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Genotypic Variation of Green Gram Accessions in the Arid and Semi-Arid Lands of Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. All the authors designed the study. Under the guidance of authors SMG, CMO and PWM, author MKM developed the protocol, undertook literature searches, carried out the research work, collected and analyzed the data and wrote the first draft of the manuscript. The other authors SMG, CMO and PWM supervised the research work, reviewed and corrected the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A study was carried out to evaluate 40 green gram accessions at Machakos Agricultural Training Centre in Machakos County. The experiment was laid out in a Randomized Complete Block Design with three replications. Data was recorded on eight quantitative agronomic parameters including plant height, number of days to maturity, number of pods per plant, 100 seeds weight and seed yield. The results indicated highly significant (P<0.05) differences in most of the traits studied among the accessions. Accession GBK-022494A had 103 pods per plant as compared to Nylon-2 with 19 pods per plant obtained during the 2011 short rains. Accession GBK-022501A had the highest (4.7 ton ha^{-1}) grain yield followed by GBK-022494A which attained 4.5 ton ha^{-1}. Cluster analysis results indicated that the accessions were divided into two main clusters. One cluster consisted of only one accession- GBK-022494A, while the other cluster had two sub-clusters. Correlation analysis results indicated that pods per plant was significantly and positively correlated

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with plant height and seed yield, while it was significantly and negatively correlated to pod length and 100 seeds weight. Seed yield was significantly and positively correlated to plant height and number of pods per plant.

Keywords: Green gram; Vigna radiate; landraces; accessions; grain yield; ASALs; Kenya.

1. INTRODUCTION

Green gram has been grown by farmers since millennia, providing nutritionally balanced food to the people of many countries in the world [1] and is said to be superior to other pulses in terms of food quality [2]. The crop is sometimes grown for hay, green manure or as a cover crop [3,4]. It is considered to be the hardiest of all pulse crops [2]. The green gram is adapted to a wide range of altitudes from 0 to 1600 meters above sea level, withstands high temperature ranging from 28°C to 30°C and yields well in low rainfall areas <650 mm per annum [5]. However, the unfavorable climatic factors, unreliable rainfall coupled with increased prevalence and severity of pests and diseases lead to increased crop losses [6].

As land pressure rises, more marginal areas in the Arid and Semi-Arid Lands (ASALs) in the world are being used for agriculture [7]. Unfortunately, most ASALs predominantly depend on rain-fed agriculture [8,9] and may not be necessarily suitable for crop production. As a result, food security has been identified as a major area of concern especially in view of the limited resources for adaptation to the ASALs.

In Kenya, agriculture remains the backbone of the economy with 80% of the Country's population living in the rural areas and deriving their livelihood from agriculture and related activities [10]. In addition, ASALs cover 80% of Kenya's total area [10]. Some of these regions receive a bimodal rainfall; short rains from October to December and long rains from March to May [11, 12]. Unfortunately, the rains received in these regions are low in amount and are unreliable [13]. Drought tolerant crops such as green gram is the most suitable for the ASALs. However, the grain yields realized by the farmers are quite low as compared to those reported from research stations [5,14,15, and 16]. For instance, the potential yield of green gram in Kenya is 1.2 - 1.5 ton ha^{-1} [5] as compared to the actual yield of 0.29 – 0.49 ton ha^{-1} which was realized between 2008 and 2012 [10].

According to [11], low and erratic rainfall coupled with low quality seeds lead to low grain yield. In order to enhance green performance in the country, there is a need to identify high yielding genotypes for specific environments. However, no study has been conducted on germplasm characterization to inform on the selection of the best genotypes for particular areas in Kenya, and hence the need for this study. The objective of this study was to evaluate green gram accessions for agronomic (growth and yield) performance in the ASALs of Kenya.

2. MATERIALS AND METHODS

2.1 Site Description

The study was carried out in Machakos Agricultural Training Centre (Machakos ATC) in Machakos County, during the 2011 short and 2012 long rain seasons. Machakos ATC is located at 1°54'S; 37°24'E and at 1,614 meters above sea level (Appendix 1). It is about 66 km South East of Nairobi. Machakos ATC lies in agro-ecological zone (AEZ) IV, with a bimodal pattern of rainfall, with a mean annual rainfall of 655 mm. The long rains fall between the months of March and May, with the peak in the month of April with an average of 273 mm while the short rains fall between the months of October and December with the peak in November with an average of 382 mm. The mean maximum temperature is 24.7°C while the mean minimum temperature is 13.7°C. The main type of soil is luvisols [12].

2.2 Planting Materials

The green gram evaluated included 40 accessions (29 accessions obtained from the National GeneBank of Kenya (GBK) and 11 landraces collected from farmers' fields (Appendix 2). Nylon-1 has been released for cultivation in the region and was included as the commercial check.

2.3 Experimental Layout and Treatments

The experiment was laid out in a randomized complete block design (RCBD) with three replications. Each block measured 9 meters (m) x 39 m and contained 40 plots (one for each of the 40 accessions) each measuring 1.5 m x 3 m and separated by one meter pathway. In every plot, four furrows spaced at 0.5 m width and 1.5 m length were made. Seeds were sown at an intra-row spacing of 0.15 m. The planting took place on 3rd December 2011 (2011 short rains) and on 28th March 2012 (2012 long rain season).

2.4 Data Collection

Five plants were randomly selected and tagged in each plot. From these plants data for various traits were collected as follows; Plant height was measured as the height [in centimeter (cm)] between the soil surface and the tip of the central shoot of mature plants. The number of days to flowering was achieved by counting the number of days from planting to the date when the first flower opened. The number of days to maturity was calculated by counting the number of days from planting to the date when seventy-five percent of the pods per plant were dried. The number of pods per plant was obtained by counting pods on the plant at maturity. The number of seeds per pod was obtained by randomly selecting 10% of the pods per plant, splitting the pods, followed by counting the number of seeds per pod, summing them up, and then dividing by the number of pods involved. Weight of 100 seeds was obtained through threshing all the pods from each plant and winnowed after which, 100 seed were randomly selected and weighed using a digital balance while seed yield was obtained by extrapolating the weight of 100 seed weight through the following process; i) the number of seeds per plant which was obtained by multiplying the number of seeds per pod by the number of pod per plant ii) The weight of one seed was obtained by dividing 100 seed weight by 100 (iii) multiply the number of seeds per plant by the weight of one seed.

2.5 Data Analysis

The data for each season was analyzed separately. The data were subjected to analysis of variance (ANOVA) using GenStat ver. 12 statistical software [16]. Statistical Package for the Social Sciences (SPSS) was used to cluster accessions based on similarities in agronomical traits. Correlation analyses were done to determine the parameters that were associated with one another and with seed yield.

3. RESULTS

Daily rainfall (mm), daily mean temperature (°C) and relative humidity (%) data collected are presented in Table 1.

3.1 Plant Height

Significant ($P<0.001$) differences were recorded among the accessions during the 2011 short and 2012 long rain seasons (Table 2). In 2011 short rain season, the accessions were found to have plant height ranging from 34.4 cm to 55 cm (Table 2). Accession GBK-022500A and N26 had the highest (55 cm each) plant height but they were not significantly different from GBK-022506 (53.7 cm) and Ndengu-3 (53.0 cm). Accession GBK-017437A was the shortest (34.4 cm) although it was not significantly different from GBK-022499A (37 cm) and Nylon-2 (38.3 cm). In the 2012 long rain season, the accessions' plant height ranged from 39.9 cm to 74.3 cm (Table 2). Accession GBK-022497A had the highest (74.3 cm) plant height although it was not significantly different from GBK-022492A which was 73.9 cm tall and GBK-022499A (73.1 cm). Accession GBK-017437A had the shortest (39.9 cm) plant height and was not significantly different from Ndengu-1 (44.9 cm) and Olayo which was 51.8 cm tall.

3.2 Number of Days to Flowering

The accessions had significant ($P=0.031$) effect on the number of days to flowering during the 2012 long rain season (Table 2). The number of days to flowering ranged from 38 to 42 days. Accessions Uncle-1, Cotton, Uncle-2 and GBK-017437A were the earliest (38 days) to flower although they were not significantly different from Ndengu-1, Olayo and GBK-022491A which took 39 days to flower. Accessions GBK-022493A and N26 were the latest (42 days) to flower although they were not significantly different from Ndengu-3, GBK-022492A and GBK-022500A which took 41 days to flower (Table 2). The number of days to flowering was not significantly influenced by the accessions during the 2011 short rain season (Table 2).

3.3 Number of Days to Maturity

The number of days to maturity was not significantly influenced by the accessions during both 2011 short and 2012 long rain seasons (Table 2).

Table 1. Weather summary during the growing period of green gram in 2011 short and 2012 long rains-Machakos ATC

2011 short rains (only months which are Indicated)				
Month	**Week of the year**	**Rainfall/week (mm)**	**Mean daily tem**	**RH %**
Nov. 2011	48	27.9	19.5	78.9
Dec. 2011	49	-	19.9	63.2
	50	-	20.2	61.3
	51	0.4	20.8	61.1
	52	14.1	20.8	67.6
Jan.	1	-	20.0	53.4
2012	2	-	20.8	59.4
	3	-	21.3	50.1
	4	-	21.1	48.5
	5	-	21.2	45.8
Feb.	6	-	21.1	49.6
	7	3	22.1	53.9
	8	1.6	22.4	51.4
	9	-	22.4	50.3
Mean			21.0	56.8

2012 long rains (only months which are Indicated)				
Month/ 2012	**Week of the year**	**Rainfall/week (mm)**	**Mean daily temp.**	**RH %**
March 2012	13	-	22.4	47.6
April 2012	14	59.5	20.7	68.8
	15	22.6	21.1	68.6
	16	65.6	20.7	64.1
	17	56	20.2	74.4
May	18	186.7	20.5	72.5
	19	-	19.5	71.3
	20	2.8	19.6	69.4
	21	6.2	19.0	71.7
	22	-	18.9	67.9
June	23	23.5	19.0	69.7
	24	-	17.9	71.7
	25	13.4	18.3	69.1
	26	-	16.4	71.7
July	27	-	17.0	71.5
	28	-	16.2	71.6
	29	0.2	17.1	69.4
Mean			19.1	68.9

Mean temperature for the 2 seasons=20.1^{o}C, Mean RH for the 2 seasons=62.9

3.4 Pod Length

Significant (P<0.001) differences were recorded among the accessions' pod length during the 2011 short and 2012 long rain season (Table 2). In 2011 short rain season, pod length of the green gram accessions ranged from 8.0 to 10.3 cm (Table 2). Accession Uncle-2 had the longest (10.3 cm) pod length but was not significantly different from Uncle-1 with a length of 10.1 cm and Ndengu-4 which had a pod length of 9.5 cm. Accessions GBK-022505A, had the shortest (8.0 cm) pod length though they were not significantly different from GBK-022531A (8.1 cm) and GBK-022537A each with a pod length of 8.3 cm. In 2012 long rain season, accession Uncle-1 had the longest (10.8 cm) pod length although it was not significantly different from Uncle-2 and GBK-022539A which were 10 cm long each.

Table 2. Means of various agronomic traits recorded on 35 green gram genotypes at Machakos ATC during the 2011 short and 2012 long rain seasons

	Plant height		Days to flowering		Days to maturity		Pod length	
Accessions	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Cotton	43.3	55.8	48.7	38.2	77.7	89.3	9.3	9.6
GBK-017437A	34.4	39.9	45.7	38.9	75.0	88.2	8.5	8.9
GBK-022491A	48.7	63.0	49.3	39.1	78.0	91.5	8.6	9.1
GBK-022492A	44.3	73.9	48.3	41.7	75.3	93.3	8.0	8.5
GBK-022493A	43.9	52.7	50.7	42.1	77.5	90.8	8.2	8.6
GBK-022494A	46.0	58.7	48.7	40.6	77.5	92.4	9.7	8.1
GBK-022495A	45.1	65.0	49.3	41.5	78	90.7	8.3	8.6
GBK-022497A	52.0	74.3	48.7	40.4	76.3	93.8	8.9	9.0
GBK-022498A	51.3	58.9	47.7	41.3	76.7	91.3	8.6	8.9
GBK-022499A	37.0	73.1	50.3	41.2	78.3	92.4	8.6	9.7
GBK-022500A	55.0	66.7	48.0	41.5	76.3	94.4	8.3	8.3
GBK-022501A	45.3	59.3	49.0	40.1	77.7	91.2	8.7	8.3
GBK-022502A	44.3	62.4	47.0	41.0	77.0	89.5	8.4	8.6
GBK-022504A	50.0	55.5	48.7	40.7	76.7	92.1	8.7	8.7
GBK-022505A	44.7	55.3	49.3	41.0	77.0	92.1	8.0	8.4
GBK-022506A	53.7	63.9	47.7	40.3	76.7	90.6	8.7	8.3
GBK-022507A	49.7	55.8	48.0	39.9	77.7	91.6	8.5	8.5
GBK-022508A	39.1	59.5	49.7	40.5	77.5	92.7	8.3	8.8
GBK-022509A	45.7	63.7	47.0	41.1	77.0	90.3	8.4	8.4
GBK-022531A	43.7	61.9	48.0	40.5	77.7	91.1	8.1	9.7
GBK-022532A	45.7	52.1	49.0	41.2	78.3	89.3	8.4	8.4
GBK-022534A	49.3	55.9	47.3	40.1	76.3	88.9	8.2	7.8
GBK-022536A	44.0	57.5	48.7	40.6	79.0	91.0	8.4	9.3
GBK-022537A	42.0	68.6	48.3	40.8	78.0	94.1	8.3	8.8
GBK-022539A	46.0	71.5	48.0	41.1	76.7	91.4	8.8	10.0
N26	55.0	60.9	50.3	42.0	78.7	84.2	8.6	9.2
Ndengu-1	45.7	44.9	47.3	39.1	75.3	89.3	9.0	9.3
Ndengu-2	39.3	53.3	52.3	39.8	78.3	89.3	8.4	9.5
Ndengu-3	53.0	59.9	52.7	41.9	81.1	92.9	8.8	9.3
Ndengu-4	50.3	66.6	47.7	39.8	76.7	90.4	9.5	9.4
Nylon-1	47.0	67.3	49.0	40.8	77.7	93.7	8.4	8.4
Nylon-2	38.3	63.1	49.0	39.9	77.0	94.6	8.6	9.5
Olayo	38.7	51.8	48.3	39.1	76.7	92.2	8.0	8.7
Uncle-1	39.0	56.4	49.3	38.2	78.7	92.0	10.1	10.8
Uncle-2	46.3	60.1	47.7	38.7	77.3	91.1	10.3	10.0
Mean	45.6	60.3	48.7	40.4	77.4	91.3	8.7	9.0
Minimum	34.4	39.9	45.7	38.2	75.0	84.2	8.0	7.8
Maximum	55.0	74.3	52.7	42.1	81.1	94.8	10.3	10.8
LSD (P≤0.05)	9.1	13.1	3.8	2.3	2.8	4.8	0.9	0.8
P value	<.001	<.001	0.373	0.031	0.157	0.11	<.001	<.001
CV%	11.9	4.9	0.8	1.4	2.4	2.7	0.7	1.6

Accession GBK-022534A had the shortest (7.8 cm) pod length but was not significantly different from GBK-022494A (8.1 cm) and GBK-022501A which had a pod length of 8.3 cm each.

3.5 Number of Pods per Plant

Significant *P*<0.001) differences were recorded among the accessions' number of pods per plant during the 2011 short and 2012 long rain seasons (Table 3). In the 2011 short rain season, the average number of pods per plant ranged from 10 to 46 pods (Table 3). Accession GBK-022501A had the highest (46) number of pods per plant and was significantly different from GBK-022494A (45 pods) while GBK-022508A had the least (10) number of pods per plant. Significant (*P*=0.036) differences were observed among the accessions (Table 3). During the 2012 long rain season, GBK-022508A produced 52 pods per plant while Ndengu-1, GBK-022491A and Uncle-2 had the least (25) number of pods per plant.

3.6 Number of Seeds per Pod

Significant (*P*<0.001) differences were recorded among the accessions' number of seeds per pod during the 2011 short and 2012 long rain seasons (Table 3). During the 2011 short rain season, the average number of seeds per pod ranged from 8 to 12 seeds per pod (Table 3). Accessions N26 and Ndengu-3 had the highest (12) number of seeds per pod Nylon with the least (8) number of seeds per pod. In 2012 long rain season, the average number of seeds per pod ranged from 7 to 12 seeds per pod (Table 3). Accessions GBK-022198A, N26 & Ndengu-2 had the highest (12) number of seeds per pod while Nylon-2 had the least (7) number of seeds per pod.

3.7 Weight of 100 Seeds

Significant (*P*=0.006 and *P*<0.001) differences were recorded among the accessions' 100 seeds weight during the 2011 short rain and 2012 long rain seasons respectively (Table 3). In 2011 short rain season, the average 100 seeds weight ranged from 3.2 to 7.9 g (Table 3). Accession GBK-022501A had the highest (7.9 g) 100 seeds weight while GBK-022508A had the least (3.2 g) 100 seeds weight. During the 2012 rain season, the accessions had an average 100 seeds weight which ranged from 3.4 to 10.7 g (Table 3). Accession, Nylon-2 had the highest (10.7 g) 100 seeds weight and while Ndungu-3 had the least (3.4 g) 100 seeds weight.

3.8 Seed Yield

Significant (*P*=0.003) differences were recorded among the accessions' seed yield during the 2011 short and long rain seasons (Table 3). In 2011 short rain season, the accessions' seed yield ranged from 10.1 to 46.9 g (Table 3). Accession GBK-022501A had the highest (46.9 g) while Ndengu-2 had the least (10.1 g) seed yield. Seed yield was not influenced significantly by accessions during the 2012 long rain season (Table 3).

3.9 Cluster Analysis

The 35 accessions were separated into two main clusters (Figure 1). One cluster consisted of only one accession- GBK-022494A, which recorded the highest number of pods per plant, while the other cluster had two sub-clusters each comprising two sub-sub-clusters. There were two minor clusters; one of which consisted of 3 accessions; GBK-022506A, N26 and GBK-022498A while the other minor cluster consisted of 5 accessions; Cotton, Ndengu-2, GBK-017437A, Uncle-1 and Ndengu-1.

3.10 Correlation among Agronomic Traits Recorded at Machakos ATC

Results of correlation analysis were given in Table 4. The results indicated the number of days to flowering was found to be significantly and positively correlated to the number of days to maturity (0.393). It was significantly and negatively correlated to pod girth (-0.436). Plant height was significantly and positively correlated with the number of pods per plant (0.463) and seed yield (0.449). Number of pods per plant was significantly and positively correlated with plant height (0.463), and seed yield (0.831), while it was significantly and negatively correlated to pod length (-0.424), pod girth (-0.615) and 100 seeds weight (-0.486). Number of seeds per pod was significantly and negatively correlated with pod girth (-0.495) and 100 seed weight (-0.531). Pod length was found to be significantly and positively correlated to pod girth (0.623) and 100 seed weight (0.439), while it was significantly and negatively correlated to the number of seeds per pod (-0.424). Number of days to maturity was significantly and positively correlated to days to flowering (0.393). Hundred (100) seeds weight

Table 3. Means of various agronomic traits recorded on 35 green gram genotypes at Machakos ATC during the 2011 short and 2012 long rain seasons

	Pods per plant		Seeds per pod		100 seeds weight		Seed yield	
Accessions	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Cotton	25.3	27.6	11.7	11.9	5. 0	6.9	15. 0	23. 0
GBK-017437A	27. 0	32.6	9. 0	10.3	4.8	6.1	12.4	21.1
GBK-022491A	44.2	25.4	10.3	10.4	5.1	6. 0	25. 0	16.7
GBK-022492A	33. 0	45.6	9.7	11.7	4.1	5.3	13. 0	27.3
GBK-022493A	37. 0	35. 0	10. 0	10.1	5.5	5.9	20.9	22.2
GBK-022494A	102.5	43.3	10. 0	11. 0	4.4	5.4	45.7	25.7
GBK-022495A	44.3	37.8	10.3	10.6	5.1	5.4	24.5	21.3
GBK-022497A	43. 0	43.4	11. 0	10.7	4.8	6.1	23.1	29. 0
GBK-022498A	61. 0	49.7	10.7	12.2	5. 0	4.9	33.1	28.8
GBK-022499A	29.7	45.8	10. 0	10.4	4.2	5.6	15.2	26.9
GBK-022500A	48.7	50.5	10.3	10.1	4.8	5.4	23.3	27.8
GBK-022501A	50.8	37.7	11.7	11.1	7.9	5.7	46.9	23.8
GBK-022502A	43. 0	36.5	9.8	10.8	5. 0	5.2	19.9	21.1
GBK-022504A	45.3	38.7	10.7	11.2	4.8	5.5	23. 0	25.2
GBK-022505A	33.7	32.6	10.4	10.8	4.6	5.1	16.1	17.6
GBK-022506A	45.3	53.2	10.7	11.3	5.1	5.1	26.1	32.7
GBK-022507A	43.7	50.4	10.3	10.4	4.5	5.2	20.4	27.6
GBK-022508A	32.5	52.9	9. 0	10.7	3.2	5.6	10.5	31.6
GBK-022509A	49. 0	38.7	10.3	10.2	5.2	5.2	27.6	21.6
GBK-022531A	46.3	46.8	9.5	10.7	4.9	5.7	21.2	29.2
GBK-022532A	40.7	31.8	10. 0	10.9	4.2	5.3	17.3	18.2
GBK-022534A	43. 0	40. 0	10.7	9.9	5. 0	5. 0	22.8	21.1
GBK-022536A	43. 0	42.3	9.7	10.7	4.1	6.1	18. 0	27.2
GBK-022537A	28. 0	61.2	10. 0	11.3	4.5	4.7	12.9	33.1
GBK-022539A	42. 0	42.2	10.7	11. 0	5.1	5.2	24.1	24. 0
N26	58.3	34.3	12.3	12.1	4.3	4.9	31.7	20.3
Ndengu-1	25.3	25. 0	10.7	11.7	5.7	5.4	15.3	16.2
Ndengu-2	23.7	27.6	10.3	12. 0	3.9	6.3	10.1	22.4
Ndengu-3	44.7	40.3	12.3	11.9	4.8	3.4	26.7	16.8
Ndengu-4	34. 0	30.8	11. 0	10.7	5.9	5.7	21.9	18.8

	Pods per plant		**Seeds per pod**		**100 seeds weight**		**Seed yield**	
Accessions	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**	**2011**	**2012**
Nylon-1	45.7	35. 0	9.3	11.7	6.6	5.3	28.1	21.6
Nylon-2	18.7	29.1	8.3	7.5	7.5	10.7	11.7	23. 0
Olayo	37.7	44.7	11.3	11. 0	4.7	6. 0	19. 0	28.6
Uncle-1	23.0	27.4	10.7	9.7	5.9	7.7	16.7	21.6
Uncle-2	39.3	25.6	10.7	9.9	7.7	6.5	31.9	16.4
Mean	40.9	38.9	10.4	10.8	5.1	5.7	22. 0	23.7
Minimum	18.7	25. 0	8.2	7.5	3.2	3.4	10.1	16.2
Maximum	102.5	61.2	12.3	12.2	7.9	10.7	46.9	33.1
LSD (P≤0.05)	23.6	19.9	1.3	1.1	2.0	0.9	16.4	13.3
P value	.001	<.036	<.001	<.001	0.006	<.001	0.003	0.471
CV%	35.3	10.4	0.7	3.2	3.4	7.8	13.1	15.3

was significantly and positively correlated to pod length (0.439) and pod girth (0.678), while it was significantly and negatively correlated to the number of pods per plant (-0.486) and the number of seeds per pod (-0.531). Seed yield was significantly and positively correlated to plant height (0.449) and the number of pods per plant (0.831) while it was significantly and negatively correlated to pod girth (-0.459).

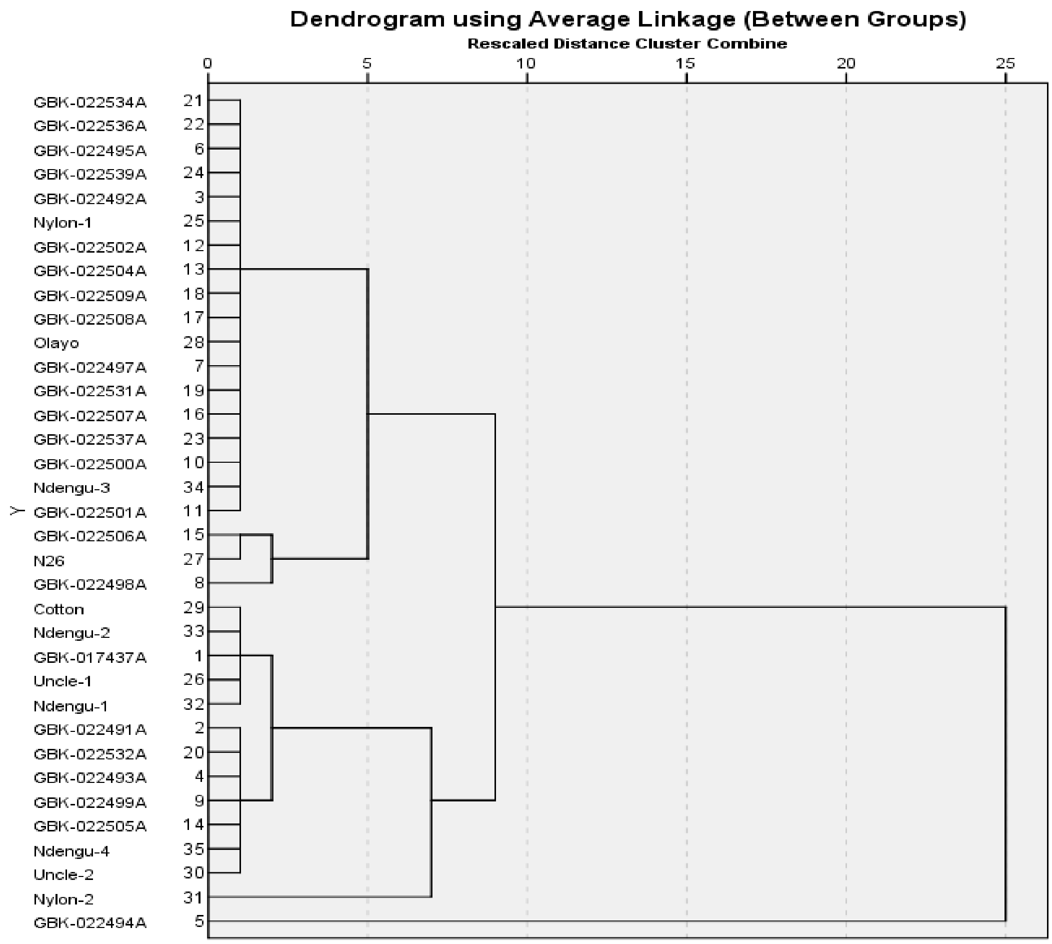

Fig. 1. Cluster diagram showing the relationship among green gram accessions evaluated at Machakos ATC

Table 4. Correlation coefficients among agronomic traits recorded on green gram accessions at Machakos ATC

	DF	PH	PP	PS	PL	DM	SW	SY
No of days to flowering								
Plant height	.323							
No of pods per plant	.181	.463**						
No of seeds per pod	.293	.216	.231					
Pod length	-.208	-.059	-.424*	.038				
Number of days to maturity	.393*	.246	.269	-.223	.013			
100 seeds weight	-.325	-.188	-.486**	-.531**	.439**	.060		
Seed Yield	.062	.449**	.831**	.280	-.166	.219	-.081	

DF=No. of days to flowering, PH=Plant height, PP= No. of pods per plant, SP=No. of seeds per pod, PL=Pod length, DM=No. of days to maturity' SW=100 seeds weight, SY=Seed yield

4. DISCUSSION

Plant height is an important agronomic trait that directly affects the yield of a crop. If the plant does not lodge, it is essential to increase the height with an objective of increasing yield [17]. The shoot lengths of green gram accessions in the study ranged from 34.4 cm to 74.3 cm, an indicator of considerable variability among the genotypes. Since the treatments for all the accessions were the same, the difference in plant height could be attributed to the genetic make-up [18]. These results were comparable to; [15,19,20,21 and 14] who reported plant height ranging from 29 cm to 58 cm; 45 cm – 54 cm; 39.8 cm - 56.3 cm; and 38 cm – 60 cm respectively. The results were, however, in disagreement with [18] who found a plant of between 65.0 cm and 80.1 cm tall.

The green gram accessions took between 42 days and 47 days from emergence to flowering. These results were comparable to those of other scientists working on *Vigna radiata;* [22] while evaluating mungbean genotypes under rainfed conditions at Chakwal who reported 45 - 47 days to flowering; [19] working on Indian *Vigna* genotypes under arid conditions reported 29 – 44 days to 50% flowering. Further, [23] reported that it took the mungbean plants 29 - 65 days to flower.

Research results indicate that the crops which take longer to mature, normally attain better yields as compared to those which take fewer days [24,25]. The accessions took a range of 75 - 94 days to mature. The accessions varied in the number of days to maturity. This is because, a plant which takes longer time to mature, grows bigger in size and can hold heavier produce. According to [22,26] variation of in a parameter among different accessions can be attributed to their inherent genes. Other researchers reported a similar range of the number of days to maturity [19] who reported 82 - 89 days to mature. The results were however not comparable to those of other researchers, for example [20,22], who reported 53 - 62 days and 47 – 50 days to maturity respectively.

The pod length of the accessions were found to range from 7.8 cm to 10.8 cm, a finding which was similar to those reported by other researchers such as [19,20,18 and 27] who reported a pod length range of 6 cm – 10 cm, 6.9 cm – 9.9 cm; and 7.1 cm – 10.3 cm and 6.4 cm – 9.1 cm respectively. The differences among the tested accessions could be attributed to their different genetic backgrounds [27].

The number of pods of the accessions per plant ranged from 18 - 102. The range was quite varied as compared to those from other studies, for instance [19,28,20,18 and 29] who reported the number of pods per plant ranging from; 9 to 23, 36 to 46, 19 to 49, 14 to 21 and from 33 to 59 respectively.

The accessions recorded the number of seeds per pod ranging from 7 seeds to 12 seeds. Other Researchers reported comparable results, for instance [15,19,18,22 and 29] who reported ranges of 8 – 12, 9 – 14, 9 – 10, 11 – 12 and 8 - 10 seeds per pod respectively. According to [27,23]; the varied number of seeds per pod among the different accessions could be attributed to the inherent genes.

The 100 seed weight was 3.2 g – 10.7 g. Comparable results were reported by; [28] 3.5 - 7.6 g; [28] 5.0 – 9.1 g; [30] 3.5 – 7.0 g and [27] 3.9 - 6.2 g. According to [27, 23], the varied 100 seed weight among the different accessions could be attributed to the inherent genes.

The green gram accessions had a seed yield range of between 10.1 and 46.9 g per plant. Seed yields in this study were higher than those reported by other researchers, for instance; [14] 7.0 – 10.8 g, [15,31] 4.1 – 9.0 g; and [27] 10.9 - 19.7 g. According to [27,23], the varied plant seed weight among the different accessions could be attributed to the inherent genes. Hence the accessions' inherent genes performed better under the conditions of the 2012 long rain season.

Cluster analysis categorized the accessions into groups which are more similar to each implying that the accessions which are clustered together may be containing similar germplasm. This could explain why the measured parameters of some accessions had different values in the different sites hence clustered in different groups. This agreed with [32] and [33] who indicated that different crops perform differently in different agro-ecological zones (AEZs). Therefore for better performance, the accessions should be grown in areas where they are best suited.

Significant and positive correlation between any two growth parameters implies that improving one parameter leads to the increased growth of the other parameter. According to [34] parameters which are significantly and positively correlated can be improved concurrently in a breeding programme.

However, significant and negative correlation implies that when one growth parameter is improved, the other one decreases. Improving plant height led to an increased number of pods per plant, pod length and seed yield while the improving plant height led to a decrease in 100 seeds weight. This is because, the higher the plant height combined with a higher number of leaves the more the leaf area index, the more the surface area for photosynthesis, the more the number of pods per plant, the higher the number of seeds per plant leading to higher seed yield. Therefore when selecting for high yielding green gram accessions, plant height parameter would be a good trait.

Improving the number of pods per plant will lead to increased seed yield [17], however, improved number of pods per plant will lead to decreased 100 seeds weight; improving the number of seeds per pod will lead to increased seed yield and decreased 100 seeds weight. Improvement in the pod length leads to an increase in 100 seeds weight and seed yield and that improving 100 seeds weight leads to increased pod length. However, Improving number of leaves per plant, number of days to flowering, plant height, number of seeds per pod, and number of pods per plant lead to decreased 100 seeds weight, improving the number of leaves per plant, plant height, and number of pods per plant, number of seeds per pod lead to increased seed yield.

5. CONCLUSION

Accessions were found to significantly vary in plant height, number of seed per pod, pod length, pod girth and 100 seeds weight during the 2011 short and 2012 long rain seasons. Seed yield varied among the accession during the 2011 short rain season while the number of days to flowering significantly varied among accessions during the 2012 long rain season. Seed yield was found to be significantly and positively correlated to the number of pods per plant, plant height and number of leaves per plant. Hence improving any one or all the three parameters would result in an increase in seed yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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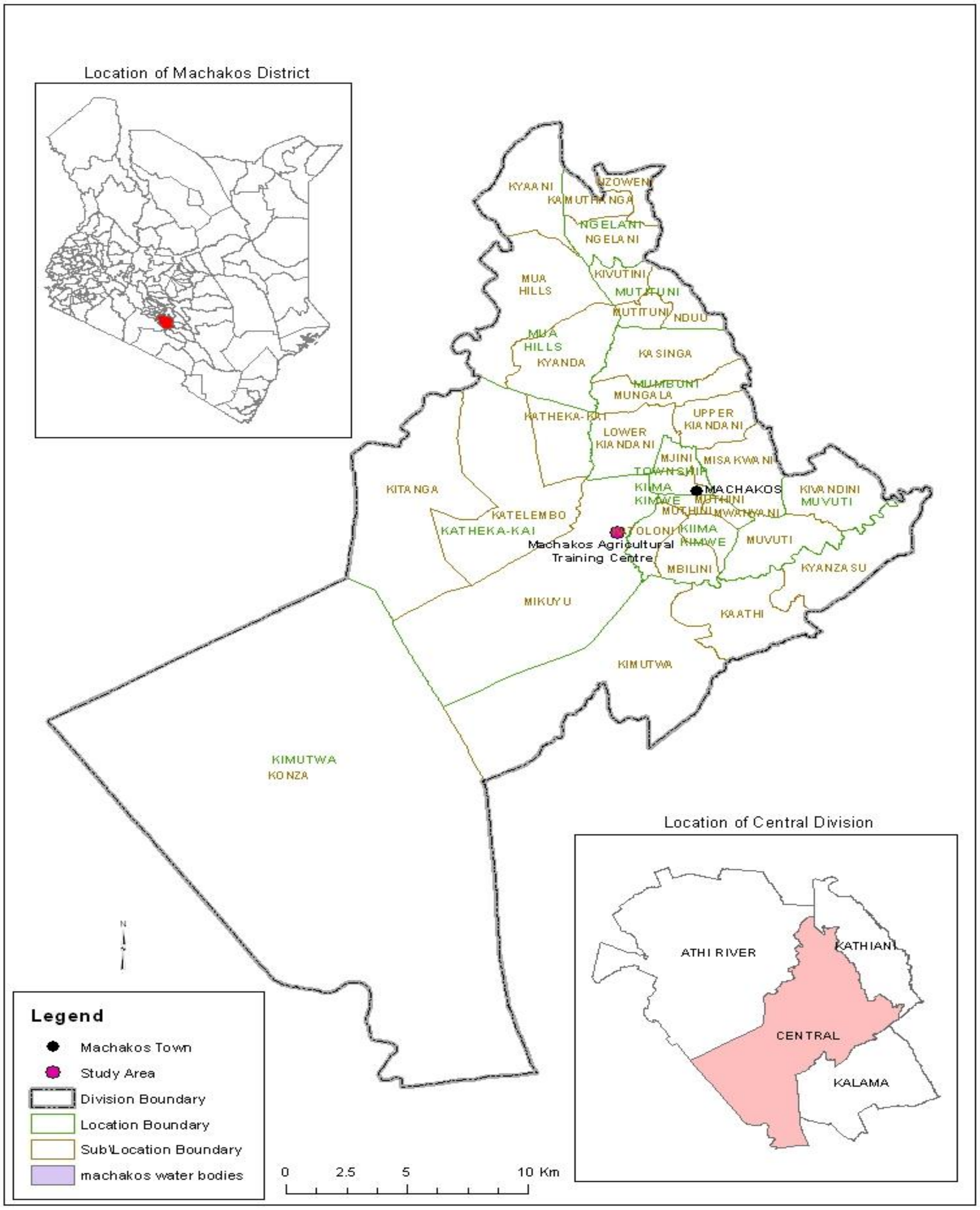
Appendix 1. Location of Machakos agricultural training centre



Appendix 2. Green gram accessions and their source

S/No	Accessions	Source
1	GBK-017437A	National Gene Bank of Kenya
2	GBK-017438A	National Gene Bank of Kenya
3	GBK-017456A	National Gene Bank of Kenya
4	GBK-018629A	National Gene Bank of Kenya
5	GBK-018633A	National Gene Bank of Kenya
6	GBK-018635A	National Gene Bank of Kenya
7	GBK-022491A	National Gene Bank of Kenya
8	GBK-022492A	National Gene Bank of Kenya
9	GBK-022493A	National Gene Bank of Kenya
10	GBK-022494A	National Gene Bank of Kenya
11	GBK-022495A	National Gene Bank of Kenya
12	GBK-022497A	National Gene Bank of Kenya
13	GBK-022498A	National Gene Bank of Kenya
14	GBK-022499A	National Gene Bank of Kenya
15	GBK-022500A	National Gene Bank of Kenya
16	GBK-022501A	National Gene Bank of Kenya
17	GBK-022502A	National Gene Bank of Kenya
18	GBK-022504A	National Gene Bank of Kenya
19	GBK-022505A	National Gene Bank of Kenya
20	GBK-022506A	National Gene Bank of Kenya
21	GBK-022507A	National Gene Bank of Kenya
22	GBK-022508A	National Gene Bank of Kenya
23	GBK-022509A	National Gene Bank of Kenya
24	GBK-022531A	National Gene Bank of Kenya
25	GBK-022532A	National Gene Bank of Kenya
26	GBK-022534A	National Gene Bank of Kenya
27	GBK-022536A	National Gene Bank of Kenya
28	GBK-022537A	National Gene Bank of Kenya
29	GBK-022539A	National Gene Bank of Kenya
30	Nylon-1	Kalama in Machakos county
31	Uncle-1	Kalama in Machakos county
32	N26	Central Div. Machakos county
33	Olayo	Homabay Sub- county
34	Cotton	Makueni County
35	Uncle-2	Machakos county
36	Nylon-2	Machakos county
37	Ndengu-1	Wote in Makueni county
38	Ndengu-2	Loitokitok
39	Ndengu-3	Makueni county
40	Ndengu-4	Loitokitok

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