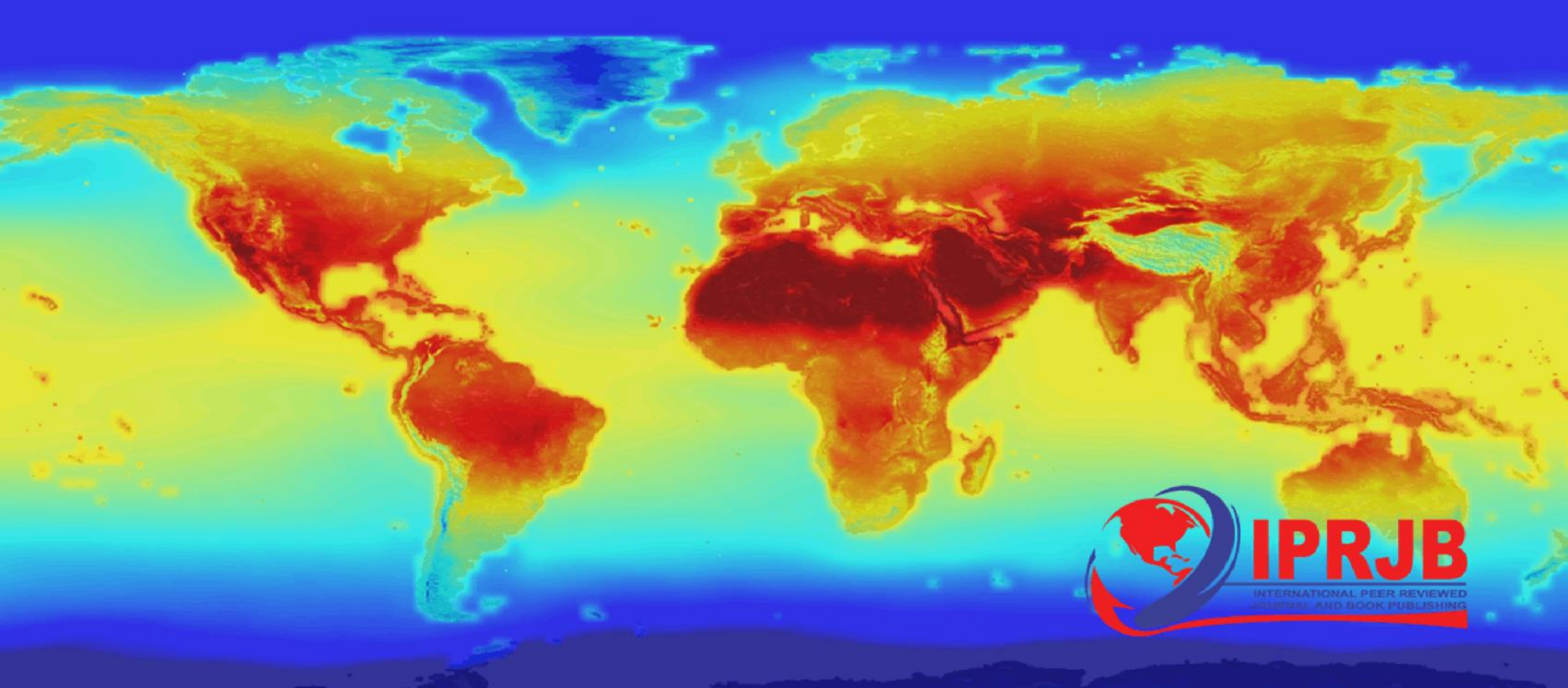
International Journal of
Climatic Studies
(IJCS)

EFFECT OF SPACING ON GRAIN YIELD AND ABOVE GROUND BIOMASS OF COWPEA

Armara Macimiliam Galwab and Prof. Peter Kamau



IPRJB
INTERNATIONAL PEER REVIEWED JOURNAL AND BOOK PUBLISHING

International Journal of Climatic Studies
ISSN: 2710-1061 (Online)
Vol.1, Issue No.1, pp. 24-35, 2017
www.iprjb.org

EFFECT OF SPACING ON GRAIN YIELD AND ABOVE GROUND BIOMASS OF COWPEA

[1 *]Armara Macimiliam Galwab
[1]Masters student: Kenya Methodist University
[*]Corresponding Author's Email:armara2005@yahoo.com

[2]Prof. Peter Kamau
Lecturer: Kenya Methodist University

Abstract

Purpose: The purpose of this study was to determine the effect of spacing on grain yield and above ground biomass of cowpea.

Methodology: A randomized complete block design was used. Field experiments were conducted. The study was conducted at Agriculture demonstration farm (Dakabaricha) and Yayo's farm(Nagayo) and a private farm Demo farm. There were 18 treatment combinations consisting of three water harvesting techniques and two intra-row spacing.

Results: Tied ridges with cross bars at 2.5m interval with the spacing of 60 x 20cm (W3 /S1) and open ridges with a spacing of 60 x 20cm (W3/S1) recorded the highest grain yield of 1408 kg/ha and 1296 kg/ha respectively.

Unique Contribution to Theory, Practice and Policy: An assessment of adaptation of more cowpea genotypes at different environments across years is recommended. The investigation provided sufficiently evidence to continue with further studies.

Keywords: *Spacing, grain yield, above ground biomass.*

International Journal of Climatic Studies
ISSN: 2710-1061 (Online)
Vol.1, Issue No.1, pp. 24-35, 2017 www.iprjb.org

INTRODUCTION

The greater Marsabit District is situated in Northern Kenya, Eastern Province. It borders the Federal Republic of Ethiopia to the North, Moyale District to the North East, Turkana District to the West, Samburu District to the South and Isiolo and Wajir Districts to the East respectively. The district lies between latitude 01º 15' and 04º 27'North and longitude 36˚ 03'and 38˚ 59' East.The district is approximately 61,590km^2 in size and has a population of 187,367 people in 40,333 households. Marsabit district is home to approximately 1.1 million shoats, 200,000 cattle, 160,000 camels and 40,000 donkeys. Marsabit Central has a population of 46,502 people (KNBS, 2009).

Agricultural activities are concentrated around Marsabit Central District where between 20-30% of the land is under farming. The main crops grown are maize, beans, wheat, sorghum, millet, teff and cowpeas. Thirty five percent of the land area is considered to have high agricultural potential (GOK 2002, LRMP 2010). However, agricultural development has been slow and is not being fully encouraged because areas with a high agricultural potential also serve as important water catchment areas, national parks and forest reserves. The small fraction used to grow crops is competing with *khat* (miraa) growing which is an economically important stimulant in the region. Miraa is an immediate cash earner especially to the resource poor farmers in the region. A kilogram of miraa costs about 300 kenya shilings (4$). According to a miraa business dealer interviewed, approximately ten people can buy from her every day at cost of 300 kenya shilings (4$) translating into 3,000 shilings (40$) per day. Water harvesting techniques have not been practiced in the region due to lack of technical knowhow on the role drought tolerant crops and water harvesting techniques play. Cowpea is grown at small scale usually intercrop with maize in the district.

The soils in Marsabit Central are generally red loam clay soils which are slightly acidic with moderate levels of the major macronutrients (Muya et al, 2010). The area receive low and erratic annual rainfall which ranges from 400mm to 600mm with maximum and minimum temperaures of 27^{0}c and 20^{0}c respectively (Muya *et al*, 2010). The rainfall distribution is bimodal where short rains are normally during the November-December while long rains in April-May (Borghesio 2004). The climate of the area is arid and semi-arid zone.

Most of the communities practicing crop production in Marsabit central were either previously pastoralist who have limited farming skills or moved in from the Ethiopian highlands where the climatic conditions are humid. Therefore they do not grow the most appropriate crops nor do they practice water harvesting technologies suitable for semi-arid areas (Muya et al., 2010). In most of the region within the proposed study area, farmers are practicing mixed farming where farmers integrate livestock rearing with small scale farming involving the use of highbrid maize and beans. This study therefore seeks to evaluate the performance of a known drought tolerant crop i.e. cowpea under different water harvesting technologies so as to generate information for assisting the communities and policy makers to improve the agricultural production within the District. The idea of the use of drought tolerant crop has been necessitated by global warming. Climate change has interfered with the rainfall pattern in the region. The long and short rains are no longer predictable which has motivated the use of drought tolerant crop coupled with water harvesting techniques. The water harvesting techniques are simple to construct by the peasant farmer and are cost effective as well.

International Journal of Climatic Studies
ISSN: 2710-1061 (Online)
Vol.1, Issue No.1, pp. 24-35, 2017

Problem Statement

Marsabit central district faces persistent food insecurity despite the relatively good agro climatic conditions found in the area. One of the most limiting factors to optimal crop production is water scarcity occasioned by poor and unreliable rainfall. On-farm water harvesting has been shown to increase the yields of maize in parts of Machakos District where rainfall is also low. However the effect of such water harvesting techniques on the performance of cowpeas in Marsabit Central District is not well understood.

Pastoralism and communal small scale farming is the chief source of livelihood in the Marsabit Central but the rain fed agriculture is highly vulnerable to the vagaries of climate change which calls for water conservation techniques and drought tolerant crops to meet the demands of the residence of Marsabit Central (Warui, 2000). This is worsened by the fact that the area is an agricultural marginal area and has a fragile ecosystem. Physical presence of relief agencies almost yearly to provide food handouts is now a common phenomenon which provides evidence that agricultural production has drastically fallen as farmers cannot produce enough to meet their daily subsistence food requirements.

The mountain region within the central division receives higher rainfall of between 400 – 800mm as compared to the riverine with 180 – 200mm (Lost Crops of Africa, 2006). Conservation of soil moisture within this range of rainfall can give good yield. The use of highbrid varieties of maize have been tested in the region but was not adopted by farmers due to lack of water in the soil. Limited literature is available on the use of spacing techniques in Marsabit Central for crop production. It is therefore envisaged that spacing techniques are not well understood by farmers in the County. It is for this reason that this study is conducted to determine the effect of spacing on cowpea production in Marsabit Central.

Objective of the Study

The objective of the study was to determine the effect of spacing on grain yield and above ground biomass of cowpea.

LITERATURE REVIEW

Maximum yield of a particular crop in a given environment can be obtained at row spacing where competition among the plants is minimum. This can be achieved with optimum spacing which not only utilize soil moisture and nutrients more effectively but also avoids excessive competition among the plants. However, beyond certain limit yield cannot be increased with decreasing/increasing row spacing. Hence, optimum row spacing induces the plant to achieve its potential yield. When water is no longer a limiting factor as is expected to be if water harvesting techniques are efficient then the recommendations for spacing may change. In cowpea Arora *et al.* (1971) reported the higher growth parameters viz., plant height, lateral branches and number of trifoliate leaves at 30 cm row spacing as compared to 20 cm. Performance at 40 cm row spacing was intermediate of the other two spacing. Verma (1975) conducted experiment in Jabalpur, to know the effect of spacing on forage yield of *Dolichos lablab* with three inter-row spacings (25, 50, 75 cm). Morphological observations such as plant height (149.8 cm) and number of branches per plant (21.65) were higher at 50 cm row spacing as compared to 75 cm (142.2 cm and 18.4 plant height and number of branches, respectively) and 25 cm (110.8 cm and 16.65 plant height and number of branches, respectively) spacings. Gill *et al.* (1977) reported that, the growth parameters of cowpea such as plant height, lateral branches and trifoliate leaves increased with increased spacing from 20 cm (110.3 cm plant height, 14.3 lateral branches and 32 trifoliate leaves), 30 cm (116.4 cm plant height,16.3 lateral branches and 35 trifoliate leaves) to 45 cm (122.8 cm plant height, 18.4 lateral branches and 39 trifoliate leaves). From the experiment conducted in Bangalore on sandy loam soil during *kharif* in field bean, Thimmegowda (1990) observed significantly higher growth parameters at 66 cm row spacing (148.8 cm, 7 and 43, plant height, branches and trifoliate leaves, respectively) as compared to 88 cm (139.3 cm, 4 and 35, plant height, branches and trifoliate leaves, respectively) and 44 cm (136.7 cm, 5 and 39, plant height, branches and trifoliate leaves, respectively).

METHODOLOGY OF THE STUDY

The field experiments were conducted on short rain season of October to December 2012 under rain fed. The experiment was laid out in a randomized complete block design with three replications. The treatments consisted of two intra-row spacing of 60 and 45cm designated as S1 and S2 respectively and three water harvesting techniques namely: flat seed beds as a control, open ridges and tied ridges with cross bars at 2.5m interval, designated as W1, W2 and W3 respectively. Seeds were sown on rows of 20 cm apart; in intra-row spacing of 60 and 45cm.

RESULTS AND DISCUSSION

Yield in cowpea is the result of many interacting yield components such as number of pods per plant, number of seeds per pod and mean seed weight. Yield and its components are affected by various factors including phonological development, planting date, genotypic differences and the environment (Gardener *et al.*, 1985). The growth parameters under review included emergence, budding, flowering, podding and ripening.

The results of the effects of differences in the number of days the crop took to germinate, days to budding, days to flowering, days to pod formation and days to physiological maturity are presented in Table 1. The results indicates that the crop to took almost the same number of days to germinate

Table 1: Number of days to emergence, number of days to budding, number of days to 50% flowering, number of days to pod formation, number of days to physiological maturity of cowpea (k80)

Treatments.	Days to emergence.	Days to budding.	Days to flowering.	Days to podding.	Days to ripening.
W1/S1	4.50a	39.17c	62.00c	75.33c	97.50b
W1/S2	4.83a	39.33c	62.83c	76.00c	96.33b
W2/S1	4.43a	38.17b	57.33b	71.83b	95.83b
W2/S2	4.67a	38.50b	58.00b	73.50b	96.67b
W3/S1	4.40a	36.32a	55.81a	70.76a	94.03a

W3/S2	4.44a	36.68a	53.52a	70.07a	92.30a

Table 1 above shows that tied ridges with a spacing of 60 x 20cm (W3/S1) took comparatively less days to emerge (4.40 days) while flat seed bed with spacing of 45 x 20cm (W1/S2) took longer days to emerge (4.83 days). The table shows that seeds germinated uniformly after 4-5 days of after sowing.

Table 2: ANOVA for days to emergence

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	0.694	1	0.694	1.506	0.229
Error	13.833	30	0.461		
Total	**14.972**	**35**			

From the ANOVA table the results indicates that there was no significant effect in number of days the crop took to germinate as a result of the spacing treatments (P=0.229).

Number of days to budding.

The analysis from the summary table (Table 1) indicates that the tied ridges (W3/S1) took the shortest time to bud, with a mean of 36.32 days while flat seed beds (W1/S2) took long days to bud (39.33 days).

Table 3: ANOVA for days to budding

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	0.694	1	0.694	0.668	0.420
Error	31.167	30	1.039		
Total	78.972	35			

According to the ANOVA results in table 3 for effect of spacing on the days to bud formation aninsignificant effect was noted (P=0.420).

Days to 50% flowering

From the summary table (Table 1), tied ridges (W3/S2) relatively took less number of days to flowering (53.52 days) compared to open ridges (W2/S2) (58.00 days) and flat seed beds (W1/S2) (62.83 days) which took longer days to attain 50% flowering. These were as a result of heavy and prolong rains during this season.

Table 4: ANOVA for days to flowering

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	0.694	1	0.694	0.055	0.816
Error	376.500	30	12.550		

Total	756.750	35

The ANOVA results in table 4 on days to flowering shows that there was aninsignificant effectof spacing (P=0.816) on days to flowering.

Days to podding

The analysis from the table 1 indicates that tied ridges relatively took less days to pod formation (70.42 days) while open ridges and flat seed beds took comparatively longer days respectively (72.67 and 75.67 days).

Table 5: ANOVA for days to poding

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	3.361	1	3.361	0.439	0.513
Error	229.833	30	7.661		
Total	406.750	35			

The ANOVA results in table 5 shows that the spacing treatments affectedinsignificantly on the days to podding (P= 0.513).

Days to 50% ripening

The average time taken to reach for 50% physiological maturity among different treatments varied from 92.30-97.50 days (Table 1). Tied ridges took less time to mature W3/S1,(92.30 days) compared to open ridges W2/S2,(96.67 days) and flat seed beds W1/S1,(97.50 days). **Table 6: ANOVA for days to ripening**

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	5.444	1	5.444	0.946	0.339
Error	172.667	30	5.756		
Total	286.889	35			

The analysis of ANOVA results in table 6 indicates that spacing treatments had a no significance effect in days to ripening of cowpea (P=0.339).

Growth components

Table 7 summarizes the effect of varietal difference on plant height, number of leaves per plant, number of branches per plant, number of days to flowering, number of pods per plant and number of seeds per pod. The results indicate that Tied ridges with spacing combination of 60 x 20cm perfomed genearlly better.

Table 7: Plant height, number of leaves per plant, number of branches per plant, number of pods per plant, number of seeds per pod of cowpea (Katumani K80)

Treatments.	Plant heights (cm)	Number of leaves per plant	Number of branches per plant	Number of pods per plant	Number of seeds per pod
WI/S1	152.61b	126.50b	10.08b	32.79c	13.60b
WI/S2	158.10b	126.81b	10.10b	32.88c	13.98b
W2/S1	155.36b	126.75b	10.34b	34.15b	14.01b
W2/S2	156.60b	127.28b	10.60b	43.45b	14.65b
W3/S1	161.78a	137.58a	12.42a	37.00a	16.30a
W3/S2	161.27a	135.28a	12.30a	36.42a	15.30a

Plant heights

Tied ridges had the highest plant heights with a mean average of 162.03cm and flat seed beds with the lowest plant heights (155.36cm) (Table 7).

Table 8: ANOVA for plant heights

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	272.800	1	272.800	10.678	0.003
Error	766.445	30	25.548		
Total	1527.043	35			

The ANOVA results in table 8 indicates that the plants heights differed significantly from the time of sowing due to different spacing treatments (P= 0.003).

Number of leaves

Higher number of leaves were observed for Tied ridges as compared to Flat seed beds and open ridges. It can be deduced from table 7 that tied ridges had the highest number of leaves with mean average of 136.43cm followed by open ridges with mean of 127.01cm and finally flat seed beds with lowest means of 126.66cm.

Table 9: ANOVA for the number of leaves per plant

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	8.123	1	8.123	0.934	0.342
Error	260.852	30	8.695		
Total	1025.996	35			

The ANOVA shows that the difference is insignificant (P=0.342)

Number of branches

Tied ridges had comparatively a higher number of branches with a mean of 12.36 as compared to open ridges with a mean of 10.47 and flat seed beds with a mean of 10.09 (table 7).

Table 10: ANOVA for number of branches per plant

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	2.103	1	2.103	3.222	0.083
Error	19.578	30	0.653		
Total	58.248	35			

The ANOVA results in table 10 shows that there was an insignificant difference in the number of branches per plant (P=0.083).

Number of pods per plants

The analysis from table 7, indicates that significantly higher number of pods per plant were noted on tied ridges (36.71plant^{-1}). Flat seed bed produced comparatively less number of pods per plant (32.83plant^{-1}).

Table 11: ANOVA for number of pods per plant

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	1.480	1	1.480	0.580	0.452
Error	76.532	30	2.551		
Total	172.807	35			

From the ANOVA results in table 11 it can be deduced that there was an insignificant difference in the number of pods per plant (P=0.452).

Number of seeds per pod

Significantly higher number of seeds per pod was recorded in tied ridges with a mean average of 15.80 plants^{-1}. Less number of seeds per pod was collected from flat seed beds (13.79 plants^{-1}).

Table 7 illustrates that Tied ridges with a spacing of 60 x 20cm had the highest number of seeds per pod as compared to both open ridges and flat seed beds.

Table 12: ANOVA for number of seeds per pod

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	.694	1	0.694	1.018	0.321
Error	20.463	30	0.682		
Total	51.490	35			

The analysis from the ANOVA table shows that the number of seeds per pod differed insignificantly among the different spacing treatments (p=0.321).

Above ground biomass

Table 13 summarizes the effects of water harvesting techniques and spacing on above ground biomass yield and dry grain yield and their yield in hactare. It was evidence from the table that water harvesting techniques had a profound effects on the yields of cowpea. Tied ridges responded well to water harvesting techniques and gave the highest yield of 18732 kg/ha (above ground biomass).

Table 13: Above ground biomass and dry grain yield of cowpea (k80)

Treatments	Above ground biomass Yield (kg)	Above ground yield (kg/ha)	Dry grain yield (kg)	Dry grain yield (kg/ha)
W1/S1	30.06b	12024	2.89b	1156
W1/S2	26.50b	10600	2.20b	880
W2/S1	35.39b	14156	2.85b	1140
W2/S2	26.62b	10648	2.78b	1112
W3/S1	46.83a	18732	3.52a	1408
W3/S2	36.06a	14424	3.24a	1296

Table 14: ANOVA for above ground biomass

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	292.524	1	292.524	4.317	0.046
Error	2032.858	30	67.762		

Total	3621.769	35			

The ANOVA indicates that interaction effect due to spacing were non-significant (P= 0.046).

Grain yield

Table 15: ANOVA for dry grain yield

Source of variation	Type III Sum of Squares	DF	Mean Square	F	Sig.
Spacing	0.106	1	0.106	0.223	0.640
Error	14.193	30	0.473		
Total	18.456	35			

The ANOVA shows that there was an insignificant difference (P=0.640) as a result of spacing treatments.

The row spacing of 60 x 20cm produced significantly higher grain yield (1408 kg ha^{-1}) and above ground biomass yield (18732 kg ha^{-1}) respectively compared to row spacing of 45 x 20cm (Table 4.14). The increase in grain yield and above ground biomass yield with 60 x 20cm row spacing was mainly due to significantly higher performance of all the growth and yield components compared to 45 x 20cm (Table 4.2, 4.8). These results are in conformity with Angne *et al.* (1993), Arora *et al.* (1971) and Yadav (2003) in cowpea, Mc Ewen (1973) in field bean, Dwivedi *et al.* (1994), Singh and Tripathi (1994) in French bean in closer spacing compared to wider spacing

The 60 x 20cm row spacing recorded significantly higher plant height (161.78 cm), number of leaves per plant (137.58 $plant^{-1}$), number of branches (12.42 $plant^{-1}$), number of pods per plant (17.00 $plant^{-1}$) number of seeds per pod (16.30 $plant^{-1}$) (Table 4.8), above ground biomass (46.83 kg $plant^{-1}$), and grain yield (3.52 kg $plant^{-1}$) (Table 4.13), days to emergence (4.40 $plants^{1}$), days to budding (36.32 $plant^{-1}$), days to flowering (55.81 $plant^{-1}$), days to pods formation (70.76 $plant^{-1}$) and days to 50% ripening (94.03 $plant^{-1}$) (Table 4.2).

These results are in conformity with the findings of Angne *et al.* (1993) for growth parameters, Yadav (2003) for plant height and Arora *et al.* (1971) for plant height, lateral branches and number of trifoliate leaves in cowpea, Mc Ewen (1973) for plant height in field bean, Singh and Tripathi (1994) for plant height, branches and leaves per plant and Dwivedi *et al.* (1995) for plant height, number of leaves and branches per plant in french bean.

These high productions in all the parameters might have increased the photosynthetic area and activity of the crop leading to better growth and yield components contributing to more yields.

Significantly least grain yields (1296 kg ha^{-1}) and above ground biomass yield (14424 kg ha^{-1}) was recorded with 45 x 20cm row spacing due to the significantly lowest growth and yield components.

CONCLUSIONS AND RECOMMENDATIONS Conclusions

Tied ridges with cross bars at 2.5m interval with the spacing of 60 x 20cm (W3 /S1) and open ridges with a spacing of 60 x 20cm (W3/S1) recorded the highest grain yield of 1408 kg/ha and 1296 kg/ha respectively.

Recommendations

An assessment of adaptation of more cowpea genotypes at different environments across years is recommended. The investigation provided sufficiently evidence to continue with further studies.

REFERENCES

Angne, M.N., Patil, R.A., Mahadkar, U.V. And Khanvilkar, S.A., 1993, Response of cowpea to nitrogen, phosphorus and stand geometry. *Journal of Maharashtra Agricultural Universities*, 18(1): 121-122.

Arora, N.D., B.S Malik, and G.P.Lodhi, (1971), Studies on the effect of row spacing and seed rate on the grain yield of cowpea (*Vigna sinensis* L.). *Haryana Agricultural University Journalof Research*, 3: 28.boards, or shades applied at different stages of plant development

Gill, P.S. Kanwar Singh and H.P. Tripathi, (1977), Effect of seed rates and row spacings on the forage yield of cowpea (Vigna unguiculata L.) varieties. Haryana Agricultural University Journal of Research, 2:1-6.

Gok, 1989: Marsabit District Development Plan 1989 – 1993: Ministry of Planning and National Development, Government of Kenya: Government Printer, Nairobi, Kenya, pp 1 – 24.

Gok, 1994c: Marsabit District Development Plan 1989 – 1993: Ministry of Planning and National Development, Government of Kenya: Government Printer, Nairobi, Kenya, pp 1 – 43.

Gok, 2002b: Marsabit District Development Plan 2002 – 2008: Government of the Republic of Kenya, Ministry of Planning and National Development, Government Printers, Nairobi, Kenya, pp 3 – 49.

Heluf Gebrekidan and Yohannes Uloro; Soil and water conservation (tied ridges and planting methods) on cultivated lands: The case of eastern Ethiopian; Soil and Water Management Research Program, Alemaya University (AU); 2002; 154p.

Jackai, L. E. N., R.A, Daoust, (1986). Insect pests of cowpeas. Annual Review of Entomology. Vol 31: 95-119.

Lost Crops Of Africa: Volume Ii: Vegetables (2006). Development, Security, and Cooperation (DSC). Online read-only: The National Academy Press: www.nap.edu/catalog/11763.html

Muya, E. M., Obanyi, S. N., Ngutu, M., Bulle, H., Dub G., Mamo, S., Okoti, M., Charfi, H., Miano, D. and Maingi, P. (2010).Characterization of Mountains and Oasis Areas of Kenya Arid and Semi-Arid Lands. Kenya Agricultural Research institute, Marsabit, Nairobi 86pp

Singh, S. R., H.F Van Emden, (1979). Insect pests of grain legumes. Annual Review of Entomology. Vol 24: 255-278.

Singh, S.R., K.O,Rachie. (Eds.)(1995). Fungal, Bacterial and Viral Diseases of Cowpeas in the USA- Patel, P.N. Chapter 14 in Cowpea Research, Production and Utilization. John Wiley & Son. http://www.hort.purdue.edu/newcrop/afcm/cowpea.html

Thimmegowda, S., 1990, Influence of row spacing and fertilizer levels on straw and bhusa of *Dolichos lablab* under rainfed cropping. *Current Research*, 19: 106-107.

Verma, C.M., 1975, Effect of spacing and phosphatic fertilizer on forage and seed yield of Dolichos lablab var. lignosus. Annals of Arid Zone, 14: 235-240.

Warui H.M (2000). The socio-economic and ecological impact of land use changes and charcoal production on Marsabit Mountain. International Livestock Research Institute (ILRI), Nairobi, Kenya 8 pp

Yadav, G.L., 2003, Effect of sowing time, row spacing and seed rate on yield ofcowpea under rainfed condition. Indian Journal of Pulses Research, 16 (2): 157-158. yield of soybean. *Crop Science* 18: 29-34.