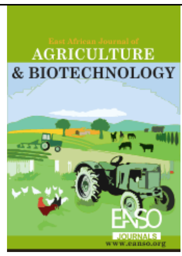

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Original Article

Effect of Shade Intensities on Growth, Biomass and Grain Yield of Green Grams (Vigna radiata) and Maize (Zea mays) in Kitui County

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Maize, Green Grams, Shade Intensities, Kitui, ASAL, Yield.

ABSTRACT

Maize and green grams are important food security crops grown and consumed in the arid and semi-arid regions of Kenya. High temperatures and low soil moisture lead to yield reduction. A two-season study was conducted to investigate the effect of different shade intensities (0 %, 50 % and 70 %) on green gram and maize growth, biomass and grain yield in Kitui County (1.4° S, 37.9° E). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications at the South Eastern Kenya University (SEKU) farm. Results showed that maize had significantly ($p<0.05$) higher plant height, Ear height, cob weight, total biomass and grain yield per hectare in 50%, followed by 70% and lowest in 0%. Green gram plants had significantly ($p<0.05$) higher number of pods, seeds per pod, total above-ground biomass and grain yield per hectare 50 % (1759 kg/Ha), 70 % (1553 kg/Ha) and lowest in 0% (478 kg/Ha). The plants grown under 50% shade intensity had higher grain and biomass yield for both green grams and maize compared to those under 70% and 0% shade intensity, which may be attributed to adequate moisture due to reduced evapotranspiration. The study demonstrated that the cost-benefit analysis of shade intensity on green grams farming system yield and break-even price was best at 50% shade intensity. The study demonstrated that the cost-benefit analysis of shade intensity in maize farming systems is not significant. To improve grain and biomass yield of both green grams and maize for food and nutrition security, study recommends the use of 50% intensity in growing green grams in ASALs due to benefits including soil moisture conservation, improved plant growth, yield, economic efficiency and cost-benefit ratios.

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INTRODUCTION

Maize is a key food security crop for the majority of the Kenyan population, with an estimated 5.3 million hectares of crops harvested (Omoyo *et al*., 2015). The consumption of maize per capita in Kenya is 103 kg per person per year as compared to other East African countries like Tanzania, Ethiopia and Uganda, which are estimated at 73 kg, 52 kg and 31 kg, respectively (CIMMYT, 2015). Farmers in arid and semi-arid lands (ASALs) grow maize despite the fact that it is not the best-suited crop for the areas because it is preferred as the staple cereal. Although in 2015, yields were at an average production of 3.5 tons per hectare in high potential areas and 1.622 tons per hectare in semi-arid areas, analysis of yields between the year 1980-2013 revealed a reduction of 1 kg per hectare per year. Statistics on maize production show that its production is below its potential of 4.5 tonnes per hectare, hence risking food security (Smollo et al., 2017). Mabonga (2017) reported that the estimated maize production is 26 million bags per year, which is below domestic consumption, which is approximately 34 million bags. Furthermore, an increase in the production of maize was due to an increase in expanded area rather than its productivity (CIMMYT, 2015).

Green grams are among the most important legumes as staple foods in the ASALs (Kitui County Ndengu Revolution Policy, 2018). Green gram is able to survive harsh conditions escaping drought due to its early maturing ability (Rowe, 1980). Most green gram varieties mature within a short period of approximately 60 days, giving reasonable yields even when the rains are as little as 650 mm of rainfall (Muriithi et al., 2020; Sahelian Solution Foundation (SASOL), 2015). Additionally, green gram forms associations with mycorrhiza, hence the ability to adapt to poor soils (Valsalakumar et al., 2007) and can be used as an intercrop with maize, hence playing environmental conservation and food security roles, respectively. Green gram production is constrained by low soil moisture levels due to high temperatures caused by climate change, with average yields ranging from 300-700 kg/Ha despite the high potential of 1250 kg/Ha to 3000 kg/Ha obtained in trials (Mogotsi et al., 2006). (Kesery, 2013) recounted that in Kenya, especially in ASALs like Kitui and Makueni where green gram production has been practised, within season moisture stresses have contributed to low yields experienced, and as a result of this, the level of production and the output therein has been dismal.

Research to ease the effect of high temperatures on green grams in Kenya has been minimal. Due to changing climate patterns and increasing global warming, there is a need for more research on green grams and innovative ways introduced to mitigate the effect of high temperatures since it is one of drought tolerant crops that do well in the lower Eastern part of Kenya(Mwangi et al., 2022).

Low yields in green grams and maize are caused by high temperatures, among other factors that result from increased solar radiation reaching the earth's surface (Masaku, 2019). Elevated solar radiation accompanied by unsaturated air increases the rate of both evapotranspiration and evaporation, resulting in constant water loss, hence reducing the amount

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available for plant growth (Masaku., 2019). Gladys (2017) predicted that extreme climate events are expected to occur due to constant increases in temperatures and reductions in rainfall. The adoption of shading technology regulates both soil and air temperatures, thereby limiting water loss by transpiration and evaporation, improving plant growth and yield (Masaku et al., 2018). (Hadi *et al*., 2006) found out that an increase in shading resulted in an increase in grain weight, grain filling period, days to physiological maturity, days to flowering, leaf area ratio and leaf area index in common beans (*Phaseolus Vulgalis*), (Kimatu et al., 2014). The shade net technology improves both the quality of light required by plants for growth and also the crop being harvested by reducing direct exposure to adverse conditions of the environment, which include solar radiation, heat, wind and drought(Ilic et al., 2018).

Temperature and precipitation are key factors that hinder the attainment of maximum crop yields in the tropics (Mumo *et al*., 2018). High temperatures result in low soil moisture, negatively impacting plant growth and yield. Inadequate water also affects the absorption of water by plants from the soil, resulting in reduced plant growth (Masaku, 2019). Therefore, the productivity of important crops is expected to be limited due to increased temperatures accompanied by erratic rainfall, resulting in food insecurity and reduced income levels (Gladys, 2017). Ministry of Agriculture, Livestock, Fisheries and Irrigation (2018) acknowledged that poor growing conditions characterized by moisture stress in Kitui County resulted in maize production below the normal yield with only between 10-20% of yield realized (Omoyo *et al*., 2015). Gladys (2017) noted that changes in climatic conditions within Kitui County have resulted in reduced crop yields. This can be attributed to elevated temperatures of between 32° to 36° Celsius that increase the rate of evapotranspiration, resulting in a reduction of available soil moisture (Masaku *et al*., 2018).

Among the mitigation measures that have been developed to counter evaporation and transpiration include growing crops under shade or reduced light intensity to retain soil moisture for plants. Plants grown under shade perform better agronomically than those under direct interaction with sun's energy (Masaku., 2019). Masaku *et al*. (2018) noted that the performance of green grams under reduced light intensity during short rains in Arid and Semi-arid lands was good, with plants showing an increase in pod length and number of seeds.

Preliminary studies have evaluated green gram genotypes performance under shade net that reduced light intensity by 35% so as not to disrupt the Photosynthetically Active Radiation(PAR) in Machakos and Makueni Counties(Masaku, 2019; Masaku *et al*., 2018), however, shade nets that reduce light intensity by 70% and 50% have not been explored. This study examined the effect of reducing radiation by 0 %, (control), 50% and 70% on growth, grain and biomass yield of green grams and maize.

MATERIALS AND METHODS

The field experiment was carried out at South Eastern Kenya University Farm. The university farm lies between longitude 37.755011°E and latitude 1.307689°S and an altitude of 1157 m above sea level(Kitui County Ndengu Revolution Policy, 2018). The rainfall patterns are bimodal, ranging between 300 mm – 1050 mm per annum and are estimated to be 40% reliable, while temperatures range between 14 °C to 34 °C annually (Koima, 2018). The site was selected because it is ecologically suitable for green gram and maize production and is located among major production zones in Eastern Kenya (Kilimo Trust, 2017). It also lies in Kitui County, which is characterized by high variations in weather (Omoyo et al., 2015).

One green gram variety, N26, from KALRO and a Maize variety, DH 02, from Kenya Seed Company Limited, was used for the field trial. The green gram variety N26 was selected because it's among the

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popular local varieties in the Kenyan Markets that have registered low yields (Muriithi *et al.*, 2020) but has shorter maturity days of between 90 to 120 days (Sahelian Solution Foundation (SASOL), 2015), DH 02 was selected because it is adapted and perform well in Arid and Semi-Arid areas (Recha *et al*., 2013).

The two seasons experiment was laid out in a split-plot using a randomized complete block design (RCBD) with three replications (Gomez and Gomez, 1984). Each block had six plots. The three treatments under study included light reduction by 70%, 50% and a control 0%. The plot size for both green grams and maize measured four (4 m) meters in width by two meters (2 m) in length. Green grams had seven rows with a spacing of 60 cm between rows and 20 cm between plants (Muriithi et al., 2020). Maize was planted in five rows, with a spacing of 75 cm by 30 cm, as recommended by (The Kenya Cereal Enhancement Programme, 2016). Weeds, pests and diseases were scouted and controlled throughout the experiment period (SASOL, 2015; The Kenya Cereal Enhancement Programme, 2016).

Data Collection

The growth and yield parameters data collection for green grams was done using procedures described by Masaku *et al*. (2018), where five plants were selected and tagged randomly. The parameters collected were plant height, number of pods per plant at maturity, number of seeds per pod, number of days to maturity from sowing to 75% of dried pods and weight of 100 seeds. The growing degree days were calculated using procedures described by (Ravi Babu et al., 2020), while the profitability–gross margin analysis was calculated from the gross income and variable costs as net returns, cost-benefit ratio, production and economic efficiency protocol described by (Kumar et al., 2015; Kumar & Kumawat, 2014) (*Table 1*).

Table 1: Green grams data collection procedures

Parameter	Reference	Measurement details
Plant height (Centimetres)	Masaku *et al*. (2018)	Measured from the ground to the tip of the central shoot of a mature plant
Growing degree days	Ravi Babu et al. (2020)	Calculated GDD = (Tmax+Tmin)/2 – Tbase GDD: Growing degree days Tmax: Daily maximum temperature (°C) during the day Tmin: Daily minimum temperature (°C) during the day Tbase: Base temperature of 10°C
Number of pods per plant	Masaku *et al*. (2018)	Counted the number of pods at maturity.
Number of seeds per pod	Masaku *et al*. (2018)	done by selecting 10% of the pods per plant in a random manner, splitting the pods, counting the seeds in each pod, then adding them and dividing them by the number of pods sampled
Weight of 100 seeds (grams)	Masaku *et al*. (2018)	After threshing pods from each plant, 100 seeds were selected randomly and weight recorded.
Profitability – gross margin analysis	Kumar *et al*. (2015) and Kumar and Kumawat (2014) protocols.	Calculated from the gross income and variable costs as net returns, cost-benefit ratio, production and economic efficiency

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For maize, growth and yield data were collected using procedures described by Belay and Adare (2020). .10 plants were randomly selected, and the following parameters were collected at physiological maturity: plant height (cm), ear height (cm), number of ears per plant, ear length (cm), number of kernels per ear, above-ground dry biomass yield (grams), grain yield dried to 12.5% moisture content. The harvest index was estimated by dividing the grain yield obtained by the above-ground dry biomass yield and then multiplying by 100. The Leaf area index – a sample ten plants, was obtained by measuring the breadth of the widest part and length of the tallest leaf when tussling has happened (this is the maximum height and also the maximum number of leaves). The average was multiplied by a leaf area index of 0.7. to determine the leaf cover. {this assisted in calculating the leaf area and plant height correlation on the yield and/or biomass (Patil et al., 2018). The average chlorophyll content (micromole per cm^2) using SPAD 502 Plus Chlorophyll Meter (*Table 2*).

Data Analysis

Both growth, yield components and grain yield of maize and green grams were subjected to analysis of variance (ANOVA) and their difference in means determined by Duncan's multiple range least significant difference test (LSD) at 5% ($P< 0.05$) significant level using SAS; version 8.0 (SAS Institute 2001).

RESULTS

There were significant ($P \leq 0.05$) differences recorded for pods per plant in green grams. A high number of pods per plant were recorded under 70% shading intensities (29.6), followed by 50% shading and 0% with 26.6 and 11.96, respectively (*Table 3*). There were significant ($P \leq 0.05$) differences for seeds per pod in green grams. Green grams grown under 50% shade had a higher number of seeds (13.6) per pod compared to 13.2 seeds per pod 11.2 seeds per pod, in 70% and 0%, respectively. (Table 3)

There were significant ($P \leq 0.0046$) differences in green grams 100 seeds yield under different shade intensities. Heavier 100 seed weight was recorded under 0% shading intensity (6.3 g), followed by 50% shade (5.5 g) and 70% shade (4.3 g). (Table 3). Green grams grain yield per hectare was higher in 50% shade intensity (1759 kg/Ha), 70%(1553 kg/Ha) and lowest in 0% (478 kg/Ha) (*Table 3*). There were significant ($P \leq 0.001$) recorded for dry matter yield in green grams. Above-ground biomass was significantly higher under 50% shade intensity, with 123.4 g compared to 113 g in 70% and 91 g in 0% shade (*Table 3*).

There were significant ($p<0.05$) differences in maize 100 seeds, above-ground dry biomass yield, and cob weight at maturity. Heavier 100 seed weight was recorded under 50% shade (40.3 g), followed by 70% shade (30.6 g) and 0% shade intensity (22.5 g). (*Table 4*). The highest above-ground dry biomass was in 50% shade intensity (440.5 g), followed by 70% shade (298.5 g) and 0% shade (214.8 g) (*Table 5*). The 50% shading intensity recorded the highest cob weight at maturity (208.5 g), followed by 70% shade 129.5 g and 128.4 g 0% shade (*Table 5*). In season two, the cob weight was highest in 50% shade (140.5 g) compared to 70% (134.6 g) and 0% (107.4 g). The total above-ground biomass was highest under 50% shade (440.5 g) compared to 70% (298.5 g) and 0% (214.8 g). Season two recorded lower total above-ground biomass intensity, which was highest under 50% shade (245.0 g) compared to 70% (164.9 g) and 0% (93.6 g) (*Table 4*). Maize grain yield per hectare was higher at 50% (5114 kg), followed by 70% (4791 kg) and lowest at 0% (4209 g) (*Table 4*).

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Table 2: Maize data collection procedures

Parameter	Reference	Measurement details
Ear length (cm)	Belay and Adare (2020)	10 ears were randomly selected per plot, measured from the point where ears are attached to the stalk to the tip with a glass ruler
Above-ground dry biomass yield (Grams)	Belay and Adare (2020)	selected plants were cut above ground and weighed at harvest
Grain yield	Belay and Adare (2020)	sampled plants were harvested, grains dried to around 12.5% moisture content and weighed
Harvest index	Belay and Adare (2020)	estimated by dividing the grain yield obtained by the above-ground dry biomass yield, then multiplying by 100
Leaf area index	(Patil *et al*., 2018)	sample ten plants, measure the breadth of the widest part and length of the tallest leaf when tussling has happened (this is the maximum height and also the maximum number of leaves). The average was multiplied by a leaf area index of 0.7. to determine the leaf cover. {this will assist in calculating the leaf area and plant height correlation on the yield and/and biomass
Average chlorophyll content (micromole per cm^{-2})	SPAD 502 Plus Chlorophyll Meter	ten leaves from ten plants were randomly sampled, and SPAD 502 Plus Chlorophyll Meter was used to quantify and monitor the chlorophyll content of the plants as a measure of crop health

Table 3: Shade intensities on green grams' yield components

Shading Intensities	100 seeds weight (g) S1	100 seeds weight (g) S2	No. of pods per plant S1	No. of pods per plant S2	No. of seeds per pod S1	No. of seeds per pod S2	Biomass weight (g) S 1	Biomass weight (g) S2	Grain yield (g/Ha) S1	Grain yield (g/Ha) S2
70%	4.33c	3.20 b	29.60a	8.4 a	13.63a	7.50 b	113.03b	75.33 a	1035.1 a	1553 a
50%	5.47b	5.47 a	26.27a	9.33 a	13.17a	13.17 a	123.43a	77.93 a	1110.6 a	1759 a
0%	6.27a	4.93 a	11.967b	4.17 b	11.47a	7.20 b	91.00c	58.57 b	307.7 b	478b
Sign	***	**	*	***	*	*	**	ns	**	**
P	0.0046	0.0227	0.05	0.0069	0.05	0.0398	0.05	0.051	0.017	0.018
LSD0.05	0.5	1.1	2.94	1.77	2.77	3.55	2.34	15.98	8.6	6.81
C.V%	2.78	10.66	2.78	10.67	12.29	16.88	2.78	9.96	10.1	10.71

Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 5% (P<0.05)

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Table 4: Shade intensities on maize's yield components

Shading Intensities	100 seeds weight (g)		Biomass weight (g)		Grain yield (g/Ha)	
	Season 1 (S1)	Season 2 (S2)	S1	S2	S1	S2
70%	30.3 b	30.62 b	298.5b	164.9 b	2646.7 b	4791.0 b
50%	40.3 a	40.11 a	440.5a	245.0 a	2844.3 a	5114 a
0%	22.1 c	22.53 c	214.8c	93.60 c	1834.1 c	4209.0 c
Sign	*	***	***	***	***	***
p	0.05	0.0011	0.002	0.0013	0.0014	0.001
LSD $_{0.05}$	1.26	3.5	36.5	31.16	29.12	-
C.V%	8.7	5	5	8.18	1.7	1.3

Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test (P<0.05)

Table 5: Shade intensities on cob characteristics

Shading Intensities	Cob weight at maturity (g)		Cob length at maturity (cm)	
	S1	S2	S1	S2
70%	129.5 b	134.6 a	18.5 a	13.13 b
50%	208.5 a	140.5 a	19.23 a	15.33 a
0%	128.4 b	107.4 a	15.5 a	11.47 b
Sign	***	ns	ns	ns
p	0.009	0.134	0.305	0.075
LSD $_{0.05}$	41.21	26.942	5.79	2.1
C.V%	11.7	9.32	14.4	6.76

Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 5% (P<0.05)

The cost-benefit analysis of 0%, 50% and 70 % shade intensities on green grams and maize farming systems.

The Gross margin was calculated from the gross income and variable costs as net returns, cost-benefit ratio, production and economic efficiency. Green grams Yield was best at 50% shade intensity (1759 kg/Ha), 70% shade (1553 kg/Ha) and least at 0% shade (479 kg/Ha). The Green Grams break-even price noted was 60 KES per Kilo under 0% shade intensity, 70% shade (49.5 KES /Kg) and lowest at 50% shade (44.1 KES/Kg at eight years shade net lifespan. The cost-benefit ratio was highest at 50% shade intensity 65.9, 60.5 (70% shade) and lowest at 0% shade 49.8. Production efficiency was highest at 50% shade intensity 28.4, 25(70%) and lowest at 0% shade at 7.7. Economic efficiency was highest in 50% shade 1871.00 Kgs/Ha/day, 1515.20 kg/Ha/day (70%) and lowest in 0% shade at 383.75 kg/Ha/day (*Table 6*).

Table 6: The cost-benefit analysis of 0%, 50% and 70 % shade intensities on green grams farming systems

Green grams profitability - gross margin analysis	0% Shade	50% Shade	70% Shade
A) Marketable yield per season (Kilograms /HA)	478.0	1,759.0	1,553.0
B) Marketable yield per season (Kenya shillings /HA)	52,580.0	193,490.0	170,830.0
C) Total Variable Costs/HA Per Season (KES)	28,787.5	77,487.5	76,887.5
D)Gross Margin (B-C)/HA Per Season (KES)	23,792.5	116,002.5	93,942.5
E) Production Cost Per Kilo	60.2	44.1	49.5
F) Break-Even Price (KES)	60.2	44.1	
G) Total duration taken by the crop	62	62	62
H) Cost-benefit ratio D/A	49.8	65.9	60.5
I) Production efficiency A/G	7.7	28.4	25
J) Economic Efficiency D/G	383.75	1871.00	1515.20

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Maize yield was best at 50% shade (5114 kg/Ha), 70% shade (4791 kg/Ha) and least at 0% shade (4209 kg/Ha). The Maize break-even price noted was 49.6 KES/kg (50% shade), 55.7 KES (70% shade) and highest at 66 KES per Kilo under (0%) at eight years shade net lifespan. The cost-benefit ratio was highest at 0% shade net 56, 47 (50% shade) and lowest at 70% shade 46. Production efficiency was highest at 50% shade 53, 50(70%) and lowest at 0% shade at 46. Economic efficiency was highest in 0% shade 2568 Kgs /Ha/day, 2501 kg/Ha/day (50%) and lowest in 70% shade at 2293 kg/Ha/day (*Table 7*).

Table 7: The cost-benefit analysis of 0%, 50% and 70 % shade intensities on maize farming systems

Maize Profitability - gross margin analysis	0% Shade	50% Shade	70% Shade
A) Marketable yield (Kilograms /HA)	4,209	5,114	4,791
B Marketable yield (Kenya shillings /HA)	269,376	327,296	306,624
C) Total Variable Costs (KES)	33,165	87,173	86,485
D) Gross Margin (B-C) (KES)	236,211	240,122	220,139
E) Production Cost Per Kilo	69.4	49.6	55.7
F) Break-Even Price (KES)	69.4	49.6	55.7
G) Total duration taken by the crop	92	96	96
H) Cost-benefit ratio D/A	56	47	46
I) Production efficiency A/G	46	53	50
J) Economic Efficiency D/G	2568	2501	2293

DISCUSSION

This study demonstrated that plants grown under shade performed better agronomically than those grown in the open, which is in agreement with Masaku *et al*. (2018), who noted that the performance of green grams under reduced light intensity during short rains in Arid and Semi-arid lands was good with plants showing an increase in pod length and a number of seeds. It is also in agreement with (Chastain . T.G. & Garbacik C.J., 2011) observed that optimum and efficient solar energy capture improved the yield of grass seed.

The study demonstrated that there was an effect of shade intensities on green grams and maize grain yield and above-ground biomass yield where high grain and dry biomass yield were recorded on plants grown under shade intensities than in the open and in agreement with Masaku *et al*. (2018) and Hamdani *et al*., (2018). This may be linked to reduced water loss from the soil through evaporation, which creates a cool microenvironment around the roots for enhanced plant growth (Masaku *et al*., 2018). (Hamdani et al., 2018) also noted that shade nets enhance water use efficiency by plants, arising from regulated light intensity, evapotranspiration and temperature, leading to improved availability of available soil moisture. The difference in shade levels can also alter certain conditions of the environment and forge suitable microclimates, creating variation in the heights of plants under different shade intensities (Yasoda *et al*., 2018). Hadi *et al*. (2006) found that an increase in shading resulted in an increase in grain weight, grain filling period, days to physiological maturity, days to flowering, leaf area ratio, and leaf area index of common beans. These findings are in agreement with Ilic *et al*. (2018), who observed that shade net technology improves both the quality of light required by plants for growth and also the crop being harvested by reducing direct exposure to adverse conditions of the environment, which include solar radiation, heat, wind and drought. However, maize yields are reduced significantly if moisture stress occurs during the post-anthesis stage rather than the pre-anthesis stages (Olaoye *et al*., 2009). Munyiri *et al*., 2010) noted moisture stress increased days to tassel in maize by one to five (1-5) days in 65% of germplasm tested, delayed silking by three (3) days, increased anthesis silking interval by two (2) days, reduced tassel size from 3.2 to 2.9, number of ears per plant from 1.1 to 0.9 and caused grain yield loss between 17% to 81%.

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CONCLUSIONS AND RECOMMENDATIONS

This study showed that plants grown under 50% shade intensity had heavier grain and above-ground biomass yield of both green grams and maize compared to those under 70% and 0% shade intensity. This may be attributed to adequate moisture due to reduced evapotranspiration, which improved plant growth and yield. The study demonstrated that the cost-benefit analysis of shade intensity on green grams farming system yield and break-even price was best at 50% shade intensity. In contrast, the cost-benefit analysis of shade intensity on the maize farming system was not significant.

The study recommends the use of 50% shade intensity in the growing of green grams in ASALs due to benefits that range from conserving soil moisture to improved plant growth, yield, economic efficiency and cost-benefit ratios.

Further investigation should be done on the effect of the 50% and 70% shade intensity on the crop canopy, crop water absorption and crop water requirements at different stages of growth.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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