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The dynamics of physical properties, seed moisture content, market economics and post harvest management of six bean varieties (Phaseolus vulgaris) grown in the sub Saharan region in Africa

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Abstract

KAT X56 varieties had the highest moisture content retention but the KKZ variety the lowest. This explained why KKZ is favoured more by famers in arid areas with less rain during fruit maturation. Managing grain moisture content is important because maximum economic return can be achieved by marketing at a certain moisture level of grain. Post-harvest management dictates that grains must be dried to certain levels to avoid development of fungal and insect problems, respiration and germination.However, over drying can also a lead to economic losses. Most farmers are aware of fungal development in moist grains but few are aware that they make less profit by over drying. Moreover, there are also bean varieties which genetically retain more water than others and hence can be safer and have more economic returns compared to others. But, this also should be matched to the rain pattern in a growing region. We compared six varieties of beans (KAT B1, KAT B9, and Kakunzu (KKZ), Rose Coco (GLP2/RCC), Kenya Tamu and KAT X56) grown in the South Eastern region of Kenya and found significant differences in dry moisture content, physical properties and grain weights. The Rose Coco and

Key words: post harvest losses; grain; moisture; bean; economic.

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INTRODUCTION

Kidney bean (*vulgaris*) is one of the five cultivated species of the genus *Phaseolus;* it includes several other cultivars which remain as one of the most important vegetable protein source for humanity. Furthermore, recent studies show that it has a role in reducing weight (Onakpoya et al., 2011). It is anthropogenic, i.e., it grows in man-made or disturbed habitats, meadows and fields. Its fruit type in generalis dry but does not split open when ripe. The fruit length is 80–200 mm.*P. vulgaris* are extremely diverse crops in terms of cultivation methods, uses, the range of environments to which they have been adapted, and morphological variability (Broughton et al., 2003). Beans are a major staple of eastern and southern Africa where yearly bean consumption is as high as or higher than in Latin America reaching up to 66 kg per person in some rural areas of Kenya. Beans are estimated to be the second most important source of dietary protein and the third most important source of calories in the region. They are regarded as “meat for the poor” (Sperling, 2001).In Kenya, beans are often combined with such energy sources as maize to make the most common food in schools called *Githeri*. The high nutritional quality of beans in terms of percentage protein is an important complement to these starchy foods. In addition the high mineral content of beans, especially of iron and zinc, are advantageous in regions where there is a high prevalence of micronutrient deficiencies such as irondeficiency anemia (Broughton et al., 2003).

At physiological maturity bean seeds usually have 50% grain moisture content but as they dry the moisture content drops to 13-15% (David, 1998). Studies in the bean grain, however, revealed that the bean moisture content does not directly affect its quality but can indirectly affect quality since grain can spoil at high moisture content. Fungi and some insects like weevils require moisture and certain temperatures to grow (Bonifacio-Maghirang et al., 1997). Hence there is need to establish the best economical grain moisture (BEGMC) level of each grain. Studies show that early harvesting of bean has the potential of increasing yields and grain quality. For example harvesting at higher moisture levels could give yield increases equivalent to more than ten years progress in plant breeding, at present rates (Banks, CSIRO). However, harvesting grain with higher moisture content can also increase the risk of lowering postharvest quality of grains. Hence, grain needs careful moisture analysis in storage management strategies by carefully balancing the weight value economics and minimizing post harvest risks so as to achieve maximum benefits from grains.

In Africa, most beanshave been harvested after they have been sun-dried on the farms. This is usually manually done. For example farmers observe when the bean pod starts to dehisce easily, and then the bean is uprooted and taken to an open space to be threshed with sticks. The moisture contentdetermination of bean has been difficult and requires more experience. For a long time farmers have been testing bean seed moisture content by biting the seed with teeth or by pinching it between fingers. The results they obtained were based on the hardness or softness of the grain (David, 1998)!This traditional method is still the main method to date used by many small scale farmers apart from the salt test. Studies show that it may not be the best practice because there can be more economical and quality benefits by harvesting the beans at higher acceptable moisture levels. The advent of digital moisture meters can be utilized to achieve these benefits and make farming a more beneficial venture.

Furthermore, physiological and morphological studies in legumes show that when bean plants in the field reach physiological maturity they become detached from the pod and nutrients are no longer transferred to the seeds. Therefore the seed now depends on constitutive defenses against biotic and abiotic stresses. The grains at this stage however rapidly lose water into the atmosphere during the hot harvest seasons in the tropical Africa which is sometimes accompanied by strong winds and low humidity. The grain moisture usually starts at 25% after detachment and starts to drop up to the lowest levels of even up to 10%. Other studies show that grain will normally be harvested at a moisture content of 18–25% (wb), but it can be substantially higher or lower depending on other factors like stage of maturity, season, weather pattern and drying facilities available. In between the two levels of moisture content farmers can identify the optimum temperature for maximum quality and economic benefits which is hereby referred to as BEGMC. However, in Africa, most beans could even be harvested at lower qualities due to ranges of maturity levels, varieties of beans, the harvesting practices, the post harvest storage methods available, technology available and the set market standards. Studies in models of harvesting at different moisture levels show the optimum harvest time can be achieved if the moisture content is about 16% followed by careful post-harvest drying to give a storable and marketable product for each bean variety. We examined the morphology, analyzed the weight and moisture content of four bean varieties grown in the Sub-Saharan region to establish which seed has the BEGMC in the prevailing markets. .

MATERIALS AND METHODS

The beans varieties used in this study were collected from farms of farmers in the South Eastern region or bought in the regional markets when dry enough for storage. The samples were kept sealed in plastic containers in order to keep them dry. We used a Grain moisture meter; model GMK-303RS (Korea). Most meters and probes rely on an inbuilt calibration between moisture and either electrical capacitance or resistance. They are calibratedagainstoven-basedmoisturedeterminations. We used whole bean grains and obtained averages of the percent grain moisture contents. The GMK-303RS is calibrated to measure bean grain of moisture content 12.5 - 19.7%. It had an accuracy of $\pm$ 0.5%.It has an operation which is by the electrical resistance method;it also has a microprocessor control and automatic temperature compensation capable of obtaining average data by just a tap of a button.

We also determined the average weight of 500 seeds using a digital weighing balance of 0.01 g accuracy in order to make comparisons of the beans and relate them with the moisture contents. The measurements were repeated to achieve an average for each variety.

The morphological inspection of the bean was also done in order to estimate the possible aesthetic market value of each bean variety together with the phenotype variations. These included physical properties like shape, lengths, widths and thickness (Olajide and Adeomowaiye, 1999).Then, the geometric mean diameter of the seeds was evaluated using the relationship given as: $D_{g\,=}$ (LWT) 1/3

Where; D_g = geometric mean diameter; L = length;W = width;T = thickness. The degree of sphericityof the various varieties of beans were determined using the equation; φ = $D_{g\,/L=}$ (LWT) 1/3L. Where; φ = degree of sphericity; D_g= geometric mean diameter; L = length; W = width; T = thicknessas described by Adejumo and Abayomi, 2012.

RESULTS

Average grain weights of the bean varieties

The average weights of 500 beans in grams are shown in Figure 1 below. The KT bean variety had the highest weight while the KAT B1 variety had the lowest. ANOVA showed that at the 0.05 level, the population means are significantly different while the Levene's and Brown-Forsythe's Test for equal variance showed at the 0.05 level, the population variations are significantly different.

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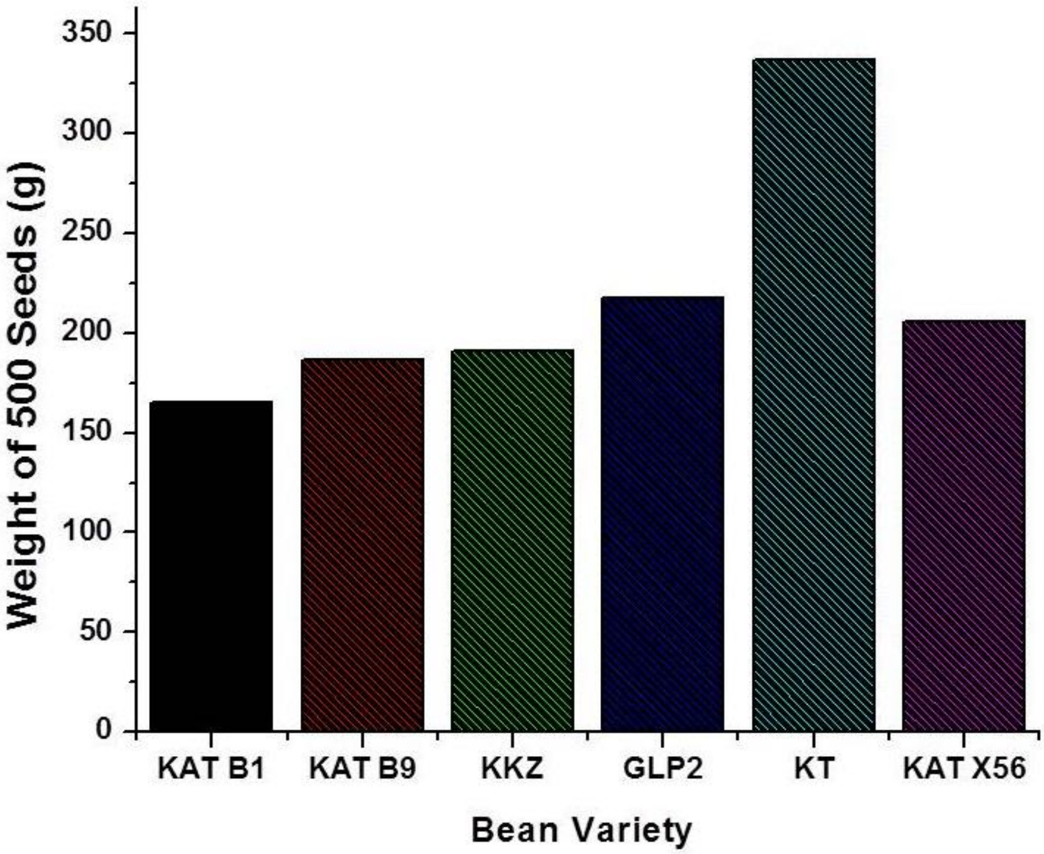

Figure 1. The average weights of 500 beans seeds from various varieties. The average weight of the bean was 217.75g. The bean variety KT had the highest value while KAT B1 had the lowest, although visual observations could not have guessed so. The expected red bean weight is usually 200 to 275 g per 500 seeds.

Morphological examination and physical properties of the bean varieties

The morphological examination of the bean grains included seed colour, seed coat texture and shape. The Kakunzu (KKZ) variety has red bright patterns while the KAT X56 variety has one red colour. However, the economics of whole farming process seemed to override aesthetic factors when it came for the farmer to choose what to plant. Although we can say that this might to some degree be also influenced by the farmer colourchoice or by the taste of the bean variety cooked or even by the market demand of the variety at a particular season. The Figure 2 below shows the external appearance of the seeds.

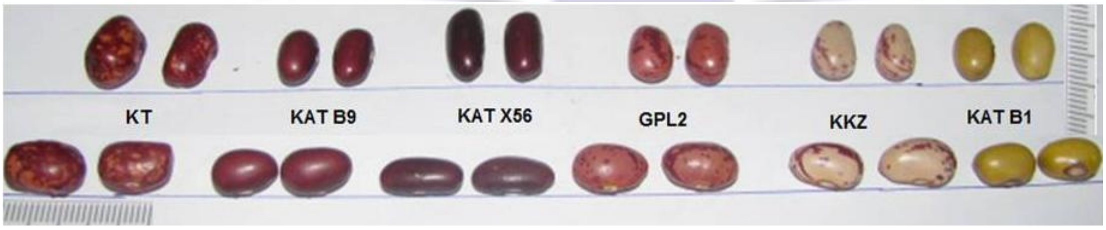

Figure 2:The morphology of the six bean varieties (Kenya Tamu (KT), KAT B9, KAT X56，Rose Coco (GLP2/RCC), Kakunzu (KKZ), and KAT B1 showing the proportional transverse (above) and longitudinal (below) appearances.

Analysis of the physical properties of the beans varieties showed the KAT X56 the highest length, but the Kenya Tamu (KT) had the greatest thickness and width. The KAT X56 had quite a low degree of sphericity (DOS) as shown in Figure 3 below. The normality Test (Shapiro-Wilk) showed all physical dimensions measurements were Normal at 0.05 level with p values between 0.08999 and 0.62100. One way ANOVA showed that at the 0.05 level, the population means are significantly

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different. The Brown-Forsythe's Test for Equal Variance showed that at the 0.05 level, the population variations are significantly different.

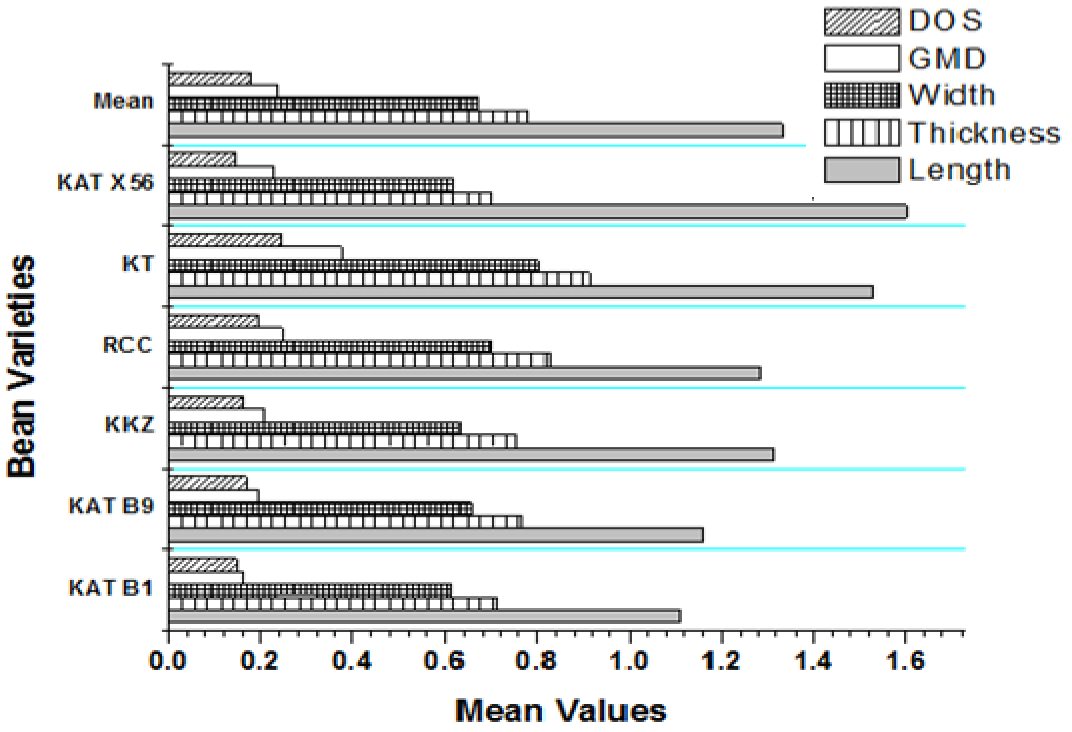

Figure 3: An analysis of the beans shapes and bean physical dimensions, showing the Degree of sphericity (DOS), Geometric mean diameter (GMD), Width, Thickness and Length.

The percentage grain moisture Content (GMC) comparisons of the varieties

Two seeds were randomly picked after thoroughly mixing the beans. They were crushed inside the grain moisture meter and five readings taken. The process was repeated for five different seeds. Ten readings were taken for each and the average recorded for analysis. The average grain moisture content of the varieties is as shown in Figure 4 below. The Rose Coco had the highest grain moisture content. In the field the bean is recommended for medium rainfall areas, it matures within 90 days. The KAT B1 also called Kipepeo is recommended for dry and semi arid areas where rainfall is less that 250mm per season. It matures within 65 days (East Africa Seed Co. Ltd, http://www.easeed.com/index.php?view=detail&id=17&option=com_joomgallery#joomimg). Field studies revealed that is also amongst the most expensive bean variety in the markets and is very sensitive to rainfall patterns. When the flowering time has little rainfall the yield is highly reduced affected and the bean grains produced are usually smaller than the normal. This kind of observation has also been observed especially in acid soils.

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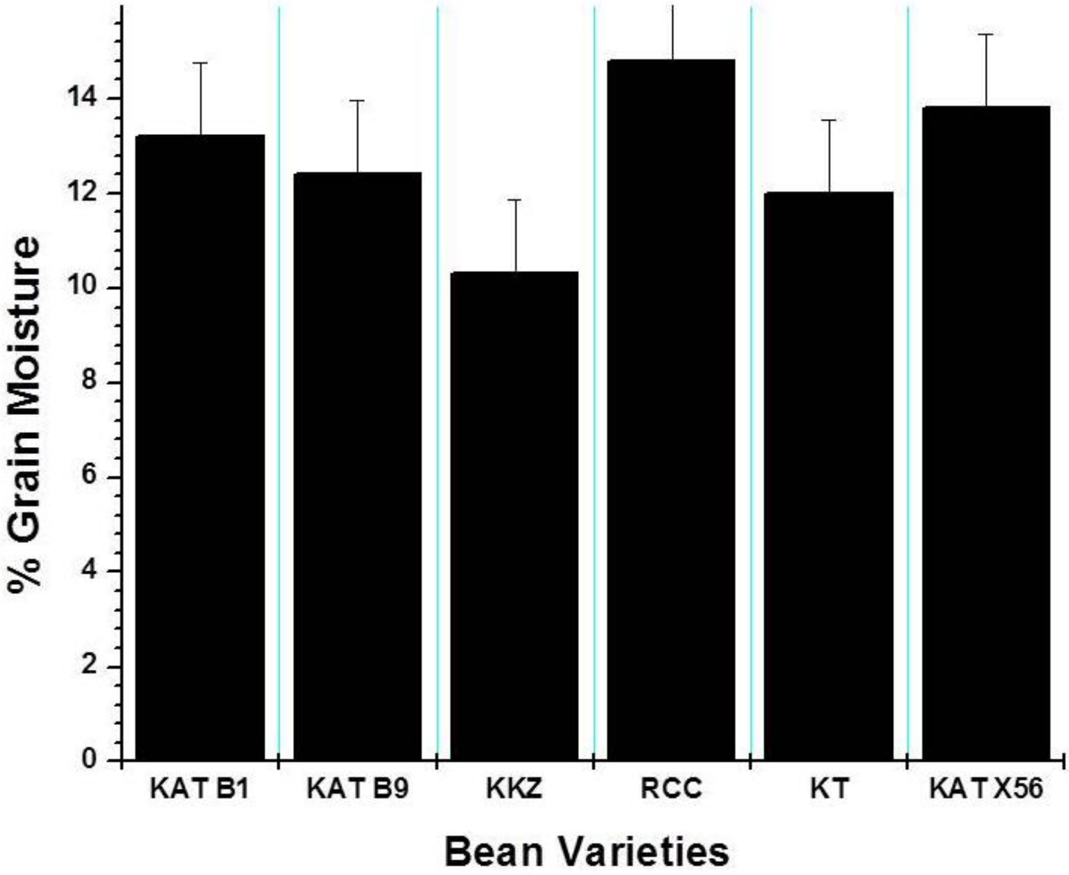

Figure 4. The percentage grain moisture content of the various bean varieties grown in the sub Saharan region in Africa, especially in the arid and semi arid South Eastern region in Kenya, namely; (KAT B1, KAT B9, Kakunzu (GPL24/KKZ), Rose Coco (GPL2/RCC), Kenya Tamu (KT) and KAT X56.

The percentage grain moisture content meansof the bean varieties were tested using Turkey mean comparison at 0.05 level and showed that means are significantly different, with a SD of 1.56 and SE of 0.6375. Both the Levene's Test and Brown-Forsythe's Test for equal variance showed that the population variations are significantly different at the 0.05 level (Origin 7.0 Statistic software, 1992-2001).

DISCUSSIONS AND CONCLUSIONS

Much poverty in the sub Saharan region in Africa is found in the rural areas, and thus success of agriculture is a central issue in ameliorating living conditions. Legumes in general are considered to be relatively profitable crops compared to other options such as cereals, and beans are no exception. In this region, beans are frequently produced on acid soils that are low in available P and/or high P-fixing capacities. Over 65–80% of these areas in Africa are thought to be critically deficient in P. Such soils are often high in Al and beans are affected by Al toxicity (Broughton et al., 2003). The effect of moisture content on the physical properties of seeds such as sunflower seed, neem nut, pumpkin seed, gram, pigeon pea, soybeans, karingda, canola seed (Desphandeet al., 1993; Dutta et al., 1988; Gupta and Das 1997; Joshi et al., 1993; Kukelko et al., 1988; Amin et al., 2004; Shepherd and Bhardwaj 1986; Suthar and Das 1996; Viswanathan et al., 1996) have beeninvestigated. For example, a decrease in bulk density with increase in moisture content was reported for soybeans, gram seed, sunflower seed, pigeon pea, neem nut and lentil seeds. (Desphande et al., 1993; Dutta et al, 1988; Gupta and Das 1997; Shepherd and Bhardwaj 1986; Viswanathan et al., 1996; Amin et al, 2004). In this study we have evaluated that farmers should invest in harvesting *Phaseolus vulgaris* (beans) at optimum moisture levels so as to maximize yield, quality and profitability of grain and on the other hand endevour to reduce moisture to avoid fungal and insect contamination. The latter is extremely important because higher grain moisture content which can increase post-harvest risks of quality loss, which would result in extra expenses.

The addition of grain moisture on beans for economic reasons

In some developed countries, scientists have come up with techniques of adding moisture to grain so as to achieve the highest economically profitable safe weight of grains. Balancing these opposing risks is not easy due to the variable nature of grains within a bulk and the inherent difficulties of measuring grain moisture accurately. However, digital flat forms are making this measurement more easy and accurate especially in Africa.They can save time and expense though monitoring dryness and accurately helps to prevent deterioration and decay caused by grain moisture whilst in storage;therefore grain processing can be made more conveniently and efficiently.It is worth noting that storage and handling methods used should minimize losses, but must also be appropriate in relation to other factors, such as economies of scale, labour cost and availability, building costs etc (Nielsen, 2002).

Correlating seed moisture content, post harvest management and marketing of beans

Moisture content is the most important factor following harvest, because it affects postharvest losses both in quantity and quality. Generally, mechanical injury occurs during harvesting when the pods are threshed, but injury can also occur any time when the seeds are processed or handled including during planting (Copeland and Saettler, 1982). Harvesting legumes at low moisture make them susceptible to mechanical injury. Depending on the operation, legume crops may experience free fall ranging from a few meters on the farm to a drop of over 50 m at certain grain terminals (Chawla *et al.*, 1998). The mechanical resistance to the impact damage of seeds, such as beans, among other mechanical and physical properties, plays a very important role in the design of harvesting and other processing machines (Baryeh, 2002). The knowledge of this basic information is necessary, because during operations, in these sets of equipment, seeds are subjected to impact loads which may cause mechanical damage. Impact damage of seeds depends on a number factors such as velocity of impact, seed structural features, seed variety, seed moisture content, stage of ripeness, fertilization level and incorrect settings of the particular working subassemblies of the machines. These parameters must be considered during harvest, transport, storage, processing and other technological stages for seeds, in which the damage occurs. Among the above factors, the seed moisture content and impact velocity (energy) are important factors influencing the damage. Khazaei, 2009 indicated that increasing the impact velocity from 5 to 12 m/s caused an increase in the mean percent of physical damage of kidney beans from 3.25 to 37.5%. With increasing the moisture content from 5 to 15%, the mean values of percentage of damaged beans decreased by 1.4 times. Therefore our study shows that the Rose Coco, KAT X56 and KAT 1 B1 which have moisture contents of 14.8%, 13.8% and 13.2% respectively are better placed to have less physical damage compared to Kakunzu, Kenya Tamu and KAT B9 which have 10.3%, 12.0% and 12.4% respectively.

Furthermore, the above information on the physical properties of the beans varieties is essential for plant breeders, engineers, machine manufacturers, food scientists, processors, and consumers. This data on physical properties can be used in designing relevant machines and equipment for harvesting, handling, transportation, separating, aeration, sizing, storing, packing and the other processing. The data have also been used for assessing the product quality as it has been done for several beans such as faba beans (Altuntas and Yildiz, 2007). Hence, the moisture-dependent physical properties of agricultural grains are important in designingpost-harvestfacilities (Zareiforoush et al, 2009).

The relationship between grain moisture content, growth and rain patterns

Growing beans in arid and semi-arid regions can be regulated by several factors. This is greatly influenced by the amount of rain during the imbibing and germination stage of the seeds and during flowering and pod maturity. Analysis of the grain moisture content and farming experience of farmers in the South Eastern region shows that the beans which had higher moisture content like, Rose Coco and KAT X56 could survive better at the germination stage compared to the seeds with less grain moisture content. But, the seeds which required less grain moisture content at ripening and drying like Kakunzu (KKZ) and KAT B9 survived more if there was little rain at that final stage of legume pod development and maturity. This information is vital for the improvement of food securitystatus in the Sub Saharan region in Africa.

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