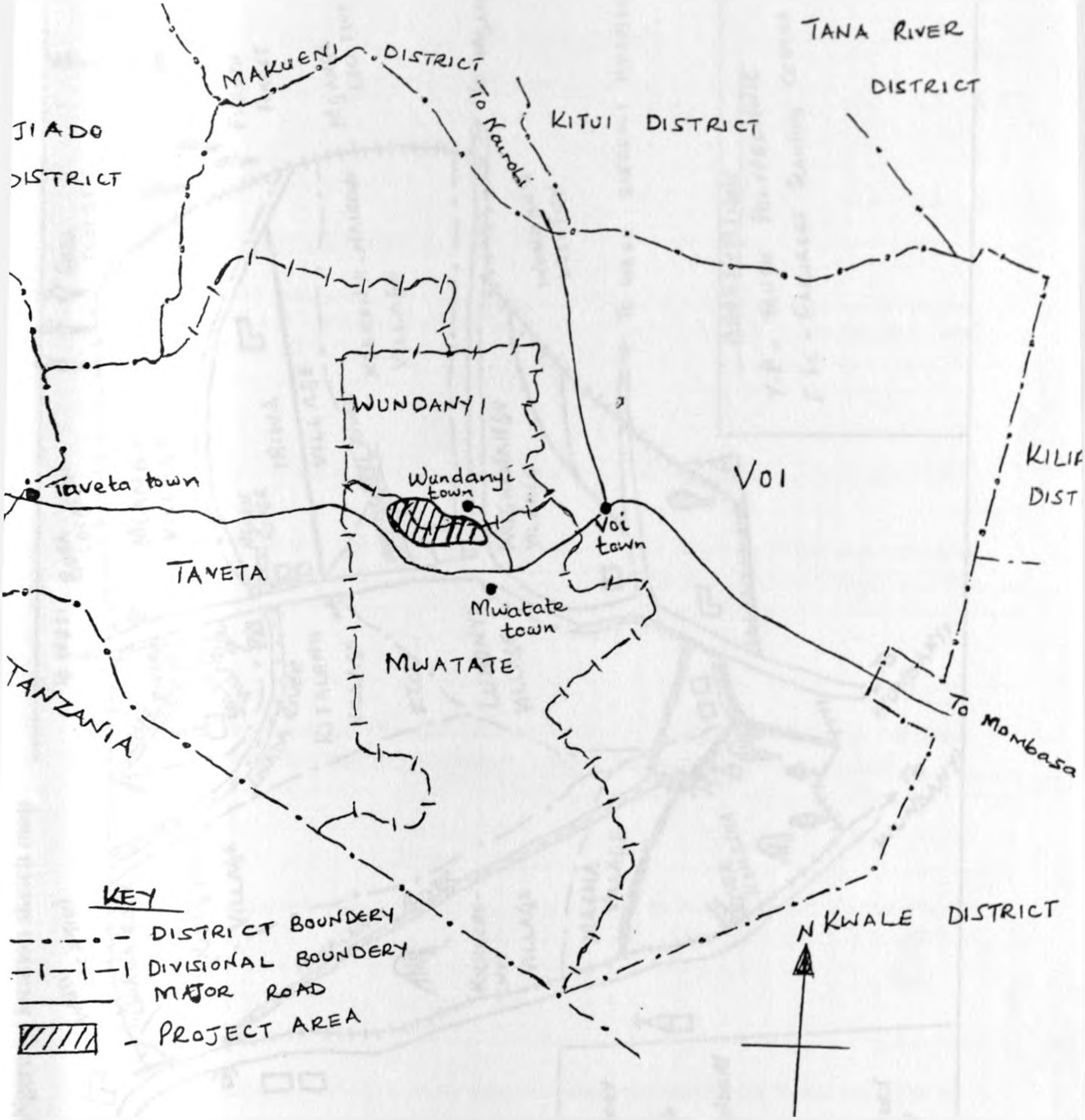
Ingredients	
Potato extract	4.0g
Glucose (dextrose)	20.0g
Agar No. 1 (Oxoid 11)	15.0g

200g of freshly picked bean leaves were macerated in a blender for 2 minutes and then added to 500ml of distilled water. The mixture was strained through cheese cloth. 35g of the above was suspended in this mixture and the solution made to 1 litre by adding distilled water. The suspension was then boiled in the autoclave to dissolve completely.

Appendix 4a: Location of Taita Taveta District in the map of Kenya

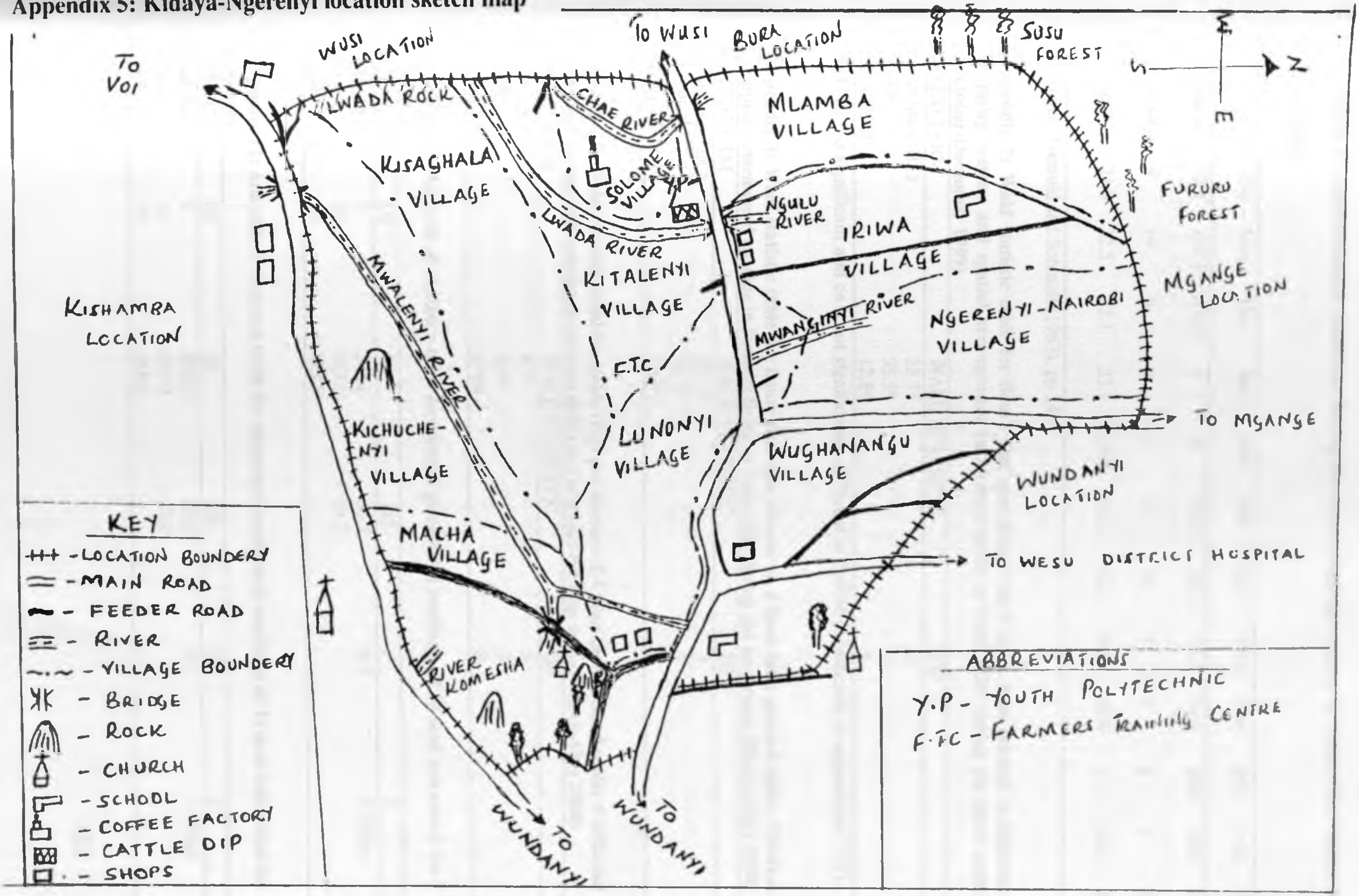


Appendix 4b: Taita Taveta District map showing the project area



Source: Taita-Taveta District Development Plan, 1994-1996, 63pp

Appendix 5: Kidaya-Ngerenyi location sketch map



Appendix 6: Environmental conditions during the bean cropping seasons in Taita hills, Ngerenyi FTC station

	Oct.	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
Rfal(mm)	78.5	163.3	214.5	0	0	176.8	292.3	56.0	74.8	66.0	32.0	94.0
No.of days	4	14	6	0	0	11	16	5	4	4	3	4
Temp °C*	21.6	22.5	22.1	23.1	24.4	24.2	22.3	20.1	18.9	17.9	18.1	19.6

* Source: Jaetzold and Schmidt (1983). pp 248.

Appendix 7: Wald statistic table for floury leaf spot disease on 4 bean lines planted in different cropping systems and spatial arrangement in farmers fields in Taita hills during the short rains (October-December 1999)

FIXED TERM	WALD STATISTIC	DF
Bean lines (BL)	28.7*	3
CSSP	95.5*	3
BL x CSSP	12.8*	9

NOTE: * is significant and ns is not significantly different at P=0.05 (Applicable to appendices 7-29)

Appendix 8: Wald statistic table for floury leaf spot disease on 4 bean lines planted under different cropping systems and spacing in farmers fields in Taita hills during the long rains (March-May 2000)

FIXED TERM	WALD STATISTIC	DF
Bean lines (BL)	53.1*	3
CSSP	30.2*	3
BL x CSSP	16.9*	9

Appendix 9: Wald statistic table for yields (Kg) per hectare of 4 bean lines planted under 4 different cropping systems and spacing in farmers fields in Taita hills the long rains (March-May 2000)

FIXED TERM	WALD STATISTIC	DF
Bean lines (BL)	4.3*	3
CSSP	4.3*	3
BL x CSSP	0.4ns	9

Appendix 10: Analysis of variance table for normal germinated seedlings of 10 seed lots stored for 2 months

SOURCE	DF	SS	MS	F	P
Seed lots	9	316.8	35.2	0.7	0.708ns
Error	10	512.0	51.2		
Total	19	828.8			

Appendix 11: Analysis of variance table for abnormal germinated seedlings of 10 seed lots stored for 2 months

SOURCE	DF	SS	MS	F	P
Seed lots	9	256.0	28.4	0.7	0.729ns
Error	10	432.0	43.2		
Total	19	688.0			

Appendix 12: Analysis of variance table for normal germinated seedlings of 10 seed lots stored for 5 months

SOURCE	DF	SS	MS	F	P
Seed lots	9	2616.9	290.8	7.3	<0.001*
Error	30	1195.0	39.83		
Total	39	3811.9			

Appendix 13: Analysis of variance table for abnormal germinated seedlings of 10 seed lots stored for 5 months

SOURCE	DF	SS	MS	F	P
Seed lots	9	2195.6	244.0	8.8	<0.001*
Error	30	828.0	27.6		
Total	39	3023.6			

Appendix 14: Analysis of variance table for electrical conductivity of 10 seed lots stored for 2 months

SOURCE	DF	SS	MS	F	P
Seed lots	9	1513.2	168.1	129.7	<0.001*
Error	30	38.9	1.3		
Total	39	1552.1			

Appendix 15: Analysis of variance table for electrical conductivity of 10 seed lots stored for 5 months

SOURCE	DF	SS	MS	F	P
Seed lots	9	1183.1	131.5	101.8	<0.001*
Error	20	25.8	1.3		
Total	29	1208.9			

Appendix 16: Analysis of variance table for moisture content of 10 seed lots stored for 2 months

SOURCE	DF	SS	MS	F	P
Seed lots	9	29.2	3.2	19.7	<0.001*
Error	20	3.3	0.2		
Total	29	32.5			

Appendix 17: Analysis of variance table for moisture content of 10 seed lots stored for 5 months

SOURCE	DF	SS	MS	F	P
Seed lots	9	175.8	19.5	212.7	<0.001*
Error	20	1.8	0.09		
Total	29	177.6			

Appendix 18: Analysis of variance table for floury leaf spot incidence in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the long rains (March-May 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	7556.9	3778.5	3.3	
Bean lines (BL)	4	35301.7	8825.4	7.7	0.007*
Error (a)	8	9140.2	1142.5	0.5	
CSSP	3	8138.2	2712.7	1.2	0.338ns
BL x CSSP	12	21950.4	1829.2	0.8	0.658ns
Error (b)	30	69620.8	2320.7	21.9	
Time	4	121486.4	30371.6	287.1	<0.001*
BL x Time	16	3764.8	235.3	2.2	0.006*
CSSP x Time	12	2165.4	180.4	1.7	0.070ns
BL x CSSP x Time	48	5626.5	117.2	1.1	0.314ns
Error (c)	160	16928.5	105.8		
Total	299	301679.9			

NOTE: CSSP is cropping systems and spacing arrangement (Applicable to appendices 18-29)

Appendix 19: Analysis of variance table for floury leaf spot incidence in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the residual rains (June-September 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	4992.9	2496.5	10.5	
Bean lines (BL)	4	5801.8	1450.5	6.1	0.015*
Error (a)	8	1897.9	237.2	0.7	
CSSP	3	639.8	213.3	0.7	0.589ns
BL x CSSP	12	3148.1	262.3	0.8	0.648ns
Error (b)	30	9841.3	328.0	5.8	
Time	4	8008.2	2002.0	35.5	<0.001*
BL x Time	16	954.3	59.6	1.1	0.401ns
CSSP x Time	12	355.4	29.6	0.5	0.896ns
BL x CSSP x Time	48	952.7	19.9	0.4	1.000ns
Error (c)	160	9027.9	56.4		
Total	299	45620.2			

Appendix 20: Analysis of variance table for floury leaf spot severity in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the long rains (March-May 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	9.9	5.0	3.1	
Bean lines (BL)	4	154.7	38.7	24.1	<0.001*
Error (a)	8	12.9	1.6	0.8	
CSSP	3	385.1	128.4	63.2	<0.001*
BL x CSSP	12	43.0	3.6	1.8	0.102ns
Error (b)	30	60.9	2.0	5.3	
Time	4	573.9	143.5	375.7	<0.001*
BL x Time	16	91.9	5.7	15.1	<0.001*
CSSP x Time	12	234.2	19.5	51.1	<0.001*
BL x CSSP x Time	48	53.8	1.1	2.9	<0.001*
Error (c)	160	61.1	0.4		
Total	299	1681.6			

Appendix 21: Analysis of variance table for floury leaf spot severity in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the residual rains (June-September 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	2.4	1.2	1.3	
Bean lines (BL)	4	9.8	2.5	2.6	0.115ns
Error (a)	8	7.5	0.9	3.2	
CSSP	3	13.0	4.3	14.9	<0.001*
BL x CSSP	12	0.7	0.06	0.2	0.998ns
Error (b)	30	8.7	0.3	4.2	
Time	4	21.0	5.2	76.3	<0.001*
BL x Time	16	2.5	0.2	2.3	0.005*
CSSP x Time	12	6.6	0.5	8.0	<0.001*
BL x CSSP x Time	48	0.8	0.02	0.2	1.000ns
Error (c)	160	11.0	0.07		
Total	299	83.9			

Appendix 22: Analysis of variance table for yields (Kg) per hectare in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the long rains (March-May 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	128075	64038	0.5	
Bean lines (BL)	4	1129033	282258	2.2	0.166ns
Error (a)	8	1049679	131210	1.2	
CSSP	3	4900411	1633470	14.8	<0.001*
BL x CSSP	12	1049712	87476	0.8	0.654ns
Error (b)	30	3311091	110370		
Total	59	11568002			

Appendix 23: Analysis of variance table for yields (Kg) per hectare in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the residual rains (June-September 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	73643	36821	0.9	
Bean lines (BL)	4	98078	24519	0.6	0.678ns
Error (a)	8	331327	41416	1.6	
CSSP	3	3122699	1040900	39.0	<0.001*
BL x CSSP	12	401229	33436	1.3	0.296ns
Error (b)	30	800842	26695		
Total	59	4827818			

Appendix 24: Analysis of variance table for number of pods per plant in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the long rains (March-May 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	6.6	3.3	1.5	
Bean lines (BL)	4	50.2	12.6	5.5	0.02*
Error (a)	8	18.2	2.3	0.6	
CSSP	3	0.5	0.2	0.05	0.99ns
BL x CSSP	12	1.8	0.2	0.04	1.00ns
Error (b)	30	112.6	3.8		
Total	59	189.9			

Appendix 25: Analysis of variance table for number of pods per plant in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the residual rains (June-September 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	8.2	4.1	1.2	
Bean lines (BL)	4	28.7	7.2	2.1	0.167ns
Error (a)	8	26.8	3.3	5.0	
CSSP	3	0.1	0.03	0.05	0.984ns
BL x CSSP	12	5.3	0.4	0.7	0.775ns
Error (b)	30	20.1	0.7		
Total	59	89.2			

Appendix 26: Analysis of variance table for number of seeds per pod in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the long rains (March-May 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	1.9	0.99	2.2	
Bean lines (BL)	4	23.7	5.9	13.4	0.001*
Error (a)	8	3.5	0.4	1.7	
CSSP	3	0.5	0.2	0.6	0.630ns
BL x CSSP	12	1.7	0.1	0.5	0.873ns
Error (b)	30	8.0	0.3		
Total	59	39.4			

Appendix 27: Analysis of variance table number of seeds per pod in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the residual rains (June-September 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	3.9	1.9	2.8	
Bean lines (BL)	4	48.8	12.2	17.3	<0.001*
Error (a)	8	5.6	0.7	5.1	
CSSP	3	0.7	0.2	1.7	0.182ns
BL x CSSP	12	1.9	0.2	1.2	0.359ns
Error (b)	30	4.1	0.1		
Total	59	65.0			

Appendix 28: Analysis of variance table for 100 seed weight in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the long rains (March-May 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	3.6	19.3	0.9	
Bean lines (BL)	4	8020.4	2005.1	94.9	<0.001*
Error (a)	8	169.1	21.1	1.4	
CSSP	3	38.8	12.9	0.9	0.470ns
BL x CSSP	12	132.6	11.1	0.7	0.702ns
Error (b)	30	447.8	14.9		
Total	59	8847.3			

Appendix 29: Analysis of variance table for 100 seed weight in 5 bean lines planted in 4 different cropping systems and spatial arrangement during the residual rains (June-September 2000) in Taita hills

SOURCE	DF	SS	MS	F	P
Block	2	76.3	38.2	1.5	
Bean lines (BL)	4	5376.1	1344.0	52.45	<0.001*
Error (a)	8	205.0	25.6	3.6	
CSSP	3	14.1	4.7	0.7	0.580ns
BL x CSSP	12	50.6	4.2	0.6	0.827ns
Error (b)	30	211.5	7.1		
Total	59	5933.6			