EFFECTS OF SPACING, ROW ARRANGEMENT AND GENOPTYPE ON GRAIN YIELD OF PIGEONPEA (*Cajanus cajan* (L) Millsp) INTERCROPPED WITH SORGHUM

BY

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DECLARATION

I, Adam Mohammed Nsengo Swai, hereby declare that all the work presented in this dissertation is my own work and has not been submitted for a degree at this or any other University.

Signature ....

Date ....

APPROVAL

This dissertation of Adam Mohammed Nsengo Swai is approved, fulfilling part of the requirements for the award of the Master of Science Degree in Agronomy (Crop Sciece) by the University of Zambia.

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Kalinda ------------------------ 28/11/99

DEDICATION

To Allah, the creator and sustainer: my wife Ramlah and the children; Issah, Meku and Moza for the tolerance, true love and patience during the two years I was away from home. To my parents, brothers and sisters for all they did for me.

A LIST OF ACRONYMS

ESD	=	Extra Short Duration
SD	=	Short Duration
MD	=	Medium Duration
LD	=	Long Duration
UNZA	=	University of Zambia
ZAMSEED	=	Zambia Seed Company
ICRISAT	=	International Crop Research Institute for Semi-Arid Tropics
LER	=	Land Equivalent Ratio
PAR	=	Photosynthetically Active Radiation (400-700nm)
N	=	Nitrogen
P	=	Phosphorus
WAE	=	Week After Emergence

ABSTRACT

An experiment was conducted at UNZA and ZAMSEED farms in Lusaka Zambia, during the 1994/95 season to study the effects of spacing, row arrangement and genotype on the grain yield of Pigeonpea *(Cajanus cajan (L.) Millsp)* intercropped with Sorghum *(Sorghum bicolor)*.

A split-split plot design was used with genotypes [Short Duration (SD) and Medium Duration (MD)] as sub-subplots, spacings (70 cm x 30 cm; 60 cm x 40 cm; 50 cm x 50 cm) as the sub-plot and the row arrangements (1:1 and 2:1)as main plots.

Sorghum (KUYUMA cv.) was planted in single and double rows 20 cm apart and the within row spacing of 50 cm. Recommended basal fertilizer application of 30 kg N ha^{-1} and 8 kg P ha^{-1} were applied by broadcasting at planting. Other husbandry practices were also timely ensured.

Due to prolonged terminal moisture stress which coincided with flowering stage, the medium duration genotype failed to produce grains therefore omitted in the results. Increased spacing led to a decline (r= -0.487) in the grain yield of pigeonpea, but had no effect (r= 0.196) on grain yield of sorghum. The 70 cm x 30 cm spacing gave the highest overall productivity (LER = 1.4). The combination of 1:1 row arrangement and a spacing of 70 cm x

30 cm gave the highest grain yield (519 kg ha^{-1}) of pigeonpea; in contrast to the combination of 2:1 row arrangement and a spacing of 50 cm x 50 cm that gave the highest yield (4667 kg ha^{-1}) of sorghum. The best combination of row arrangement and spacing was 1:1 and 60 cm x 40 cm which gave an overall productivity of LER=1.85. The fact that all the intercrop treatments had relatively higher LER (1.07-1.85), signify that pigeonpea/sorghum intercropping was more advantageous than monocropping of either of the two crops. On average, the pigeonpea/sorghum intercropping system provided 103% of the equivalent yield of sorghum and 43% of the sole pigeonpea. Effects of row arrangement of yield components of pigeonpea revealed that the control gave the highest branches/plant (15) while 2:1 produced the highest number of seeds/plant (174). The control also gave the highest 100 seed weight (15.1 g). For sorghum the 1:1 row arrangement gave the highest 100 seed weight (4.8 g).

There was no significance difference among the row arrangements nor among the spacings for pigeonpea height. However, the change in spacing had a significant ($P \leq 0.05$) effect on the height of sorghum at 6 weeks after emergence (WAE). Tallest plants for pigeonpea and sorghum (124.2 cm and 173.6 cm respectively) were observed in the 2:1 arrangement and 60 cm x 40 cm spacing. Basing on the results it is concluded that 1:1 arrangement and

70 cm x 30 cm spacing were the most suitable combination for higher yield of pigeonpea. On the other hand, the 2:1 row arrangement and 50 cm x 50 cm spacing were the most suitable combination for increased yield of sorghum. In an intercrop the best combination for increased productivity was 1:1 row arrangement and 60 cm x 40 cm spacing.

Though no inference could be drawn on the effect of MD genotype on the grain yield of the intercrop, more research work on the same is required to extend to other agro-ecological zones for verification purpose.

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My sincere thanks are also extended to ZAMSEED Company through the Production and Farm Managers for providing the experimental site and labour on demand for farm operations.

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1.0 INTRODUCTION

Pigeonpea (*Cajanus cajan* (L) Millsp) is one of the most important pulse crops of the world and is a major source of protein to many people (Nene and Sheila, 1990; Kimani et al., 1994). In Africa, major pigeon-pea producing countries include Kenya, Malawi, Uganda, Tanzania, Zaire, Nigeria, Zambia and Ghana at altitudes ranging from sea level to 2050 m above sea level (Van der Maesen, 1983; Ali, 1990; Nene and Sheila, 1990). Published reports on cropping systems involving pigeonpea are however scanty.

In Eastern and Southern Africa, pigeonpea is grown as a sole crop or as an intercrop with either cereals such as maize or sorghum, short duration legumes like cowpea, or other long duration annuals such as cassava (Laxman 1991; Silim et al.,1991). Pigeonpea/sorghum, pigeonpea/maize, and pigeonpea/groundnuts combinations are by far the most popular intercrops in Africa and South Asia (Ali, 1990; Nene and Sheila, 1990; Silim and Omanga, 1992). Special attention is now being paid to analyzing production constraints in these intercrops so as to improve their productivity (Tuwafe et al.,1993).

Like other intercrops, intercropping pigeonpea with sorghum has numerous advantages in terms of enhancing diversity of diet and income source, stability of production, reduced insect and disease incidence, efficient use of family labour, and intensive production with limited land resources (Tuwafe et al., 1994). The same authors have also observed that pigeonpea provides long-term benefits in terms of nitrogen fixation, increased phosphorus availability, and improved soil structure.

Generally, the productivity of pigeonpea/sorghum intercropping is low. In Eastern Africa (Tanzania, Kenya, Uganda), the average grain yields of small scale farmers are very low (less than 1 to t ha^{-1}) as compared to 1.2 - 4 t ha^{-1} obtained from experimental plots of short and long duration genotypes (Musaana, 1978; Kimani et al., 1994; Mligo and Myaka, 1994). In Zambia, the grain yield from experimental plots of short and medium duration pigeonpea genotypes ranges between 1.0 and 3.5 t ha^{-1} (Mulila-Mitti, 1994).

Tuwafe et al (1994) have reported that the low productivity of pigeonpea in pure stand and in intercrop is due to inadequate and variable plant density, drought stress and losses caused by pests and diseases. Venkateswarly et al. (1981) have reported that high productivity from sorghum/pigeonpea intercrop was obtained when the optimal population of both crops (18 plants m^{-2} for sorghum and 4 plants m^{-2} for pigeonpea) were maintained in a 2:1 row arrangement. This might not be the case for all the other places. Field trials are needed to research on the various production constraints so as to improve the current yield levels.

In Zambia, the Food Legume Research Team has identified short duration (SD) and medium duration (MD) pigeonpea genotypes which need to be evaluated and introduced into the cropping system. For such an introduction to be successful, trials are needed to determine the most appropriate genotype(s) for intercropping, intercropping pattern, and other agronomic information currently not available.

The objective of this research therefore, was to identify suitable genotype(s) of pigeonpea, spacing and row-arrangement for increased grain yield of pigeonpea/sorghum intercrop under Zambian conditions.

2.0 LITERATURE REVIEW

2.1 General

Pigeonpea (*Cajanus cajan* (L) Millsp) is one of the major grain legume (pulse) crops of the semi-arid tropics where it is used either as staple diet, key diet supplement or major source of income for one sixth of the world's population (Mughogho, 1994; Nene and Sheila, 1990). It is a hardy plant that, when intercropped with cereals, ensures a measure of food and income stability.

India accounts for over 80% of the world supply of pigeonpea (ICRISAT, 1986). In Africa, particularly Eastern and Southern Africa, pigeonpea is commonly intercropped or mix-cropped with sorghum, maize, cowpea or cassava (Tuwafe et al., 1994; Laxman Singh, 1991; Silim et al., 1991). Surveys conducted between 1990 and 1993 in Kenya, Tanzania and Uganda suggest that the total area under pigeonpea in these countries was well over 800,000 ha. The reported yields ranged between 300 and 500 kg ha^{-1} (Omanga et al., 1991) which is an underestimate because it does not include a large proportion consumed as green peas (Silim and Omanga, 1992, Tuwafe et al., 1994).

Pigeonpea is consumed mainly as cooked whole dry seed or as green peas. Leaves can be used for forage while stems served as fuel wood (Nene and Sheila, 1990). According to Tuwafe et al. (1994), the export potential of split pigeonpea (dhal) is high, and there is considerable scope to increase utilization at both domestic and export levels. Currently, there are large agro-processing plants in Kenya, Malawi, and Tanzania which dehull pigeonpea seeds for local consumption and for export to India, Middle East, Europe, and North America. Both processing capacity and export demand for pigeonpea, far exceed production levels. Similarly, demand for export of whole grain is greater than supply (Shah, 1992).

2.2 Yield potential

Inspite of its importance, farmers' yield of pigeonpea is still low. In Eastern and Southern Africa, the average grain yields are less than 1.0 t ha^{-1} as compared to 1.2 - 4.0 t ha^{-1} obtained from experimental plots of short and long duration genotypes (Musaana, 1978; Kimani et al., 1994; Mligo and Myaka, 1994).

In Zambia, Mulila-Mitti (1994) reported yields of 1.0 - 3.5 t ha^{-1} obtained from experimental plots of short and medium duration pigeonpea genotypes. By the following year, Mulila-Mitti et al. (1995) reported lower yields of 0.44 - 1.74 t ha^{-1} and 0.41 t ha^{-1} for 12 SD genotypes and 18 LD genotypes respectively, recorded from sole stands.

The productivity of pigeonpea/sorghum intercrop, like other intercrops, is greatly influenced by several factors among which is the selection of compatible crops with reference to the rainfall characteristic and edaphic conditions of the region, identification of genotypes with varying duration and growth rhythms, use of suitable sowing geometry, optimal populations of the component crops, fertilizers at the optimum rate and proper management of pests, disease and weeds (Ali, 1990; Steiner, 1982; Andrews and Kassam, 1976).

The efficiency of intercrops can be assessed by using Land Equivalent Ratio (LER) in combination with the absolute yields of the component crops (Steiner, 1982). In Sudan, the intercrops of pigeonpea with millet, groundnuts, sesame and cowpea gave LER of 0.4, 1.0, 1.1 and 0.7 respectively (El Award et al., 1995).

A report by Reddy et al. (1989) on three pigeonpea genotypes intercropped with maize in Zambia showed LER values of 1.03 - 1.98.

2.3 Compatible Crops

Selection of compatible crops is done basing on their peak periods of growth. Crops of varying maturity duration are chosen so that a rapidly maturing crop completes its life cycle before the major growth period of the other crop starts. Results of a study conducted by Willey et. al., (1981) at ICRSAT on Medium duration pigeonpea intercropped with sorghum and groundnuts showed that initial slow growth rate of pigeonpea offers good scope for intercropping with fast-growing early maturing sorghum or groundnut.

Rao and Willey (1981) analyzed results from 80 experiments on pigeonpea/sorghum intercrops and found that, on average, the intercropping system provides 90% of the equivalent yield of sole sorghum and 52% of the sole pigeonpea.

Ali (1990); Nene and Sheila (1990) have reported that other crops can be intercropped with pigeonpea and these included maize, pearl millet, rice, finger millet, urdu beans, mung bean, cowpea, groundnuts, sesame, and soya bean. In such intercrops, the yields of both crops were reduced as compared to their sole crop yields, but the total productivity and LER of the system were usually higher. According to Ali (1990) intercropping of pigeonpea with such long duration crops as cotton and castor has not given encouraging results, probably due to their similar growth pattern.

In Zambia, pigeonpea is generally grown by small farmers in their home backyards and around the fields of annual crops. Studies on the genotypic compatibility of pigeonpea/maize intercropping (2 maize: 1 pigeonpea) revealed that LRG 30, C 11 and ICP 7035 were ideal genotypes for maize/pigeonpea intercropping (Kannaiyan et al., 1988). The yield of intercropped maize was the same as that of sole-crop maize (3.99 t ha^{-1}). According to Mulila-Mitti et al. (1989), trials of groundnut intercropped with pigeonpea produced 78% of the sole groundnut yield and 46% intercropping benefit. Less benefit was obtained when groundnut was intercropped with maize and sorghum.

2.4 Genotypic compatibility

The identification of compatible genotypes for component crops is required for the complementarity of an intercropping system. Selection is done on the basis of genotypes duration, growth rhythm, canopy structure, and rooting pattern. There is experimental evidence to show that the genotypes which give high yields in sole-cropping systems are not necessarily high yielders in intercropping systems (Rao et.al., 1981).

High yield advantages can be expected only when the maturity period of the genotypes differ widely. Ali (1990) reported that in pigeonpea/sorghum intercrop, the longer the duration of sorghum the lower is the yield of pigeonpea. Intercropping with short duration pigeonpea often leads to drastic reduction in pigeonpea yield. However, early-maturing dwarf sorghum hybrids and determinate (150-day duration) pigeonpea cultivars have proved to be most promising in intercropping systems at ICRISAT Centre (Venkateswarlu at al., 1981).

The canopy structure of the component crop genotypes also determines species compatibility. Ali (1990); Rao et al. (1981) have compromised that the ideal pigeonpea genotypes are those that grow compactly in their early stages thus avoiding competition from the intercrop, but later develop a spreading habit so that they can utilize available resources. In a pigeonpea/sorghum intercrop, a compact but long duration (270 -

280 days) genotype proved better than the medium duration (240 - 250 days) one (Kushwaha, 1987).

Ali (1990); reported that some of the intercropped genotypes produced identical or higher yields than when they were sole cropped. The same author pointed out that detailed studies are needed to examine the behaviour of genotypes of different sowing geometries and population densities.

2.5 Sowing Pattern and Plant Density

The sowing pattern and spatial arrangement of the intercrops considerably influence competition among component crops (Choudhary and Bhargava, 1986). The same authors reported that a suitable plant geometry is the one that minimizes competition and at the same time enhances total productivity. When the component crops are sown in rows, different row ratios are used depending on the importance and growth rhythms of the components. A suitable sowing pattern allows more radiation to reach dwarf component crops grown between the base crop rows, and minimizes competition.

Shelke and Krishnamoorthy (1980) observed that in sorghum/pigeonpea intercrop, the yield of the component crops increased as their proportion was increased from 1:4 to 4:1. The yield of sorghum in the 1:4 row ratio was 1.02 t ha^{-1} as against 3.63 t ha^{-1} in the 4:1 row ratio. Similarly, pigeonpea yield was increased from 0.65 t ha^{-1} to 2.20 t ha^{-1} as its population increased in the system. Ali and Raut (1985) found that a 2:1 row ratio of pigeonpea/sorghum system with 67% sorghum population and 33% pigeonpea population equivalent to their sole-crop populations proved most productive and efficient on Alfisols of Bundelkhand.

Summarizing results of 80 experiments on sorghum/pigeonpea intercrops, Rao and Willey (1981) found that a 2:1 ratio was better than a 1:1 ratio.

Low plant populations are generally recognized as one of the constraints in the productivity of intercropping systems. Studies conducted by All India Coordinated Research Project for Dryland Agriculture(AICRPDA) have shown that high productivity of sorghum/pigeonpea intercrops was obtained when the optimal populations of both crops (18 plants m^{-2} for sorghum and 4 plants m^{-2} for pigeonpea) were maintained in a 2:1 row arrangement

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Natarajan and Willey (1980) observed that in pigeonpea/sorghum intercropping, pigeonpea yields were limited by poor light interception after the sorghum harvest. An increase in pigeonpea population improved light interception and productivity. Willey et. al (1981) have reported results of sorghum/pigeonpea intercrop studies conducted at ICRISAT Centre whereby the normal populations of sorghum (18 plants m^{-2}) and pigeonpea (4 - 5 plants m^{-2}) were maintained. The sorghum produced 4.2 t ha^{-1} as against 4.5 to ha^{-1} (its sole crop yield). After the sorghum harvest, the pigeonpea was free from competitions and finally produced 54% of its sole - crop dry matter.

3.0 MATERIALS AND METHODS

This study was conducted at ZAMSEED and UNZA Farms, concurrently during 1994/95 season.

3.1 Site description

Two sites, Zamseed Farm and UNZA field station were located within Lusaka which is at 15^0 23'S, 28^0 E and 1140 metres above sea level. The climate in this province has a marked wet and dry season of about five and seven months respectively.

The soil class for both sites was Ferric Luvisols according to FAO classification. The texture was fine clay loam and sandy loam for UNZA and ZAMSEED sites respectively.

3.2 Agricultural Inputs

Seeds of two pigeonpea genotypes CPL 87105 short duration (SD) and ICP 7035 medium duration (MD), were provided by the Legume Improvement Programme of the Ministry of Agriculture Food and Fisheries. Sorghum seeds (KUYUMA cv.) were bought from ZAMSEED Company. Germination test was carried out for the two genotypes and sorghum before planting in order to adjust seeding rate.

Nitrogen and phosphorus fertilizers i.e. Urea (NH_2CONH_2) and triple super phosphate ($Ca(H_2PO_4)_3.H_2O$), were used to provide 30 kg N and 8 Kg P ha^{-1}, respectively.

3.3 Soil Analysis

This was carried out before planting at both sites to determine the general fertility status in terms of nitrogen, phosphorus, and pH. The results were very useful in derterming the fertilizer rates used. Details of the soil analysis are given in Appendix A.

3.4 Field Experiment

The total experimental area was 0.2 ha per site. The experiment was a factorial with three factors in three replications at each site. The three factors were (i) Two pigeonpea genotypes CPL 87105 (SD) and ICP 7035 (MD) (ii) Two row-arrangements (1:1 and 2:1) and (iii) Three spacings, 70 cm x 30 cm, 60 cm x 40 cm and 50 cm x 50 cm.

A split-split plot design was used whereby the genotypes were the sub-subplots, the spacings as the subplots, and sorghum row arrangements as the main-plots. Each replication consisted of fifteen (15) randomized treatments. The sole crop treatments were included as controls. The field layout for the experiment is presented in Appendix B.

3.4.1 Treatments

T1 : G1S1A1	T4 : G2S1A1	T7 : G1S1A2	T10 : G2S1A2
T2 : G1S2A1	T5 : G2S2A1	T8 : G1S2A2	T11 : G2S2A2
T3 : G1S3A1	T6 : G2S3A1	T9 : G1S3A2	T12 : G2S3A2
T13: G1(Sole)	T14: G2(Sole)	T15: SO (Sole)	

Key: T - Treatment S - Spacing (Sub-plot)

G - Genotype (Sub-subplot), A- Row arrangement (Main plot)

S1= 70 cm x 30 cm (i.e. 47619 plants ha^{-1})

S2= 50 cm x 40 cm (i.e. 41667 plants ha^{-1})

S3= 50 cm x 50 cm (i.e. 40000 plants ha^{-1})

A1= 1 row of sorghum between 2 rows of pigeonpea

A2= 2 rows of sorghum between 2 rows of pigeonpea

G1= CPL 87105 (SD)

G2= ICP 7035 (MD)

SO= Sorghum (KUYUMA cv.)

NOTE: T13, T14 and T15 were controls i.e. Sole stands of Sorghum and pigeonpea.

3.4.2 Plot Size

The size of the sub-subplot was 6 m long and 4.2 m wide, while that of subplot was 6 m by 8.4 m. The main-plot size was 18 m by 8.4 m. Due to the difference in pigeonpea inter-row spacing, the number of rows per plot varied from 6 - 8.

3.4.3 Planting

Planting took place after the onset of the rainy season on 15^{th} to 16^{th} December and 20th to 21^{st} December, 1994 for UNZA and ZAMSEED farms respectively. Both pigeonpea and sorghum were sown on the same dates.

3.4.4 Fertilizer Application

Basal dressing of 30 kg N ha^{-1} and 8 kg P ha^{-1}, were applied, to the pigeonpea/sorghum intercrop by broadcasting at planting. There was no top dressing.

3.4.5 Weeding, Pests and Diseases Control

Three weedings were carried out, to ensure minimal competition from weeds.

Dursban and Karate chemicals were used at 35 and 40 ml/151 of water respectively, to control *Spodoptera exempta, Busseolla fusca, Melanogromyza obtusa* and termites which appeared to be the main pests from the seedling stage to just before flowering period.

3.5 Parameters of Evaluation

The following data were collected from the experiment during the growing season and at harvest:

(i) Plant height of pigeonpea and sorghum.

The height measurements were taken every 2 weeks. The height of the plant was measured from the ground level to the central growing tip.

(ii) Grain yield of pigeonpea and sorghum per plot.

The harvested area per plot was $4m^{-2}$ (2 m x 2 m) from which the pigeonpea pods and sorghum panicles were harvested and processed.

(iii) Yield components

These included number of branches/plant, pods/branch, grains/pod, seeds/plant and 100 seed weight. All these were counted from a sample of 10 plants obtained from the harvested area. The seed weight was obtained by weighing 100 seeds of each crop from each treatment in the experiment. The number of plants in the harvested area was also counted.

(iv) Land Equivalent Ratio (LER) as a measure of relative yield advantage was calculated by using the yields of sole and intercrop treatments (Stainer, 1982) as follows:-

LER = LA + LB = YA/SA + YB/SB; where LA and LB are land equivalent ratios for pigeonpea and sorghum.

YA and YB are the crop yields of pigeonpea and sorghum in intercrops.

SA and SB are the yields of sole crops for pigeonpea and sorghum.

A ratio greater than 1 indicates a yield advantage, and a ratio less than 1 means a yield disadvantage.

3.6 Data Analysis

The collected data were analyzed using MSTAT programme; and means were separated by using Duncan Multiple Range Test (DMRT) at $P \leq 0.05$. The correlation analysis was performed using the same programme in order to get correlation coefficients for different parameters of interest.

4.0 RESULTS

4.1.0 General

The climatic data (rainfall, temperature and relative humidity) for 1994/95 season are given in Appendix C. The amount of rainfall (< 500 mm) was not adequate for proper crop growth and development. The last and lowest rainfall (23.9mm) was obtained in the first week of March when the pigeonpea was at flowing stage.

The general soil fertility status of the two sites (ZAMSEED and UNZA) in terms of nitrogen, phosphorus, and pH are in Appendix E.

Due to prolonged drought stress during the reproductive phase of crop growth (Appendix C), all the data from UNZA site were discarded. Also data for the medium duration genotype, ICP 7035 on the grain yield and yield components could not be obtained. For this reason, only results for ZAMSEED site involving the CPL 87105 (SD) pigeonpea will be presented in this study.

4.2.0 Effect of row arrangement on grain yield of pigeonpea and sorghum

The 1:1 row arrangement had significantly ($P \leq 0.05$) higher yield of pigeonpea than the 2:1 arrangement (Table 1). Row arrangement on the other hand had no effect on the grain yield of sorghum. The correlation coefficients for row arrangement against yield were r= -0.743 and r= -0.180 for pigeonpea and sorghum, respectively (Appendix D).

Highest overall performance of the intercrop (LER = 1.5) was obtained in the 1:1 arrangement as compared to the 2:1 arrangement (LER = 1.3) which represented an increase of 20%.

The control gave the highest yield of pigeonpea (696.0 kg ha^{-1}) while the 2:1 row arrangement had the lowest (317.0 kg ha^{-1}). Row arrangement had no effect on yield when compared to the control for sorghum.

Table 1: Effect of row arrangement on the average grain yield (kg ha^{-1}) and LER of pigeonpea and sorghum

Row arrangement	Pigeonpea	Sorghum	LER
1:1	483.7b[$]	3958.3a	1.5a
2:1	317.0c	3927.1a	1.3b
Control	697.0a	3833.3a	1.0c
Mean	498.9	3906.2	1.3
CV (%)	10.16	24.82	27.6

$ Means with the same letter are not significantly different at ($p \leq 0.05$).

4.3.0 Effect of spacing on grain yield of pigeonpea and sorghum

Table two shows significant differences ($P \leq 0.05$) among spacings for pigeonpea yield. Sorghum yield on the other hand was not affected by the change in spacing. There was significant difference ($P \leq 0.05$) between 70 cm x 30 cm and 50 cm x 50 cm; similarly differences were observed between 60 cm x 40 cm and 50 cm x 50 cm. Highest yield of pigeonpea (697 kg ha^{-1}) was obtained in the control treatment while that of sorghum (4208.3 kg ha^{-1}) was obtained in the 50 cm x 50 cm spacing, though not different from the control at 3833 kg ha^{-1}.

Table 2: Effect of spacing on the average grain yield (kg ha^{-1}) and LER of pigeonpea and sorghum

Spacing	Pigeonpea	Sorghum	LER
70 cm x 30 cm	483.1b[$]	3847.2a	1.4a
60 cm x 40 cm	450.5b	3736.1a	1.3a
50 cm x 50 cm	365.4c	4208.3a	1.3a
Control	697.0a	3833.3a	1.0b
Mean	498.9	3906.2	1.3
CV (%)	10.16	24.82	25.35

$ Means with the same letter are not significantly different at ($P \leq 0.05$)

The correlation analysis showed that while yield of pigeonpea decreased with increased spacing (r= -0.487) (Appendix D), the yield of sorghum was not affected (r= 0.196). The highest overall performance (LER = 1.4) for both crops was in 70 cm x 30 cm spacing but not different from the other spacings other than the control.

4.4.0 Interaction effect of row arrangement and spacing on yield of pigeonpea and sorghum

Table 3 shows that yield of pigeonpea in 1:1 row arrangement decreased significantly ($P \leq 0.05$) from 519.0 k ha^{-1} to 246.2 kg ha^{-1} as spacing changed from 70 cm x 30 cm to 50 cm x 50 cm. The 2:1 arrangement, had no effect.

There was significant interaction between row arrangement and spacing for pigeonpea yield as evidenced by the change in the magnitudes of yield from one spacing to another in the different row arrangements [Appendix E, Table 3, Fig (a)]. There was no significant ($P \leq 0.05$) interaction between row arrangement and spacing for sorghum yield though a tendency to change ranking as *spacing changed was evident* from one row arrangement to another [Appendix F, Table 3, Fig 1 (b)].

The combination of 1:1 row arrangement and 60 cm x 40 cm spacing gave the highest numerically overall performance (LER = 1.8) for the intercrop. The control treatment was significantly ($P \leq 0.05$) different from all row arrangement by spacing combinations with respect to pigeonpea yield only.

Table 3: Interaction effect of row arrangement and spacing on grain yield (kg ha^{-1}) and LER of pigeonpea and sorghum

Arrangement	Spacing										
	70cm x 30cm			60cm x 40cm			50cm x 50cm			Control	
	P/pea	Sorgh	LER	P/pea	Sorgh	LER	P/Pea	Sorgh	LER	P/Pea	Sorgh-
1:1	519b	3583a[$]	1.7a	472b	4292a	1.8a	246c	4125a	1.5a	697a	3833a
2:1	236c	4125a	1.4a	182c	3083a	1.1a	153c	4667a	1.4a	697a	3833a
Ctr	697a	3833a	1.0a	697a	3833a	1.0a	697a	3833a	1.0a	697a	3833a
Mean	484	3847	1.4	450.3	3736	1.3	365.3	4208.3	1.3	697a	3833a

CV (%) P/Pea 10.16 Sorgh 24.82 LER 22.82

[$] Means with the same letter are not significantly different at ($P \leq 0.05$)

4.5.0 Effect of row arrangement on the 100 seed weight (g) of pigeonpea and of sorghum

There was no significant difference among row arrangements for 100 seed weight of pigeonpea and of sorghum (Table 4). The similarity in the seed weights for both crops at different row arrangements was observed when compared to the control.

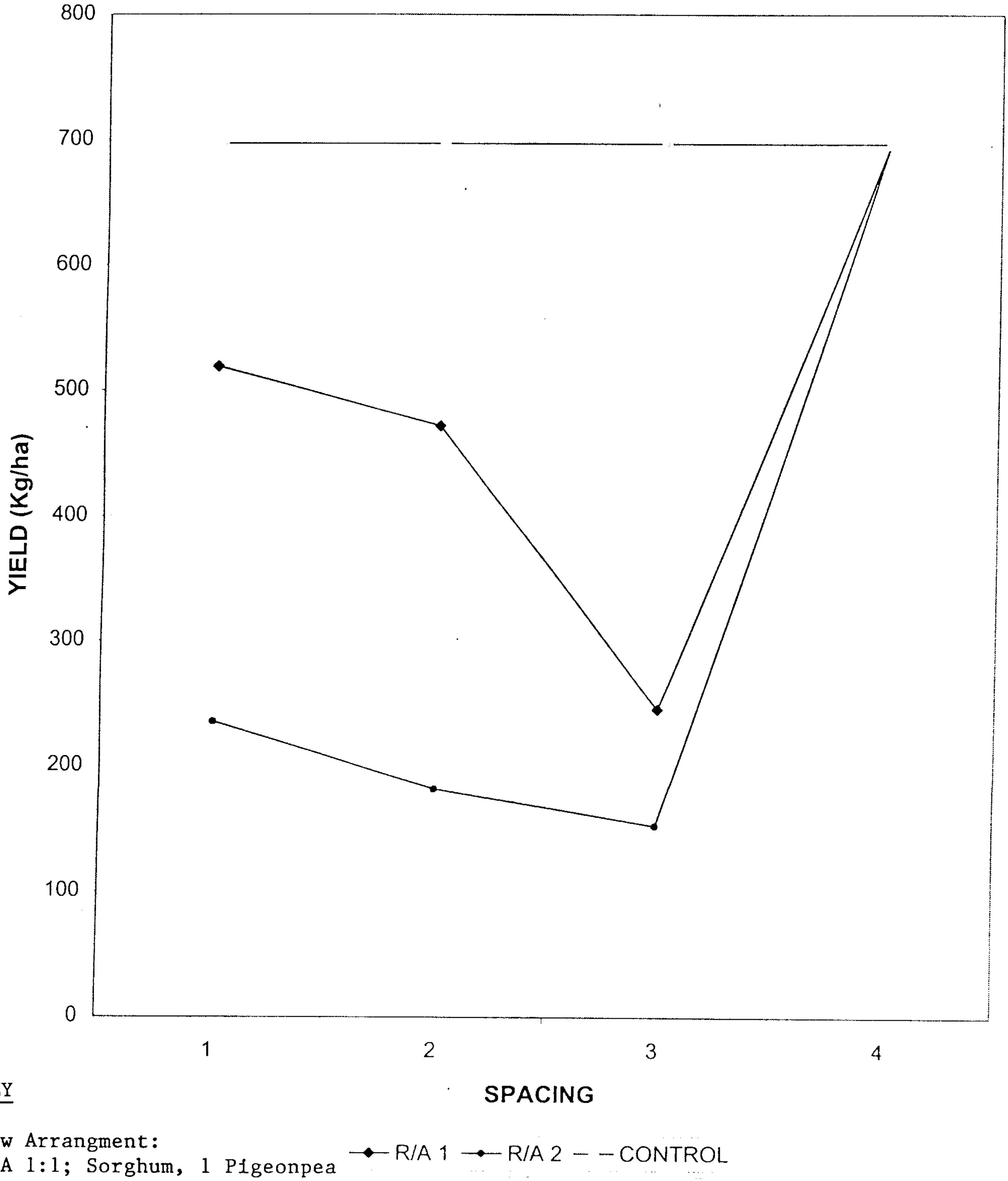
4.6.0 Effect of spacing on the 100 seed weight of pigeonpea and of sorghum

The control treatment gave the highest 100 seed weight (15.1g) for pigeonpea compared to 14.4g at the 60 cm x 40 cm Spacing which was not different from other spacings (Table 5). The 100 seed weight for sorghum was highest (4.8g) in the 60 cm x 40 cm though not different from the 50 cm x 50 cm which in turn was similar to the other spacings; including the control. Change in spacing tended ($r = -0.125$) to reduce 100 seed weight for pigeonpea while increasing ($r = 0.409$) that for sorghum (Appendix D).

4.7.0 Interaction effect of row arrangement and spacing on the 100 seed weight (g) of the pigeonpea and of sorghum

The effects of a change in both spacing and row arrangement on 100 seed weight of pigeonpea and of sorghum are presented in Table 6. No significant ($P \leq 0.05$) differences were observed among the different combinations of spacing and row arrangement on the 100 seed weight of pigeonpea and sorghum.

Figure 1 (a): Interaction effect of row arrangement and spacing on Pigeonpea yield (kg/ha).



Y

w Arrangment:
A 1:1; Sorghum, 1 Pigeonpea
A 2:1; Sorghum, 1 Pigeonpea

acing:
= 70cm x 30cm   3 = 50cm x 50cm
= 60cm x 40cm   4 = Control

Figure 1(b): Interaction effect of row arrangement and spacing on the yield of Sorghum (Kg/ha)

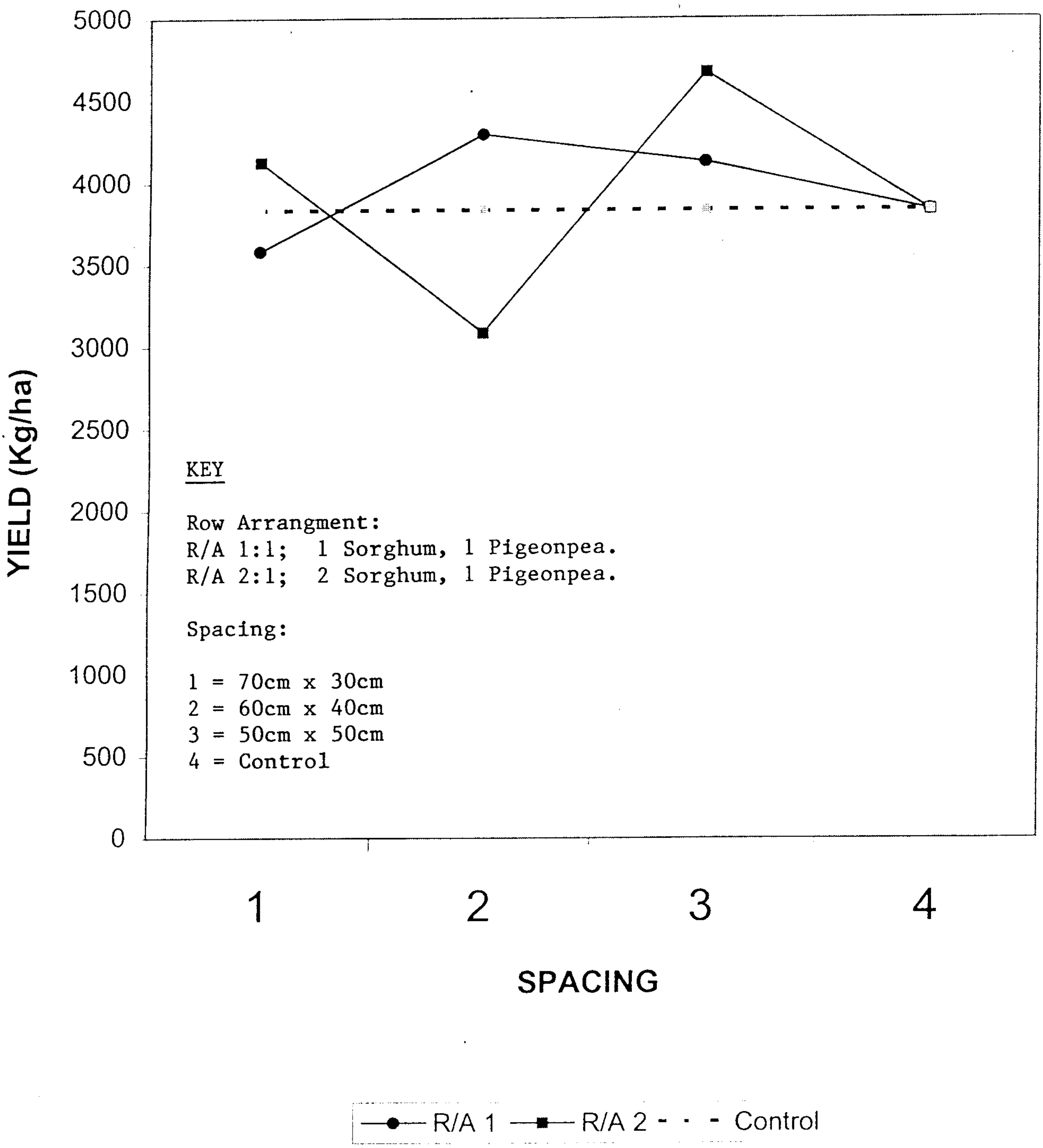


Table 4: Effect of row arrangement on the 100 seed weight (g) of pigeonpea and sorghum

Row arrangement	Pigeonpea	Sorghum
1:1	13.9a[$]	4.6a
2:1	14.5a	4.5a
Control	15.1a	4.0a
Mean	14.5	4.4
CV (%)	5.7	13.27

[$] Means with the same letter are not significantly different at ($P \leq 0.05$)

Table 5: Effect of spacing on the 100 seed weight (g) of pigeonpea and sorghum

Spacing	Pigeonpea	Sorghum
70 cm x 30 cm	14.3ab[$]	4.1b
60 cm x 40 cm	14.4ab	4.8b
50 cm x 50 cm	14.2b	4.6ab
Control	15.1a	4.0b
Mean	14.5	4.4
CV %	5.70	13.27

[$] Means with the same letter are not significantly different at ($P \leq 0.05$).

Table 6: Interaction effect of row arrangement and spacing on the 100 seed weight (g) of pigeonpea and sorghum

	Spacing					
Row Arrangement	70cm x 30 cm		60cm x 40 cm		50 cm x 50 cm	
	P/pea	Sorghum	P/pea	Sorgh	P/Pea	Sorgh
1:1	13.4a	4.0a$	14.0a	5.2a	13.2a	5.2a
2:1	14.5a	4.1a	14.1a	5.1a	14.2a	4.5a
Ctr	15.1a	4.0a	15.1a	4.0a	15.1a	4.0a

$ Means with the same letter are not significantly different at ($P \leq 0.05$).

4.8.0 Effect of row arrangement and spacing on the other yield components

The number of seeds/pod, pods/branch, branches/plant, seeds/plant and 100 seed weight for pigeonpea at different row arrangements and spacings are given in Table 7(a), 7(b) and 7(c). To the exception of number of branches per plant, row arrangement had no significant effect on the other pigeonpea yield components. The two row arrangements were significantly different ($P \leq 0.05$) from the control with respect to the number of branches per plant for pigeonpea. The control had the highest number (15) of branches per plant.

There was significant difference ($P \leq 0.05$) between the 70 cm x 30 cm spacing when compared to 60 cm x 40 cm spacing and the control treatments for the number of seeds per pod.

There was no significant different among the row arrangement by spacing combination for the pigeonpea yield components [Table 7(c].

4.9.0 Effect of row arrangement and spacing on the growth of pigeonpea and sorghum.

The effects of row arrangement and spacing on the plant height of pigeonpea and of sorghum are given in Appendix F. There was no significance difference among the row arrangements nor among the spacings for pigeonpea height. However, the change in spacing had a significant ($P \leq 0.05$) effect on the height of sorghum at 6 weeks after emergence. Interaction effect of row arrangement and spacing on the height of sorghum was also significant ($P \leq 0.05$) at 10 weeks after emergence. Tallest plants (174 cm) were observed in the 1:1 row arrangement and 60 cm x 40 cm spacing.

Table 7(a): Effect of row arrangement on the yield components of SD pigeonpea

Arrang	Sds*/pod	Pods/branch	Bra[ss]/plt[&]	Sds/plt	100 sd wt
1:1	3.3a[$]	4.3a	11.3b	177.8a	13.5a
2:1	3.2a	5.8a	10.0b	194.1a	14.2a
Control	3.3a	5.0a	15.0a	253.0a	15.1
Mean	3.3	5.0	12.1	208.3	14.3
CV %	11.74	50.6	15.53	50.0	5.7

[$] Means with the same letter are not significantly different at ($P \leq 0.05$). * Sds = Seeds [ss] Bra = No. of branches [&] plt = No. of plants; sd wt = Seed weight

Table 7(b): Effect of spacing on the yield components of SD pigeonpea

Spacing	Seeds/pod	Pods/branch	Bra/plt	Seeds/plt	100 sd wt
70cm x 30cm	3.0b[$]	4.7a	11.2a	172.0a	14.3ab
60cm x 40cm	3.4a	4.8a	10.1a	186.9a	14.4ab
50cm x 50cm	3.2ab	5.7a	12.1a	221.3a	14.2b
Control	3.4a	5.0a	15.0a	253.0a	15.1a
Mean	3.3	5.1	12.1	208.3	14.5
CV (%)	11.74	50.6	5.53	50.0	5.7

[$] Means with the same letter are not significantly different ($P \leq 0.05$)

Bra= No. of branches; Plt= No. of plants

sd wt= Seed weight

Table 7(c): Interaction effects of row arrangement and spacing on the yield components of SD pigeonpea.

RA X SPC	Seeds/pod	Pods/branch	Bra/plt	Seeds/plt	100 sd wt
1:1 x S1	2.7a[$]	4.7a	11.3a	154.7a	13.4a
1:1 x S2	3.7a	4.0a	8.3a	173.7a	14.0a
1:1 x S3	3.3a	3.3a	10.7a	130.0a	13.2a
2:1 x S1	3.0a	4.3a	7.3a	108.3a	14.5a
2:1 x S2	3.3a	5.3a	7.0a	134.0a	14.1a
2:1 x S3	3.0a	8.7a	10.7a	281.0a	14.2a
Control	3.3a	5.0a	15.0a	253.0a	15.1a
CV (%)	11.74	50.6	15.53	50.0	5.7

$ Means with the same letter are not significantly different ($P \leq 0.05$).

RA = Row arrangement

SPC = Spacing

S1 = 70 cm x 30 cm; S2 = 60 x 40 cm; S3 = 50 cm x 50 cm

plt = Plant; Bra = No. of branches; sd wt = seed weight

5.0 DISCUSSION

Low yield of pigeonpea obtained in this work could be attributed to poor crop establishment. Crop establishment depends on a number of factors among which moisture and temperature are limiting for crop emergence and hence establishment (Rowland, 1993). As a consequence, the poor establishment results into poor yield per unit area which in this case was caused by low moisture soon after planting and just before flowering (Appendix C).

Slatyer (1969) reported that moisture stress reduces rates of organ development and cell enlargement which in turn have many indirect effects on growth and physiological processes since nutrient inflow and protein and carbohydrate synthesis and metabolism are immediately affected by reduced development activity of cells and tissues. The effect on final biological and economic yield is the result of reduction in expansion of total leaf area (or the photosynthetic surface).

According to Lawn and Troedson (1990), the main effects of moisture stress on productivity of pigeonpea is in terms of the consequences for the efficiency of interception (Ei) and conversion (Ec) of photosynthetically active radiation (PAR) to biomass and the partitioning of biomass to seed.

Pigeonpea is known to have slow growth rate. This makes the crop less competitive against weeds as well as intercrop components. However, it is more advantageous to grow pigeonpea as an intercrop than as sole crop (Chauhan, 1990).

5.1.1 The effect of row arrangement on the grain yield of pigeonpea and sorghum

The increase in the yield of pigeonpea in 1:1 row arrangement compared to 2:1 row arrangement observed in this work (Table 1.0), has also been observed in the studies at ICRISAT Centre (Natarajan et al., 1985). They reported that under conditions where sorghum growth was very good and pigeonpea was suppressed, changing to a 1:1 row arrangement from 2:1 produced some overall benefit by giving a greater pigeonpea contribution without reducing sorghum yield. This was in conformity with results obtained in this study.

Studies conducted by Natarajan and Willey (1985) concluded that with a good moisture supply, alternate rows (1:1) could be an alternative to the 2:1 arrangement. With poorer moisture supply as was the case in the season of the present study alternate rows are not a worthwhile option because of the risk of reducing sorghum yield to an extent that cannot be offset by the small increase in pigeonpea yield.

In 1:1 row arrangement, it was likely that the competition for growth factors (light, water, nutrients) between pigeonpea and sorghum was less than in more dense 2:1 row arrangement; and as such the arrangement enhanced the productivity of pigeonpea. The correlation coefficient ($r = -0.743$) also indicated that there was a general trend of decreased yield of pigeonpea with increased rows of sorghum and vice versa.

The yield of sorghum in this trial was not affected by a change in the row arrangements. This contradicted the expectation as more yield was expected in 2:1 arrangement due to the high sorghum density in the latter arrangement. Probably the decline in sorghum yield in he 2:1 row arrangement was caused by increased intercrop and intracrop competition among the sorghum plants. In 2:1 row arrangement, sorghum plants were closer to each other and that resulted into more competition for growth factors, which consequently resulted into low yield. Summarizing results of 80 experiments on sorghum/pigeonpea intercrops, Rao and Willey (1981) found similar results that a 2:1 row arrangement was better than a 1:1 ratio for sorghum yield.

Results from pigeonpea/sorghum trial by Mligo and Myaka (1993) of different pigeonpea row arrangement showed that yield of pigeonpea increased from 0.57 to 1.45 t ha^{-1} in 1:1 to 2:1 row arrangement, respectively. Sorghum yield in this case decreased from 1.68 to 1.42 t ha^{-1}. From these results, there are indications that competition for growth factors among pigeonpea plants was less and that accounted for the increase of its yield in the 2:1 row arrangement.

Other results obtained by the same authors gave lower yields of sorghum (1.68 t ha^{-1}) at the recommended high density (88,800 plants ha^{-1} as compared to 1.96 t ha^{-1} at farmers density (37,000 plants ha^{-1}) when both were grown in 1:1 row arrangement with pigeonpea. The pigeonpea grain yields were 0.57 t ha^{-1} and 0.62 t ha^{-1} for the two population densities, respectively.

In the present study though there was no significant difference between the row arrangements for sorghum yield, the best performance of the intercrop (LER=1.5) was obtained in the 1:1 row arrangement; indicating that there was less competition for growth factors, therefore, higher yields of pigeonpea/sorghum intercrop can best be obtained in 1:1 row arrangements under similar environment.

5.1.2 Effect of different spacings on the grain yield of pigeonpea and sorghum

The results of this trial showed that pigeonpea yield declined significantly with increased spacing, while that of sorghum was not affected by a change in spacing. This finding agrees with what Steiner, (1982) reported that population increases are likely to cause increases in yield where there are large temporal differences in growth patterns of the components.

The yield of sorghum was expected to increase with increased spacing due to its ability to compete for growth factors in more dense situation. In this study, the increase of sorghum was not significant, however, the yields (3.5 - 4.6 t ha^{-1}) which were obtained were among the highest for sorghum varieties in Zambia (ZAMSEED publication 1994).

Reports by ICRASAT (1977); Freyman and Venkateswarlu (1977); and Shelke (1977); all cited by Steiner, (1982) suggest that in cereal/pigeonpea intercropping, optimum plant population can be increased in the extreme, up to full sole crop optimum of each crop.

ICRISAT (1980)'s work on plant population effects in sorghum/pigeonpea intercropping on Alfisols and Vertisols showed that at twice the sole crop optimum population, the average intercropped pigeonpea yield was approximately 15% higher than at the sole crop optimum population.

Lehner (1982) cited by Steiner (1982) observed that in case of combinations of tall crops with low growing, shade sensitive crops, better results were obtained when the spatial arrangement was changed from a quadratic to a rectangular pattern, as this allowed wider inter-row spacing. This partly conforms with the results in this work whereby the rectangular pattern (70 cm x 30 cm) resulted in more pigeonpea yield compared to the 50 cm x 50 cm pattern. In the present study the highest overall performance (LER = 1.4) of the intercrop was obtained in the 70 cm x 30 cm spacing indicating that in such a spacing there is less competition for growth factors (light, nutrients, water) between pigeonpea and sorghum plants.

5.1.3 Interaction effect of row arrangement and spacing on yield of pigeonpea and sorghum

The results of this work showed that higher yields of pigeonpea was obtained in the combination of 70 cm x 30 cm spacing (47619 plants ha^{-1}) and 1:1 row arrangement. Similar results were obtained by Ahlawat et. al (1985). They found that the population density of 5 plants m^{-2} was optimal. Higher population densities are likely to produce less yield due to slow initial growth rates, which make pigeonpea inefficient in using light and moisture resources, and in competing with weeds. The inclusion of additional intercrop species (eg. sorghum, cowpea etc.) as it was the case in this study help to overcome the limitation.

The higher yields of sorghum (4.6 t ha^{-1}) obtained in this study from 2:1 row arrangement and 50 cm x 50 cm spacing agrees with the findings of Shelke and Krishnamoorthy (1980). In their study the yield of sorghum increased from 1.02 to 3.63 t ha^{-1} at the 1:4 ratio. This is, however, less than what was obtained in the present study.

The highest overall performance of the intercrop (LER = 1.85) in this study was obtained in 1:1 row arrangement and 60 cm x 40 cm spacing (Table 3.0). Studies by AICRPDA (1990) showed that high productivity from sorghum/pigeonpea intercrops was obtained when the optimal population of both crops (18 plants m^{-2} for sorghum and 4 plants m^{-2} for pigeonpea) were maintained in a 2:1 row arrangement (Venkateswarlu et. al. 1981). These findings show that what is termed high productivity from one environment is not necessarily the same elsewhere. In the present study high productivity from sorghum/pigeonpea intercrop was obtained in 1:1 row arrangement with 10 plants m^{-2} for sorghum and 4 plants m^{-1} for pigeonpea.

In the present study on average, the intercropping system provided 103% of the equivalent yield of sole sorghum and 43% of the sole pigeonpea. Intercropping in this case reduced yield of pigeonpea by more than 50%. Ali (1990) reported similar results where an early pigeonpea genotype suffered more loss in intercropping with sorghum than late maturing ones.

Rao and Willey (1981)'s results from 80 experiments on pigeonpea/sorghum intercrops showed that on average the intercropping provided 90% of the equivalent yield of sole sorghum and 52% of the sole pigeonpea.

In this study the interaction effect of row arrangement and spacing had both a positive and negative influence on the yield of pigeonpea and sorghum (Fig 1a and 1b). Depending on the objective of the intercropping a farmer can make options out of the suitable row arrangements and the spacings. The highest yield of the pigeonpea/sorghum intercrop (LER = 1.85) was obtained in 1:1 row arrangement and 60 cm x 40 cm spacing.

5.2.0 Interaction effect of row arrangement and spacing on yield components of pigeonpea and sorghum

The significant differences ($P \leq 0.05$) among the pigeonpea yield components such as number of seeds/pod and branches/plant observed in this work agrees with the findings of Rao and Willey (1984). In their study intercropping pigeonpea with sorghum reduced the total branch number of pigeonpea but had little effect on the number of pod bearing branches. In the present work, the number of seeds/pods and branches/plant were reduced significantly ($P \leq 0.05$) for different row arrangements and spacings. The reason for this can be attributed to the increased competition for growth factors in the dense population.

Lawn and Troedson (1990) reported that pod number per plant is the component through which variation in seed yield due to growing conditions is predominantly expressed. Both seeds/pod and seed size may be reduced by treatments or environmental conditions that restricts the supply of assimilates during the respective growth phases. In the present work, the occurrence of prolonged drought during the growing season could be among the factors which had negative influence on the pigeonpea yield components.

5.3.0 Interaction effect of row arrangement and spacing on the growth of pigeonpea and of sorghum

The results of this work (Appendix G) show that tallest plants for pigeonpea and sorghum were obtained in 60 cm x 40 cm (41667 plants ha^{-1}) with 2:1 row arrangement. When the heights of sole and intercrops were compared, significant difference ($P \leq 0.05$) was observed in the 6th week after emergence and in the final height at harvest. Tallest plants of pigeonpea (124.2 cm) and sorghum (174 cm) were obtained in the intercrop treatments and not in the pure stands because under intercrop situation, inter and intra crop competition for growth factors was relatively high. Reddy (1990) reported that plant height is influenced by among other factors, the maturity duration, photoperiod and environment. In this case, the dense environment contributed to the increased heights of both crops.

6.0 SUMMARY

1. On average, the pigeonpea/sorghum intercropping system provided 103% of the equivalent yield of sole sorghum and 43% of the sole pigeonpea.
2. Land Equivalent Ratio (LER) of pigeonpea/sorghum intercrop was higher (1.07 - 1.85) signifying that intercropping was more advantageous than monocropping.
3. Sorghum suppressed pigeonpea growth and subsequently its final yield but generally the total productivity was higher with intercropping than monocroping.
4. The pigeonpea yield declined with increased spacing: while change in spacing had no significant effect on sorghum yield.
5. More yield of the pigeonpea/sorghum intercrop was obtained in 60 cm x 40 cm, 70 cm x 30 cm and 50 cm x 50 cm spacings in the descending manner.
6. Best yield of pigeonpea (519.0 kg ha^{-1}) was obtained in 1:1 and 70 cm x 30 cm: while for sorghum (4666.7 kg ha^{-1} was obtained in 2:1 row arrangement and 50 cm x 50 cm spacing
7. For both crops the highest (LER = 1.85) was obtained in 1:1 and 60 cm x 40 cm. The lowest LER = 1.07 obtained in 2:1 and 60 cm x 40 cm.
8. Highest pigeonpea 100 seed weight (15.1g) was obtained in

the control treatment. For sorghum, the highest 100 seed weight (4.8g) was obtained in 1:1 row arrangement.

9. Fewer number of pods/branch and more branches/plant was observed in 1:1 row arrangement. On the other hand, more pods/branch and less branches/plant were observed in 2:1 row arrangement.

10. The tallest plants i.e. 124.2 cm and 173.5 cm for pigeonpea and sorghum respectively, were observed and recorded in 2:1 row arrangement and 60 cm x 40 cm spacing.

7.0 CONCLUSION

Basing on the results obtained in this study it can be concluded that more yield of the pigeonpea intercropping with sorghum can be comparatively obtained from 1:1 arrangement and 70 cm x 30 cm spacing.

For the intercropping system, pigeonpea and sorghum can give higher yields when they are grown in 1:1 arrangement and 60 cm x 40 cm spacing: with all other improved husbandry practices in place.

No conclusion can be drawn on the effect of MD genotype on the grain yield of the intercrop; however, more research work of the same is required in other agro-ecological zones for verification purpose and should include at least two different genotypes.

8.0 REFERENCES

Ahlawat, I.P.S., Saraf, C.S. and Singh, A. (1985). Production potential of summer and rainy season pigeonpea intercropped with cowpea and green gram. Indian J of Agric. Sci 55, 565-569.

Ali, M. (1990). Pigeonpea: Cropping systems. In Nene, Y.L., Susan, D.H. and V.K. Sheila (eds) 1990. The pigeonpea. C.A.B. International, U.K.

Ali, M. and Raut, M.S. (1985). Dry matter accumulation pattern and productivity of sorghum and pigeonpea under different systems of intercropping. Indian J of Agron 30, 271-273.

Andrews, D.J. and Kassam, A.H. (1976). The Importance of Multiple Cropping in Increasing World Food Supplies. In Papendick, R.I., P.A. Sanches and G.B. Triplett (eds) Multiple Cropping. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America. Madison, Wisconsin 53711.

Chauhan, Y.S. (1990). The root system of pigeonpea. In: Adbul Salam, M. and Wahid, P.A. (eds) Rooting pattern of Tropical crops. Tata McGraw Hill Publishing Co. New Delhi.

Choudhary, B.L. and Bhargava, P.N. (1986). Statistical assessment of effect of sowing and fertilizer application on the yields of sorghum and pigeonpea intercrops. Indian J of Agric.Sci 56, 629-634.

El-Awad, H.O. Osman, A.K. and Abdallah, G.A. (1995). Pigeonpea Research for Rainfed Production Systems in Western Sudan. In Silim, S.N., King, S.B. and Tuwafe, S. (eds). Improvement of pigeonpea in Eastern and Southern Africa - Annual Research Planning Meeting 1994, 21 - 23 Sept. 1994, Nairobi, Kenya. pp 110 - 115.

ICRISAT Annual Report (1979/80). Cropping systems. Physiological studies in intercropping. Patancheru, A. P., India. p. 199 - 203.

ICRISAT Annual Report (1979/80). Cropping systems. Plant population effects. Patancheru, A.P., India. p. 203 - 205.

ICRISAT (1986). Annual Report 1985, Pantancheru, A.P., India: ICRISAT, pp 207 - 208.

Kannaiyan, J., Haciwa,H.C; Greenberg, D.C., Mbewe, M.N., Irwing, N.S. and Sohati, P.H. (1988). Pigeonpea Research in Zambia. International Pigeonpea Newsletter (7), pp 12 - 13.

Kimani, P.M., Omanga, P.A. and Silim, S.N. (1994). Status of Pigeonpea Research in Kenya, and Future Prospects. In: Silim, S.N., Tuwafe, S. and Laxman Singh (eds) 1994. Pigeonpea Improvement in Eastern and Southern Africa - Annual Research Planning Meeting 1993, 25-27 October, 1993, Bulawayo, Zimbabwe. ICRISAT, India pp 37 - 44.

Kuswaha, B.L. (1987). Performance of Pigeonpea genotypes grown in association with short duration sorghum and urdbean. In: Symposium on Alternate Farming Systems, 21 - 23 February, 1987, IARI, New Delhi, pp 36 - 37.

Lawn, R.J. and Troedson, R.J. (1990). Pigeonpea: Physiology of Yield Formation. In Nene, Y.L., Susan, D.H. and Sheila, V.K. The pigeonpea. C.A.B. International. ICRISAT p. 179 - 207.

Laxman, Singh. (1991). Overview of pigeonpea improvement research: Objectives, achievements and looking ahead in the African context. Pages 5 - 16 In: Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop 25 - 27 June, 1990, Nairobi, Kenya (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V. (eds). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, ICRISAT.

Mligo, J.K. and Myaka, F.A. 1994) Progress on Pigeonpea Research in Tanzania. In: Silim, S.N., Tuwafe, S. and Laxman Singh (eds) 1994. Pigeonpea Improvement in Eastern and Southern Africa - Annual Research Planning Meeting 1993, Oct. 1993, Bulawayo, Zimbabwe, ICRISAT pp 51 - 58.

Mughogho, L.K. (1994). ICRISAT in Africa. In: Silim, S.N., Tuwafe, S. and Laxman Singh (eds) 1994. Pigeonpea Improvement In Eastern and Southern Africa - Annual Research Planning Meeting, 25 - 27 Oct. 1993, Bulawayo, Zimbabwe. ICRISAT pp 1-3.

Mulila-Mitti, J. (1994). Current Status of Pigeonpea Research in Zambia. In: Silim, S.N. Tuwafe, S. and Laxman Singh (eds) 1994. Pigeonpea Improvement in Eastern and Southern Africa - Annual Research Planning Meeting 1993, 25 - 27 Oct 1993, Bulawayo, Zimbabwe. ICRISAT pp 81 - 84.

Mulila-Mitti, J.M. Kannaiyan, J., Haciwa,H.C., and Mbewe, M.N. (1989). Minor Legumes Research in Zambia. In: Mulila-Mutti, J.M.; Kannaiyan, J. and Sithanantham, S.(eds) 1989. Recent Progress in Food Legume Research and Improvement in Zambia pp 157 - 166. Proceedings of the National Workshop on Food Legume research and improvement in Zambia, 9 - 11 March, 1988, Mfuwe, Eastern Province, Zambia.

Mulila-Mitti, J., Muimui, K., and Kanenga, K. (1995). Current Status of Pigeonpea Research and Development in Zambia. In: Silim, S.N., King, S.B. and Tuwafe, S. (eds). Improvement of pigeonpea in Eastern and Southern Africa - Annual Research Planning Meeting 1994, 21 - 23 Sept. 1994, Nairobi, Kenya. pp 119 - 125.

Musaana, M.S. (1978). A study of hereditability and environmental influence of major agronomic and yield characteristics in pigeonpeas. In: Silim, S.N. Tuwafe, S. and Laxman Singh (eds) 1994. Pigeonpea Improvement in Eastern and Southern Africa - Annual Research Planning Meeting 25 - 27 Oct. 1993, Bulawayo, Zimbabwe, ICRISAT pp 67.

Natarajan, M. and Willey, R.W. (1980). Sorghum/pigeonpea Intercropping and the effects of plant population density. Growth and Yield. J of Agri Sci. Cambridge 95, pp 51 - 58.

Natarajan, M. and Willey, R.W. (1985). Effect of row arrangement on light interception and yield in sorghum/pigeonpea intercropping. J of Agric. Sci. Cambridge 104, 263 - 270.

Natarajan, M.: Kannaiyan, J.: Willey, R.W. and Y.L. Nene, (1985). Studies on the effects of cropping system on fusarium wilt of pigeonpea. Field crops research 10, 333 - 346.

Nene, Y.L. and Sheila, V.K. (1990). Pigeonpea: Geography and Importance. In: Nene, Y.L., Susan, D., Hall and Sheila, V.K. (eds) 1990. The Pigeonpea. C.A.B. International ICRISAT, India pp 1 - 13.

Omanga, P.A., A. Shakoor, and Siambi, M. (1991) Pigeonpea production and Research in Kenya, Pages 101 - 107 In: Proceedings of the First Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop 25 - 27 June, 1990, Nairobi, Kenya (Laxman, Singh, Ariyanayagam, R.P., Silim, S.N. and Reddy, M.V. (eds). Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program ICRISAT.

Rao, M.R., Willey, R.W., Sharma, D. and Green, J.M. (1981) Pigeonpea genotype evaluation for intercropping, In: Proceedings of the International Workshop on pigeonpeas, 2, 15 - 19 December, 1980. ICRISAT pp 263 - 270.

Rao, M.R. and Willey, R.W. (1980). Evaluation of yield stability in intercropping; studies on sorghum/pigeonpea. Experimental Agriculture 16, 105 - 116.

Rao, M.R. and Willey, R.W. (1981). Stability of performance of a pigeonpea/sorghum intercrop system. In: Proceedings of the International Workshop on Intercropping 10 - 13 January, 1979, ICRISAT Centre, India, Patancheru, A.P., India: ICRISAT pp 306 - 317.

1984

Rao, M.R. and Willey, R.W. (184). Effects of pigeonpea plant population and row arrangement in sorghum/pigeonpea intercropping. Field Crops Research 7, 203 - 212.

Reddy, M.S., Kanenga, K., Musanya, J.C. and Kannaiyan, J. (1989). Agronomic and Cropping Systems Research involving grain legumes in Zambia. In: Mulila-Mutti, J.M., Kannaiyan, J. and Sithanantham, S. (eds). Recent Progress in Food legume Research and Improvement in Zambia. Proceedings of the National Workshop on Food Legume Research and Improvement in Zambia 9 - 11 March, Mfuwe, Eastern Province, Zambia. pp 104 - 116.

Reddy, L.J. (1990). Pigeonpea Morphology, In Nene, Y.L., Hall, S.D., and Sheila, V.K. (eds). Wallingford, Oxon, U.K. C.A.B. International. pp 47 - 87.

Rowland, J.R.J. (1993). Dryland Farming in Africa. The Macmillan/CTA Press Ltd, London. pp 50 - 63.

Shah, R. (1992) Agroprocessing industry for dehulling grain legumes in Kenya - status and potential growth. Pages 53 - 56 In: Consultative Group Meeting on Production and Agroprocessing of sorghum and pigeonpea in Kenya (Laxman Singh, Mukuru, S.Z.

Silim, S.N., and King, S.B., (eds). Nairobi, Kenya: Ronkai General Supply.

Sheleke, V.B. and Krishnamoorthy, C. (1980). Studies on crop geometry in dryland intercrop system. Indian J. Genet and Plant Breeding 40A, 70 - 75.

Silim, S.N., Johansen, C. and Chauhan, Y.S. (1991). Agronomy of traditional and new cropping systems of pigeonpea and potential for Eastern Africa. Pages 17 - 30 In: Proceedings of the first Eastern and Southern Africa Regional Legumes (Pigeonpea) Workshop 25 - 27 June 1990, Nairobi, Kenya (Laxman Singh, Silim, S.N., Ariyanayagam, R.P., and Reddy, M.V. (eds) Nairobi, Kenya: Eastern Africa Regional Cereals and Legumes (EARCAL) Program, ICRISAT.

Silim, S.N. and Omanga, P.A. (1992). Survey of Pigeonpea based production systems. Usage and constraints in the major pigeonpea production areas of Kenya, Nairobi, Kenya: Eastern Africa Cereals and Legumes (EARCAL) Program, ICRISAT and Machakos, Kenya: National Dryland Farming Research Centre, KARI. pp 16.

Slatyer, R.O. (1969). Physiological significance of internal water relations to crop yield. In: Eastin, J.D., F.A. Haskins: C.Y. Sullivan and C.H. Van Barel (eds) (1969). Physiological Aspects of Crop Yield. American Society of Agronomy, Crop Science Society of America, Madison, Wisconsin USA.

Steiner, K.G. (1982). Intercropping in Tropical Smallholder Agriculture with Special reference to West Africa. Germany Agency of Technical Co-operation (GTZ) Eschborn. pp. 59 - 184.

Tuwafe, S., Silim, S.N. and Laxman Singh (1993). ICRISAT/AfDB Pigeonpea Improvement Project in Eastern and Southern Africa. In: Silim, S.N. Tuwafe, S. and Laxman Singh (eds) 1994. Pigeonpea Improvement in Eastern and Southern Africa - Annual Research Planning Meeting 1993, 25 - 27 Oct. 1993 Bulawayo, Zimbabwe. ICRISAT pp. 10 - 18.

Van der Maesen, L.J.G. (1983). World distribution of Pigeonpea. Information Bulletin no. 14. Patancheru, A.P. India: ICRISAT. pp. 40.

Venkanteswarlu, J., Sanghi, N.K. and Rao, C.H. (1981). Maximizing production in sorghum/pigeonpea intercropping system in the semi-arid tropics. In: Proceedings of the Workshop on Intercropping 10-13 Jan. 1979, ICRISAT Center, India, Patancheru, A.P. India: ICRISAT, pp 30 - 34.

Willey, R.W., Rao, M.R. and Natarajan, M. (1981). Traditional Cropping Systems with pigeonpea and their improvement In: Proceedings of the International Workshop on Pigeonpeas, 1, 15 - 19 Dec. 1980, ICRISAT Centre, India. Patancheru, A.P., India: ICRISAT, pp 11 -25.

ZAMSEED (1994). Sorghum Production Guide, Zambia Seed Company Ltd. Buyantashi Road, Lusaka Zambia.

8.0 APPENDICES

A: DATA FOR SOIL ANALYSIS FOR UNZA AND ZAMSEED SITES

Locality:	UNZA Farm			ZAMSEED Farm			
Sample	pH $CaCl_2$	N %	P mg/kg	pH $CaCl_2$	N %	P mg/kg	No.
S1	7.0	0.15	11.41	7.3	0.20	38.22	
S2	7.4	0.13	10.82	7.4	0.16	30.91	
S3	7.3	0.16	7.07	7.6	0.16	40.22	
S4	7.2	0.16	10.61	7.5	0.13	29.58	
S5	7.3	0.18	13.65	7.3	0.17	27.27	
S6	7.1	0.16	16.49	7.5	0.14	39.66	
S7	7.4	0.16	10.50	7.6	0.15	27.13	
S8	7.5	0.18	15.75	7.8	0.13	27.06	
S9	7.5	0.15	10.75	7.5	0.19	33.15	
S10	7.4	0.18	10.26	7.4	0.18	30.10	

B: EXPERIMENTAL FIELD LAY-OUT

R 1

	A1			A2			
S1	S2	S3	S2	S1	S3	So	So
P1a T4G2	P2a T2G1	P3a T6G2	P4a T8G1	P5a T10G2	P6a T8G1	P7a T13G2	P8a T15So
P1b T1G1	P2b T5G2	P3b T3G1	P4b T11G1	P5b T7GI	P6b T12G2	P7b T14G1	P8 T15So

R11

			A2			A1	
So	So	S2	S1	S3	S1	S2	S3
P9 T15So	P10a T13G1	P11a T8G1	P12a T10G2	P13a T9G1	P14a T4G2	P15a T2G1	P16a T6G2