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Overview of Green Gram (*Vigna radiata* L.) Crop, Its Economic Importance, Ecological Requirements and Production Constraints in Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MKM and EMM drafted the manuscript and all authors read and approved the final manuscript.

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ABSTRACT

Green gram (*Vigna radiata* L. Wilczek), also known as mung bean, is an important grain legume containing a high amount of digestible protein, amino acids, sugar, minerals, soluble dietary fibers, and vitamins. In Kenya, green gram production is done mainly by smallholder farmers for food and sale. The crop is mainly grown in arid and semi-arid regions and plays important role towards achieving improved human nutrition and health conditions, reducing poverty through food security and enhancing ecosystem resilience as a source of human food, animal feed, soil nitrogen and soil health. Statistics show that though average area under production has been growing since 1978, average production has been fluctuating and consumption increasing steadily upholding constant deficit which is catered for through imports. The country's average green gram yield ranges between 0.5-0.6 ton/ha compared to crop potential of 1.5 ton/ha and global average yield of 0.73

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tons/ha. The production is mainly constrained by myriad of factors such as climate change effects, pest and disease prevalence, poor agronomic practices, land degradation and soil health decline. Other challenges included: lack of structured marketing systems and poor research- extension-farmer linkages, Possession of limiting climate smart agriculture knowledge and skills. Access to credit facilities and agro processing technologies as well as narrow post-harvest loss management knowledge and skills was also identified as other key green gram production constraints more so for small scale farmers. It was however noted that the country has potential to achieve optimal greengram production and optimal production require adoption of climate smart technologies, improved flow of information, streamlined government policies, credit facilities as well as structured market system. The current work reviews green gram crop, with emphasis on its biology, economic importance, ecological requirements, current production status in Kenya, production constraints and their management.

Keywords: Green grams; production constraints; soil health; climate change; climate smart technologies.

1. INTRODUCTION

Green gram (*Vigna radiata* L.) alternatively known as mung beans, green bean, moong bean, golden gram belongs to the family leguminaccae family [1]. It is a short duration (65 - 90 days) grain legume grown on more than 6 million hectares globally in the warm areas [2,3, 4]. The crop is native to Indian subcontinent where it was domesticated as early as 1500 BC [4] but spread to other parts of the world through migration and trade routes. It is currently cultivated in many parts of the world such as United States of America, South Europe, Pakistan, Bangladesh, Thailand, Indonesia, Malaysia, China and Africa [5,6,7]. Asian continent stands out as the largest green gram's producer across the globe with India producing more than 50 % and China 19 % of total global production [8].

Green grams or mung beans undergoes epigeal germination that takes place within 4-5 days under favorable growth factors [9]. The plants possess well developed root system [5] that contains many lateral roots and root nodules [10]. Most varieties have many- branched stems, sometimes twining at the tips with young stems being purple or green and mature stems grayish yellow or brown and are normally covered with short hairs [5]. They can be divided into erect cespitose, semi trailing and trailing types with wild types being prostrate while cultivated types are more erect [10,11,12]. The crop has alternate, ovoid or broad ovoid trifoliate leaves with elliptical to ovate leaflets, 5 -18cm long and 3-15cm wide. It is self-pollinated and racemes with papillonaceous pale yellow flowers develop in the axils and leaf tips containing 4-30 flowers per pedicel. The flowers are borne in clusters of 12–15 near the top of the plant and are hermaphroditic with 5 petals and an ovary with one carpel, cavity and style [12]. Depending on the variety, the resultant fruits are hairy elongated cylindrical or flat cylindrical pods, usually 30-50 per plant [1,5]. The pods are normally 5-10cm long and 0.4-0.6 cm wide containing 10-15 septum separated seeds which are either green, yellow, brown or blue and can be cylindrical or spherical in shape [10]. Seed color and presence or absence of a rough layer usually distinguish the different types of mung beans [11]. Cultivated types are generally green or golden and can be shiny or dull depending on presence or absence of texture layer [12]. Golden gram has yellow seeds, low seed yield and pods that shatter at maturity and is often grown for forage or green manure. In contrast, green gram has bright green seeds, more prolific and ripen more uniformly, with a lower tendency for pods to shatter. Seeds are commonly green in color but sometimes yellow, brown, purplish or black depending on the type [11]. The green type is the most commonly grown in Kenya. Maturation is variety specific and most varieties takes between 60-90 days [13,14]. A mature crop can grow up to 30 inches or 76 cm tall, having multiple branches with seed pods. Most of the seed pods become brown or darker at maturity, while others remain green.

2. ECONOMIC IMPORTANCE OF GREEN GRAMS

Green gram plays an important role as a food security crop because of its nutritional quality as well as ability to survive in harsh environmental conditions such as arid and semiarid lands (ASALs) [15]. They are mainly grown for human food, in the form of boiled dry beans, stew and flour while sprouts and immature pods as a vegetable. According to [1], green grams are mainly grown for their seeds which are palatable, nutritious, digestible, non-flatulent and rich source of nutrients. The grains contain approximately 25-28% protein, 1.02-1.05% oil. 3.5-4.5% fiber, 4.5-5.5% ash and 60- 65% carbohydrates on dry weight. The grains also contain vitamin-A ((94mg), Vitamin-C (8mg), iron (7.3mg), calcium (124mg), magnesium (189mg), phosphorus (367mg) potassium (1246mg), zinc (3mg) and foliate (549mg) [1,16]. In addition, proteins from green gram are more easily digestible compared to proteins derived from other legumes and the amino acids profile of green gram is similar to that of soya bean [17]. The grains also contain significant quantities of ascorbic acid, riboflavin and cholesterol free sprouts, rich in fibre and high concentration of enzymes that facilitates digestive process [1]. Unlike other pulses, the grains, no flatulence nature and good digestibility makes it good food for babies, convalescent and elders.

Besides being a rich source of protein, green gram roots are important sources of soil nitrogen. The roots have the ability to develop nodules that help in fixing atmospheric nitrogen in the soil through nitro-bacter bacteria through biological nitrogen fixation process [18,19]. According to 18, the crop has the ability to add about 30-40kg N/ha in a single season. The vegetative parts, stocks and husks are also useful sources of leguminous fodder for livestock [2,20]. The crop also serves as an important cover and a rotation crop.

3. GREEN GRAM ECOLOGICAL REQUIREMENT

The productivity of green gram is adversely affected by several abiotic and biotic factors such as atmospheric temperature, soil moisture, soil acidity and salinity, drought, water-logging conditions, pest infestations and disease infections that which affect crop growth and development by altering physiological processes and the plant-water relationships [21,22,23,24, 25,26].

3.1 Climate Requirements

As a heat and drought tolerant annual crop that grow well in low altitude areas of between 50-1600 meters above sea level, higher elevations above 1800m asl are associated with delayed pod and seed set [5,14]. The crop has the capacity to grow and produce in areas receiving lower rainfall ranges but optimal growth and production require well distributed rainfall of between 350-700 mm per annum [13,14,27]. Higher rainfall or humidity levels either promote vegetative growth at the expense of pod formation or post-harvest loses due to delayed maturity. Higher rainfall is also associated with increased disease prevalence, increasing production cost. Adequate moisture is therefore required during flowering to early and late pod fill period. As a quantitative short- day plant, green gram crop is responsive to day length [28]. Short days result in early flowering without adequate vegetative biomass while long days promote delayed flowering. Although different varieties vary in their photoperiod response, the crop thrive most effectively at temperatures between 25°C and 35°C [2,3,14]. Significant flower shedding might occur at temperatures beyond 40°C [29,30].

3.2 Soil Requirements

Green gram crop is well adapted to grow in wide range of soils, ranging from red laterite, black cotton and sandy textured soil. It however thrives in deep, fertile, well drained loamy to sandy loam soils with pH 6.0-7.0 [31] while heavy clay soils restrict its root growth [14,38]. The crop shows limited tolerance to salinity and can show severe iron and chlorosis and other micronutrient deficiencies when grown in alkaline soils [4]

4. GREEN GRAM PRODUCTION IN KENYA

Green gram locally known as Ndengu is widely grown for food and /or sale in local and export markets [13,32,33]. It is majorly grown in arid and semiarid parts of Eastern, Coast, Western, Central, Nyanza and Rift valley with Eastern accounting for 95% of national production. Some of the major production areas in this regions are: Taita Taveta, Kilifi, Tana River, Migori, Busia, Homa Bay, Kerio valley, Elgeyo Marakwet, Baringo, West Pokot, Kitui, Makueni, Tharaka Nithi, Machakos, Meru and Embu [14,34]. Other production areas include: Tharaka nithi, Kwale, Meru, Kisumu, Lamu, Tanariver, Kirinyanga, Bungoma and Bomet [35,36]. Production within these regions is carried out by both small scale and large scale farmers [13]. Most largescale farmers establish the crop as a monocrop while small scale farmers practice either mono-cropping, intercropping, strip cropping or rotational cropping systems [11]. Intercropping is mainly carried out with grain crops such as sorghum, maize, pearl millet, cassava, citrus and finger millet while strip cropping is done with other legumes such as cowpea, pigeon peas, common beans and ground nuts. Rotations on the other hand is carried out with cereals such as sorghum, maize, pearl millet or finger millet.

Farmers within the country alternate between local and improved varieties as seed stock [34,36]. According to [14,37], local varieties are well adapted to local environment but are associated with small seeds, varied maturity time, low yields compared to improved varieties, do well in dry areas and some might have many stony seeds, which makes green gram meal difficult to eat. The common improved varieties within the country are N22 or KVR22, N26 (nylon) or KVR26, KS20 (uncle/cotton), Biashara, Karembo and Ndengu tosha (14). The grain yield potential of each variety is N22 (0.36-0.63tons/acre), N26 (0.54-0.72 tons/acre), KS20 (0.63-0.9 tons/acre), Biashara (0.72-0.81tons/acre), Karembo (0.72-0.81 tons/acre), Ndengu tosha (0.72-0.9tons/acre) [14,38]. The above improved varieties have been developed and released by KALRO in collaboration with International Centre for Tropical Agriculture (CIAT), International Institute for Tropical Agriculture (IITA) and other partners [13].

Varieties KS20 (Nylon) and N26 (Uncle) are commonly categorized as popular varieties with farmers across the country. According to [39,14], KS20 variety has a dull green color, and its pods turn brown when dry, it is tolerant to aphids, resistant to yellow mosaic virus and performs poorly in dry environments. Variety N26 on the other hand is a high yielding variety with shiny green seed color and pods turn black when dry. It possesses uniform, early maturity and does well in dry areas. Both varieties are propagated by seed. For rain fed ecosystems, planting is recommended at onset of rains to avoid crop failure or reduced yield. Depending on variety and environmental conditions, germination occur within 5-7 days. In areas with higher rainfall, it is recommended to grow green grams on raised beds [20]. For maintenance of soil health and optimal crop yields, application of basal or foliar fertilizers to supplement limiting nutrients is recommended. Because the crop is commonly grown in ASALs were pest are prevalent, integrated pest and disease management practices are recommended. Timely harvesting is also recommended to avoid field losses through shattering of the pods. Depending on prevailing environmental conditions, harvested seeds are dried for about 2-3 days, then threshed and winnowed, ready for consumption or storage. Owing to the fact that the grains are susceptible to attack by brucchids, storage in airtight containers or gunny bags in a clean ventilated room immediately after drying is recommended for short period storages and seed treatment for long term storage. General green gram value chain in Kenya normally comprises of Farm to local market -» Local market to wholesaler or miller -» Imports to wholesaler -» Wholesale market miller to retailer -» Retailer to consumer who are end user.

According to [36,40], area under green gram production and consumption rate has been rising steadily from 1978 to 2017, while production has been fluctuating. For example: Kenya recorded average production of 121.1MT of green grams in 2014 and 104.9MT in 2015, 115MT in 2016 and 107.6 in 2017 compared to average consumption of 571.9MT in 2014, 591.8MT in 2015, 603.8MT in 2016 and 659.5MT in 2017. This led to an average deficit 450.8MT in 2014, 487MT in 2015, 488.8MT in 2016 and 552.1MT in 2017. The constant production-consumption deficit growth suggests opportunities for enhancing domestic production to substitute imports. According to [13,34], the current countries average green gram yield lies within 0.5-0.6 tons/ha which fall far below the countries crop potential and compares unfavorably with the global average yields of 0.73 tons/ha. This production is not able to meet countries demand forcing the country to take up about 80% of the green grams exported by Uganda and Tanzania.

5. FACTORS AFFECTING GREEN GRAM PRODUCTION IN KENYA

Despite growing population and increased demand for climate smart crops such as green grams within the country, green gram industry growth has been constrained over the years. The low green gram industry performance and expansion can be attributed to myriad of factors such as: Pest and disease prevalence, impact of climate change, land degradation, soil health decline, limited access to good quality seeds, erratic rains leading to in adequate soil moisture, weed infestation, land tenure systems and land fragmentation, unstructured marketing systems, post-harvest losses, limited primary processing technologies and services, lack of harvesting mechanization technologies as well as poor agronomic technical knowledge [38,37,41,42, 43].

5.1 Pest and Disease Prevalence

Pest and diseases pose huge production challenge to small scale farmers because of either lack of management knowledge or capital or low farm gate prices that do not offer farmers incentive to invest in control measures [14,44]. Some of the common green gram pests within the country are: flower thrips (*Megalurothrips sjostedti*), aphids (*Aphis sp.)*, pod bugs (*Riptortus pedestri*), white flies (*Bemicia tabaci*), foliage beetles, cutworms (*Agrotis spp*), root-knot nematodes (*Meloidogyne spp*), leaf miner (*Lyriomyza spp*), pod borer (*Etiella zinckenella*), red spider mites (*Tetranychus sp*), Grass blue butterfly (*Euchrysops cnejus spiny*), African boll worm (*Helicoverpa armigera*) and bruchids [6,7,38,45]. Many of these pest attack the crop in the field while others such as bruchid cause considerable losses during storage. The pests have been documented to cause between 30-100% losses. Their management also increases cost of production for small scale poor farmers [45].

The common greengram diseases within the country include: Anthracnose (*Colletotrichum lindemuthianum*), Bacterial leaf blight (*Xanthomonas phaseoli),* Cercospora leaf spot (*Cercospora canescens*), Leaf crinkle disease, (Leaf Curl Virus), Macrophomina blight (*Macrophomina phaseolina),* Yellow mosaic (*Mungbean yellow mosaic virus*), Powdery mildew (*Erysiphe polygoni*), Root rot (*Macrophomine spp: Fusarium spp*), Leaf blight (*Rhizoctonia solani*) and rust (*Uromyces phaseoli*) [6,7,38]. The diseases can be transmitted through contaminated seeds, soil, farm implements or alternate hosts. Loses of up to 10-45% have been reported due to common blight while 80% loss has been reported due to angular leaf spot disease [14,41,46,47]. Their management also increase cost of production for small scale poor farmers leading to low return to capital [38,48].

5.2 Climate Variability and Limited Climate Smart Agriculture Knowledge and Skills

Most green gram cultivation areas are located in arid and semi-arid areas which are designated to be sensitive to climate variability and highly vulnerable to unpredictable rains, frequent droughts during cropping seasons or occasional severe floods [49,50,51]. Owing to the fact that optimal crop growth and yield require provision of all nutrients in rightful forms and amounts, water plays major role as a solvent that eventually determine germination, nutrient uptake, metabolisms, assimilation, photosynthesis and other plant biochemical processes [19]. Most green gram production areas within the country have been experiencing erratic rains and frequent drought over the past years, leading to up to 79% decrease in production in some seasons [53,54]. The constant dry spells coupled with poor water conservation technologies and limited climate smart agricultural knowledge and adoption among other factors play important role towards below optimal green gram production within the country [37].

5.3 In Adequate Access to Agricultural Information and Extension Services

Access to adequate agricultural information is vital to increased agricultural productivity [55]. According to [56,57] lack of information sources in rural areas restrain farmer’s agricultural production. Public agricultural extension officers play an important role of linking farmers with current technologies and market. The research-extension – farmer link in Kenya has however weakened over the years with the current extension: farmer ratio standing at 1800:1 compared to the FAO recommendation of 400:1 [37]. As a result, many rural smallholder farmers have limited avenues to source for useful and reliable advice and information on soil and water management, plant nutrition, seed quality, agronomic activities, value addition and marketing information leading to low uptake of technologies, poor crop production and resultant yields within the farming communities. Some farmers on the other hand who are able to produce on their own and get good harvest face the challenge of sourcing for readily available reliable markets ending up suffering either post-harvest costs and losses or low prices.

5.4 Access to Seeds

Although seed is among the most central production resources that greatly affect productivity, setting up seed production and delivery systems that encourage extensive use of quality seed throughout the marketing chain has been a challenge in Kenya [58]. In an effort to improve the countries agricultural production as part of institutional, policy, and regulatory reforms, the government of Kenya over the years have strived to come up and enact national seed policies and regulation. The policies and regulations include: The National Seed Policy, 2010, Seeds and Plant Varieties (Seeds) Regulations, 2016, Kenya Agricultural and Livestock Research Act of 2013, Crops Act no. 16 of 2013 (revised in 2016) and, Seeds and Plant Varieties Act (Cap 326) [59]). While this national seed policies, regulations and formal seed system exists within the country, a good number of farmers have been reported to rely on informal seed system as seed source [14,36,37]. This is typical for most green gram farmers within the country. According to [37,58], many of these farmers prefer growing traditional varieties because the landraces are well adapted to local conditions and have low nutrient requirements. The local varieties are however associated with low yields, long maturity periods (3 to 4 months), small seeds, prone to shattering before harvest thus high postharvest losses, susceptibility to several pest and diseases, and high percentage of stony and hard to cook grains which reduces their preference for consumption [14,37].

5.5 Access to Credit Facilities

According to research carried out by [60,61], there exists positive relationship between new technologies adoption level and availability of credit. Availability of credit ease cash constrictions enabling farmers to acquisition inputs such as improved seeds, fertilizer, pesticides with ease. Lack of collateral among rural small scale farmers in arid and semiarid areas nonetheless limit their right to benefit from credit facilities [36,57,62,63]. Furthermore, though government policies play a major role in cushioning farmers, and mung bean bill, 2020 exists, the benefits of its implementation is yet to reach many small holder farmers within the country.

5.6 Land Degradation, Access and Use of Fertilizers in Green Gram Farming

Land degradation is a major problem facing food production and sustainable development in most arid and semi-arid environments of Sub-Saharan Africa. It is defined by [64,65,66] as a complex and multifaceted phenomenon that reduces current or future capacity of either rain-fed cropland, irrigated cropland, range, pasture, forest, and woodlands to produce. The land degradation forms of importance in green gram production ecosystems include: soil erosion, deterioration of soil physical, chemical, biological or economic properties and, long-term loss of natural vegetation and biota among others [65]. According to [19], adequate availability of nutrients in rightful proportions is paramount in crop growth and productivity. The seventeen nutrients required by plants include: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), chlorine (Cl), boron (Bo) and molybdenum (Mo) [19,68]. Availability of these nutrients for crop uptake is, however, dictated by prevailing soil physical, chemical and biological properties which are often compromised in degraded lands. As a vital soil physical property, moisture which is compromised in degraded lands acts as a solvent for all chemical reactions which eventually influences nutrient sorption and uptake as well as regulating favorable rhizosphere environment. Availability of adequate moisture is however dictated by other physical attributes such as soil texture, structure, consistence, horizonation and bulk density [19] which are habitually compromised in most degraded lands. Soil pH on the other hand is a chemical property that regulates solubility and availability of all nutrients as well as soil biota population and activity [67,68]. Nutrients are soluble and available for uptake at pH range 6.0 - 7. 2. At low pH levels of less than 5.5 most macro nutrients such as Ca, Mg, P and K become unavailable for plant uptake. Majority of micronutrients will, however, be abundant, very soluble and toxic at low pH range [69]). The opposite is true when pH levels are above 7.2 because most base cations such as calcium, Magnesium and sodium become abundant, soluble and toxic while micronutrients such as Zn, Bo, Mo, and Fe become insoluble and un available [52,67]. These scenario calls for soil fertility management by supplementation of limiting nutrients through application of either farm yard manure or inorganic fertilizers [68]. This is challenging in majority of green gram growing areas because farmers grow green gram as mono-crop, season after season, without adding amendments for soil improvement [36]. This leads to nutrient mining more so for other nutrients apart from Nitrogen which is fixed through biological Nitrogen fixation leading to poor yields and return to capital. Farmers who use commercial fertilizers also commonly use straight fertilizers that don’t provide all limiting nutrients within their soils.

The current withdrawal of Kenyan government from fertilizer market and abandonment of price controls to encourage private investors have led to improved fertilizer distribution. This has also increased prices making them unaffordable to a number of smallholder farmers. Additionally, as a leguminous crop with ability to fix atmospheric nitrogen in soils, green gram farmers are not prioritized in the current subsidized fertilizer scheme operated by the government.

According to research carried by [36]), Fertilizer usage among green gram farmers is relatively low with some farmers not applying fertilizers and others using sole manure. There however exists a relationship between soil moisture availability and mineral fertilizer usage. According to myths from farmers that "fertilizers burn crops, harden soils or dries up crops prematurely". The myths can be scientifically explained by the relationship between fertilizer application timing, prevailing soil moisture levels and soil properties such as organic carbon and water holding capacity. Poor soil fertilization is associated with poor soil health leading to low production.

5.7 Poor Structured Marketing Systems for Green Grams

According to [13,70], there exists no structured marketing system for green grams in Kenya. Farmers marketing channel choices are, therefore, determined by socio-economic, institutional, and farm level factors. This acts as a setback for small scale poor famers with limited access to credit facilities, market based signals and information.

5.8 Post Harvest Losses and Management

Postharvest loss includes food loss across the food supply chain from crop harvesting until consumption [71]. The losses can be broadly categorized as spoilage, quality loss, nutritional loss, seed viability loss and commercial loss [72] attributable to lack of knowledge, inadequate technology and/or poor storage infrastructure. They account for between 20% and 40%, of total production and can go up to 80% in severe cases [73,74]. Within Kenyan green gram sector, post-harvest losses occur during operations such as threshing, winnowing, transportation, processing and storage [14]. The main cause of these postharvest losses is spoilage, due to poor and prolonged storage, spillage during transportation, breakages during threshing, destruction by rodents such as rats and attack by weevils [36]. Depending on the levels, post-harvest losses arising from poor storage, handling of produce and poor infrastructure, can make farmers to lose their crops' full value, forcing them to sell the grain throw away price [13]).

5.9 Access to Agro Processing Technologies

According to [13,75], farmers access to agro processing technologies is key to ensure profitability of a product after harvesting; something that limits crop production in most African countries. Most green gram farmers within the country either don't have access to agro processing facilities or have access to old and outdated processing methods. This exposes them to high losses leading to low enterprise profitability.

5.10 Weed Management

Weeds are one of the major problems in green gram and other crops cultivation, reducing yield through competition and interference with harvest especially during periods with favorable growing conditions [13,76]. Soil moisture availability causes weeds to multiply very fast and outgrow the main crop if intervention is not carried out on time. According to [77], weed competition can cause up to 54% total yield losses in green grams.

5.11 Land Fragmentation

Land fragmentation is a universal trait of all agricultural systems which affects farmland productivity and use of machinery. Kenyan agricultural land range from large to small (0.3-3ha) and very small land holdings of less than 0.16 ha. The very small sizes limit green gram production enterprise-mechanization and economic viability, posing crop productivity intensification challenge [13].

6. CONCLUSION AND RECOMMENDATIONS

In conclusion, green gram crop plays significant role in achieving improved human nutrition and health conditions, lowering poverty through food security and enhancing ecosystem resilience. It acts as source of human food, animal feed, soil nitrogen and soil health. It is also a wonder plant that can grow well in arid and semiarid areas. Statistics show that although area under production and consumption rates has been steadily increasing since 1978, production has been inconsistent maintaining a deficit that is catered for through imports. Some of the factors that constrain green gram production within the country are: climate change effects, pest and diseases prevalence, land degradation and soil health decline due to nutrient mining without adequate replenishment. Other factors such as poor access to agricultural information, credit facilities, poor structured marketing system as well as access to agro processing technologies play a key role in constraining green gram production within the country. Land fragmentation, poor post-harvest losses management and poor seed production and delivery systems have also as key limiting factors. It is evident that the country has potential for optimal production. Achievement of optimal production, that meets increasing demand, however, require adoption of climate smart technologies, improved flow of information to farmers, government policies as well as structured credit facilities and market system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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