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EVALUATION OF INTRODUCED PIGEONPEA *(CAJANUSCAJAN* (L.) MILLSP.) GENOTYPES FOR GROWTH AND YIELD PERFORMANCE IN SUDANO-SAHELIAN ECOLOGY OF NIGERIA

I. E. Ezeaku[1*], H. A. Ajeigbe[2] and E. C. Okechukwu[1]

[1]Department of Crop Science, University of Nigeria, Nsukka, Nigeria.
[2] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Kano Station, PMB. 3491, Kano State, Nigeria
[*]Corresponding author's e-mail: idowuezeaku@yahoo.com

ABSTRACT

Evaluation study is essential to ascertain performance and adaptation of improved genotypes across new environment. Field experiments were conducted at the Institute for Agricultural Research (IAR), Research Farm, Minjibir, Kano State, Nigeria over two years to assess the performance of twelve improved pigeonpea genotypes comprising of early (ICPL 84031, ICPL 85010 and ICPL 87), medium (ICP 7120, ICP 8863, ICPL 161, ICPL 85063, ICPL 87051 and ICPL 87119) and late (ICP 7035, ICP 8094 and ICPL 9145) flowering groups introduced from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patencheru, India. Effects due to genotype, year and genotype x year interactions were significant (P=<0.01) for most characters evaluated. Grain yield ranged from 723 kg ha^{-1} to 2,710 kg ha^{-1} with ICP 7120 having the highest grain yield followed by ICPL 87119 and then ICPL 84031genotype. The two highest grain yielding genotypes (ICP 7120 and ICPL 87119) were medium flowering type, followed by ICPL 84031, an early flowering genotype whose grain yield did not differ significantly from that of the two medium flowering genotypes. The high yielding and early flowering genotype (ICPL 84031) is a candidate genotype recommended for promotion in short rainfall environments of northern Nigeria. Significantly higher grain yields were obtained during second year with mean yield of 3,118 kg ha^{-1} compared with 838 kg ha^{-1} recorded in first year, an indication that delayed planting in first year affected yield and that genotypes responded differently to year and soil effects. Correlation analysis (pooled over two seasons) revealed that number of primary branches plant^{-1} and pod weight were the most important traits influencing grain yield in pigeonpea.

Keywords: Pigeonpea; adaptation; grain yield; evaluation; introduced varieties.

INTRODUCTION

Pigeonpea *(Cajanuscajan* (L.) Millsp.) is an important food legume in Nigeria. The crop is predominantly grown in the guinea savannah agro-ecological zone usually in mixture with cassava, maize, yam, and sorghum (Egbe and Kalu, 2006). It is an important component of traditional farming systems with its fodder having forage potential for domestic livestock during the critical dry months of December to May. The seeds and pods are consumed in many households as vegetable and also used as flour additives in soups and rice. It is an excellent food and protein source in developing tropical countries (CNCPP, 2002; Kwame, 2003). The crop is a multi-purpose leguminous crop that plays important role in food security, maintenance of soil fertility through litter fall and nitrogen fixation, provision of fodder for livestock and fuel for small-scale farmers in subsistence-agriculture (Egbe and Kalu, 2006). The crop has ability to fix 41 to 250 kg ha^{-1} of nitrogen through symbiotic association between the root nodules and a species of bacteria, *Rhizobia* (Kwame, 2003). Report by Runge-Metager and Diehl (1993) showed that pigeonpea average yields was 120 kg ha^{-1} in Ghana while Dasbak and Asiegbu (2012) obtained an average grain yield of 1,345 kg ha^{-1} in the southern guinea savannah of Nigeria.

High diversity exists in growth and development among pigeon pea genotypes and grain yields obtained in traditional farming system are reportedly low (Whiteman *et al*., 1985; Guy *et al*., 2001). The observed low yield is as a result of use of unimproved long duration accessions, attack by pests and diseases, poor crop management and low soil fertility. One of the constraints to widespread cultivation of the crop in Nigeria is the lack of early maturing and high-yielding genotypes that are adapted to drier ecologies. The release of improved photo-period-insensitive genotypes by ICRISAT required that they be tested under different agro-ecologies (IBPGR and ICRISTAT, 1993). Identification of an appropriate maturity duration type for a given location has been the dominant feature of adaptation for this crop (Sharma *et al*., 1980). The early maturing types are better suited for low-rainfall areas and for soils with poor moisture retention. These cultivars usually suffer heavy damage from pests and diseases when grown under high rainfall conditions because of extended humid and cloudy weather. Each maturity group has its specific area of adaptation. In locations with medium rainfall, medium maturing genotypes have been consistently found to give higher yield than both early and late maturing genotypes (Dasbak *et al*., 2012). Genetic improvement of pigeonpea during the last two decades have extended the frontiers of geographic adaptation in novel cropping systems both in the traditional and non-traditional regions of cultivation (Ariyanayagam and Singh, 1994).

Traditionally, long duration varieties of pigeonpea are cultivated in Nigeria and are restricted to locations with relatively longer rainfall, especially in savannah belt. However, with the development of early and extra early maturity genotypes, a new window of opportunity has opened to extend the crop production area to drier regions of Nigeria. New genotypes from the breeding program of ICRISAT that are extra early, early and medium duration and F*usarium* wilt resistant have been released. However, they need to be evaluated to determine their suitability to low and erratic rainfall areas of northern Nigeria. The objectives of this study were to obtain information on the adaptation pattern and genotype x environment interaction of some introduced pigeonpea genotypes with varying maturity groups.

MATERIALS AND METHODS

The field trials were conducted at the Institute for Agricultural Research (IAR), Research Farm, Minjibir, Kano State, Nigeria (Latitude $12^0$13′N, Longitude $8^0$69′E and altitude of 416 m above sea level) over two cropping years. The soil type was sandy with long term average rainfall of 850 mm which is uni-modal with peak in August. Pigeonpea seeds were sown on 30th June in first year while in second year it was sown on 20th June. In each year, the experiment was set up in a randomized complete block design (RCBD) with three replications. The plot size consisted of four rows of 3 m long and inter and intra row spacing of 0.75 x 0.5 m, respectively. Fertilizer with NPK of 15:15:15 was applied as a basal dose of 300 kg ha^{-1}. Each hill was sown with four seeds. Seedlings were thinned down to two plants $hill^{-1}$ for all the hills with more than three seedlings three weeks after crop emergence. Data were collected from the two middle rows from each plot during the two experimental years. Traits such as days to flowering was collected when the plants attained 50% flowering, while plant height, number of primary branches $plant^{-1}$, pod length, number of seeds pod^{-1}, pod weight, grain yield kg ha^{-1}, 100 seed mass (g) were sampled when the pods were matured, fodder weight kg ha^{-1} was sampled from the two outer rows when the pods attained physiological maturity. All the traits were assessed following recommendations by International Board for Plant Genetic Resources (IBPGR) and ICRISAT descriptor for pigeonpea (IBPGR and ICRISAT, 1993). Seeds of the twelve genotypes introduced from ICRISAT Corporate Headquarters, Patancheru, India were divided into two sets and a subset was sown in each year. The genotypes consisted of early (ICPL 84031, ICPL 85010 and ICPL 87) with 50-70 days to flowering, medium (ICP 7120, ICP 8863, ICPL 161, ICPL 85063, ICPL 87051 and ICPL 87119) with 71-100 days to flowering and late (ICP 7035, ICP 8094 and ICPL 9145) with 101-150 days to flowering. The seeds were sown at different sites with varying soil types in both experimental years. Data collected were subjected to analysis of variance (ANOVA) using GENSTAT 3 Discovery Software (2009). Detection of differences among treatment means for significant effect was by least significant difference (LSD) at 1% probability.

RESULTS AND DISCUSSION

Rainfall range of between 54 and 372.3 mm, maximum and minimum air temperature of 34.2 and 23.**7** ^{o}C respectively and 3-10 rainy days from June to October during the crop growth periods (Table 1) was adequate to support pigeon pea production in Sudano-sahelian ecology of Nigeria. Dasbak *et al.,* (2012) found rainfall of between 125.4 and 313.9 mm, 14-25 rainy days with maximum and minimum air temperature of 30.1 and 21.8 ^{o}C adequate in derived Savanna of Nigeria. Marin *et al.,* (2004) reported that water and temperature stress are critical factors limiting pigeon pea productivity. Patel *et al.,* (2001) pointed out that water use efficiency during the reproductive phase in pigeon pea decreased with increasing plant age; therefore the cessation of rainfall from November in this study means that long duration pigeon pea genotype may not thrive in this environment.

Analysis of variance (ANOVA) for nine characters studied in twelve introduced pigeonpea genotypes (Table 2) showed that variances due to genotype main effects for all the traits were highly significant (P=<0.01) while variances due to year effects were also highly significant for number of primary branches $plant^{-1}$, plant height, pod length, pod weight, 100 seed weight and grain yield. Interaction effects due to genotype x year were highly significant for days to flowering, plant height, pod weight and grain yield. Crossa *et al*. (1990) stated that test of significance for components of multi-environment evaluation are recommended for estimating relative contribution of the various components to observed variation. Significant interaction effects indicated that selection based solely on genotype means would not be reliable, since genotypes responded differently to environmental changes. The presence of genotype x year interactions confirmed that these traits changed across the test environments and across all the genotypes. This observation is in conformity with Baiyeri, (1998) who reported that highly significant environmental impact on traits would indicate that the evaluation of environments was actually different justifying the need for genotype evaluation across several environments. Baker (1988) stated that GxE interactions are the failure of genotypes to achieve the same relative performance in different environments. In view of the apparent inconsistencies in the performance of genotypes across different environments, it is necessary that multi-environment evaluation of crop cultivars be used to measure crop performance across test environment with a view to select promising genotype that will fit to a target location. Crop performance in a given location can be explained in terms of the resources available in the environment and the biological and physical hazards that affect the attainment of the potential in that environment (Kang 1998).

All the characters studied differed significantly (P=<0.01) across the two years with year 2 showing significantly higher expression of all the traits except number of seeds pod^{-1} that did not show any significant difference between the two years, and pod length that was higher in year 1 (Table 3). Higher crop productivity in year 2 may have been due to early sowing compared to delayed sowing in year 1. Ray *et al*., (2008) attributed reduction in agronomic performance in soyabean to delayed sowing. Amount, distribution as well as time of onset and cessation of rains during the growing period for the two years could have influenced the expression of genotype potentials in this study. Early onset and high amount of rains in year 1 (1,116 mm) particularly in the month of August (Table 1) may have enhanced infestation by some pests and diseases such as *Fusarium* wilt. These diseases usually reduced plant population and other productivity traits in crops. Minja (2000); and Agrios (1998) identified excess soil moisture content and high humidity as conditions that favor greater incidence of pests and diseases during crop growth period. Moreover, the extended rainfall in year 2 may have favored the accumulation and translocation of photo-assimilates in the genotypes with corresponding higher growth and yield components. Moisture deficiency during the pod filling stage in October of Year 1 may have exposed the crop to terminal drought which consequently reduced grain yield. Differences between the two years for grain yield could also be attributed to richer soils and other favorable environmental variables of the experimental site in year two than in year 1.

Performance of the genotypes for growth and reproductive characters combined over two years is presented in Table 4. ICPL 85010 was the earliest to flower while ICPL 9145 had the longest days to flowering. The present finding is in conformity with (Dasbak and Asiegbu, 2012) who also classified ICPL 87 as short duration while ICPL 85063, ICP 7120 and ICPL 87119 were classified as medium maturing genotypes. Early flowering genotypes significantly (P=<0.01) produced lower fodder weight and plant height while medium flowering genotypes produced significantly higher fodder weight and plant height. Similarly, Ezeaku and Awopetu (1992) found medium maturing soybean varieties to produce taller plants and higher vegetative characteristics than early maturing genotypes. Late flowering genotypes (ICP 7035 and ICPL 9145) produced longer pods, higher number of seeds pod^{-1} and 100 seed mass than early and medium flowering genotypes. Medium flowering genotypes, ICP 7120 produced the highest grain yield of 2,710 kg ha^{-1} followed by ICPL 87119 with grain yield of 2,607 kg ha^{-1}. The higher yield of medium flowering genotypes over both early and late flowering genotypes as observed in this study is consistent with Dasbak and Asiegbu (2012); and Sharma *et al*. (1980) who found medium maturing pigeonpea genotypes producing higher grain yield than both early and late maturing accessions. Moreover, Dasbak *et al*. (2012) equally identified ICP 7120 as high grain yielding genotype. The third highest grain yielder is an early flowering genotype (ICPL 84031) with grain yield of 2,562 kg ha^{-1} which did not differ significantly with the two medium and top grain yielding genotypes. This early maturing and high yielding genotype is a candidate genotype that should be targeted for promotion in dry region of northern Nigeria. Sharma *et al*. (1980) pointed out that the evaluation and selection of genotype with appropriate maturity duration for a given location has been the dominant feature of adaptation for pigeonpea. Furthermore, they also stated that early maturing genotypes are better suited for low rainfall areas and for soils with poor moisture retention and that such early maturing genotype if it is high yielding will trigger significant expansion of the crop to new regions of the world.The late maturing genotype (ICPL 9145) was one of the poorest grain yielding genotypes with grain yield of 1,292 kg ha^{-1}.

Means for the interactive effects of genotype x year was significant for all the growth and reproductive characters (Table 5). All the genotypes showed high disparity between the two years for the characters studied, but highest on pod weight and plant height. Genotypes flowered earlier by 4 days in year 2 than year 1. Khush (1996) noted that when same set of genotypes demonstrate differential flowering pattern due to environmental factors the earlier to flower usually takes longer time to fill pods and consequently produced higher grain yield. ICP 8094 was however, stable for days to flowering between the two years. An early maturing genotype ICPL 85010 produced the least grain yield in both years with year 1 producing average of 271 kg ha^{-1} while year 2 produced average of 1174 kg ha^{-1} suggesting that the genotype was not adapted to the location of the study. Similarly, correlation coefficient combined across the two years (Table 6) showed that number of primary branches plant^{-1} and pod weight correlated positively and significantly with grain yield per hectare. Conversely, there was negative correlation between grain per yield and fodder weight (r= -0.154), pod length (r= -0.469) and number of seed pod^{-1} (r= -0.547). This result is in conformity with Oseni (1994).

Table 1. Meteorological data for two experimental years in Minjibir, Kano state, Nigeria

Year 1	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total**
Total rainfall (mm)	0	0	0	24	117.4	151.3	261	372.3	190.5	0	0	0	1,116.5
Number of rainy days	0	0	0	3	4	8	9	10	8	0	0	0	42
Max air temp (ºC)	32.8	37.6	37.5	38	36.8	33.9	33.4	31.3	30.7	31	32.1	29.5	-
Min air temp (ºC)	11.4	10.3	18.1	23.2	24.9	23.2	22.4	22	22.3	22.2	21.2	19	-
Year 2													
Total rainfall (mm)	0	0	0	0	0	148.2	223.9	222.7	192.6	54	0	0	841.4
Number of rainy days	0	0	0	0	0	5	7	9	7	3	0	0	31
Max air temp (ºC)	26.2	31.8	35.7	36.4	36.5	34.2	33.2	31.5	31.0	31.6	30	31.9	-
Min air temp (ºC)	21.8	14.8	20.8	22.3	22.8	23.7	22.6	22.8	22.5	22.3	16.6	13.1	-

Table 2. Analysis of variance (ANOVA) for growth and reproductive characters in twelve introduced pigeonpea genotypes.

Sources	**Degree of free dom**	**Days to flowering**	**Fodder weight (kg ha^{-1})**	**Number of primary branches plant^{-1}**	**Plant height (cm)**	**Pod length (cm)**	**Pod weight (kg ha^{-1})**	**Number of seed pod^{-1}**	**100 Seed mass (g)**	**Grain yield (kg ha^{-1})**
Genotype (G)	11	2536.65**	2584**	37.10**	3284.7**	0.676**	4854805**	0.5630**	5.83**	2069886*
Year (Y)	1	268.35 ns	37849ns	190.78**	156352.3**	60.50**	230461485**	0.1606ns	13.69**	93568692**
G x Y	11	5334.15**	220ns	20.17ns	425.6**	0.41ns	2219018**	0.3751ns	0.12ns	1509399**
Error	46	2183.97	8988	8.59	291.1	0.24	2848552	0.1866	2.44	1360304

*=significant at 5% probability level, **= significant at 1% probability level, ns = non-significant.

Table 3. Effects of years on growth and reproductive characters in twelve introduced pigeonpea genotypes .

Year	**Number of primary branches plant^{-1}**	**Plant height (cm)**	**Pod length (cm)**	**Pod weight kg ha^{-1}**	**100 Seed mass (g)**	**Grain yield kg ha^{-1})**
Year 1	14.92	99.1	6.62	1415	10.77	838
Year 2	18.17	192.3	4.79	4994	11.65	3118
LSD (0.01)	1.39	8.10	0.23	800.8	0.74	553.4

Table 4. Performance of twelve introduced pigeonpea genotypes for growth and reproductive characters combined over two years

Genotype	**Days to flowering**	**Fodder weight (kg ha^{-1})**	**Number of primary branches plant^{-1}**	**Plant height (cm)**	**Pod length (cm)**	**Pod weight (kg ha^{-1})**	**Number of seed pod^{-1}**	**100 Seed mass (g)**	**Grain yield (kg ha^{-1})**
ICP 7035	100.67	293	18.43	166.3	6.28	3424	4.03	12.60	2054
ICP 7120	90	176	14.05	155.6	5.52	4685	3.53	10.48	2710
ICP 8094	100.83	340	19.88	157.1	5.18	3476	3.40	10.60	2118
ICP 8863	86.83	254	16.27	159.7	5.55	3278	3.30	11.42	2074
ICPL 161	78	291	16.38	155.8	5.73	2963	3.50	9.90	1684
ICPL 84031	65.17	162	17.17	112.8	5.73	3756	3.57	10.88	2562

ICPL 85010	56.67	286	13.22	104.1	5.80	1258	3.47	10.65	723
ICPL 85063	91.50	291	17.60	162.0	5.65	3772	3.20	11.98	2414
ICPL 87	63.67	225	14.37	106.7	5.78	2756	3.47	9.90	1577
ICPL 87051	96.50	386	18.77	163.9	5.58	3090	3.77	11.95	1923
ICPL 87119	93.50	302	19.70	157.7	5.30	3949	3.17	11.28	2607
ICPL 9145	132.83	209	12.70	146.6	6.32	2047	4.17	12.88	1292
LSD	8.00	110.2	3.41	19.83	0.57	1961.4	0.50	1.82	1355.4
($p<0.05$)	88.01	268	16.58	145.7	5.70	3204	3.55	11.21	1978
Grand mean									

Table 5. Interaction effects of genotype x year for growth and reproductive characters in twelve introduced pigeonpea genotypes.

Genotype	Days to flowering		Plant height (cm)		Pod weight (kg ha^{-1})		Grain yield	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
ICP 7035	105.67	95.67	114.3	218.3	1748	5099	1008	3100
ICP 7120	96.00	84.00	91.0	220.1	2279	7091	857	4564
ICP 8094	101.33	100.33	114.3	199.8	1176	5775	703	3534
ICP 8863	89.00	84.67	114.0	205.3	1600	4955	976	3172
ICPL 161	81.00	75.00	108.3	203.2	906	5020	467	2902
ICPL 84031	68.33	62.00	78.0	147.7	1071	6441	693	4431
ICPL 85063	95.67	87.33	115.7	208.4	2043	5501	1174	3655
ICPL 87	69.00	58.33	70.0	143.5	967	4545	549	2604
ICPL 87051	103.67	89.33	110.3	217.5	1891	4289	1309	2537
ICPL 87119	98.00	89.00	103.7	211.7	1630	6269	1065	4150
ICPL 9145	107.00	158.67	105.0	188.1	1233	2861	988	1596
Mean	89.94	86.08	99.1	192.3	1415	4994	838	3118
LSD (0.01)	11.325		28.04		2773.9		1916.9	

Table 6. Correlation Coefficient between growth and reproductive characters in twelve introduced pigeonpea genotypes combined across years.

	Days to flowering	Fodder weight	Number of primary branches $plant^{-1}$	Plant height	Pod length	Pod weight	Number of seed pod^{-1}	100 Seed mass	Grain yield
Days to flowering	**1**								
Fodder weight	.160	**1**							
Number of primary branches $plant^{-1}$	.132	.615*	**1**						
Plant height	.686*	.458	.533	**1**					
Pod length	.245	-.302	-.498	-.152	**1**				
Pod weight	.118	-.152	.511	.502	-.465	**1**			
Number of seed pod^{-1}	.510	-.119	-.295	.056	.804**	-.324	**1**		
100 seed mass	.729**	.162	.124	.464	.519*	-.066	.552	**1**	
Grain yield	.125	-.154	.571*	.466	-.469	.977**	-.347	.019	**1**

*=significant at 5% probability level, **= significant at 1% probability level

Conclusion: The introduction of adapted pigeonpea genotype in the farming systems of Sudano-sahelian ecology of Nigeria may increase its resilience in the face of increasing unpredictability of the climatic conditions and will also trigger large scale commercialization of pigeonpea production enterprise in the region. With increasing demand for cheap and healthy sources of plant protein the search for high yielding adaptable genotype is a priority particularly in a non-traditional pigeonpea growing but consuming ecology of northern Nigeria.

REFERENCES

Agrios, N.G. (1998). The effects of growing season on *Cercospora* leaf spot disease severity and grain yield. Centre point Science Edition. Plant pathology. Acad. Press, London. 8(6): 47 – 55.

Ariyanayagam, R.P, and N. B. Singh (1994). Pigeonpea breeding-accomplishments and Challenges. Plant Breeding Abstracts. 64 (6): 773- 782.

Baiyeri, K.P. (1998). Evaluation of growth, yield and yield components of 36 *Musa*genotypes under four different environments. Ph.D thesis (unpublished).University of Nigeria, Nsukka, Nigeria. Pp 261.

Baker, R. J. (1988).Tests for crossover genotype-environmental interactions. Canadian J. Plant Sci., 68: 405-410.

CNCCP, (2002). Centre for New Crops and Plants Products. *Cajanuscajan* (L.) Millsp. Purdue University http://www.hort.purdue.edu/ newcrop/ duke-energy/cajamus_cajun.html.

Crossa, J., H.G. Gauch, and R.W. Zobel (1990). Additive main effect and multiplication interaction analysis of two international maize cultivar trials. Crop Sci., 30:493-500.

Dasbak, M.A.D., B. C. Echezona and J. E. Asiegbu (2012). Field insect pests and crop damage assessment of pigeonpea (*Cajanus cajan (L.) Huth*) grown under ratoon and in mixture with maize. Chilean J. Agri. Res. 72(1): 45-52.

Dasbak, M.A.D, and J.E. Asiegbu (2012). Grain yield assessment of six pigeonpea genotypes in production systems and their ratoon ability in a humid tropical agro-ecology of Nigeria. Agro-Science J. Tropical Agri. Food Environ. Ext., 11(2): 38 – 45.

Egbe, O.M, and B.A. Kalu (2006).Farming system study: Participatory Rural Appraisal of Pigeonpea cropping systems in Southern Guinea Savanna of Nigeria. J. of Environ. (Abia State University Environmental Review). 5(1): 37-47.

Ezeaku, I.E, and J.A. Awopetu (1992). A numerical analysis of variation patterns in some accessions of soyabeans (*Glycine max*). Nigeria J. Botany.5: 51-62.

Genstat release 12th edition Statistical Software VSN International Ltd (VsNi) (2009). Hemel Hempstead H P 1 IES.http:// support. genstat. co.uk/

Guy, M., P. Kimamni., A. MwangOmbe., F. Olubayo., C. Smith., P. Audi., J. Baudom, and A. Le Roi (2001). Survey of pigeonpea production systems, utilization and marketing in semi-arid lands of Kenya in Biotechnol.Agron. Soc. Environ. 5(3): 145-153.

IBPGR and ICRISAT (1993).Descriptors for Pigeonpea *(Cajanuscajan*(L.) Millsp.). International Board for Plant Genetic Resources Rome Italy, International Crops Research Institute for the Semi-Arid Tropics. Patencheru, India.

Kang, M.S. (1998).Using genotype by-environment interaction for crop cultivar development. Adv. Agron. 62:199-252.

Khush, G. S. (1996). Strategies for increasing crop productivity. Proceedings of 2nd International Crop Science Congress. 19-43 .V. L. Chpra, R. B. Singh and Anupamvarma editors Oxford x IBH Publishing Co. PVT. Ltd. New Delhi and Calcultta.

Kwame, F.P. (2003). Correlation and Path Coefficient analysis of yield and yield components in pigeonpea. Pakistan J. Bio. Sci., 6(19): 1689-1694.

Marin, A., D.M.M. dos Santos., D.A. Banzatto, and A.S. Ferraudo (2004). Seed germination of pigeon pea (Cajanus cajan (L.) Millsp.) under water stress and aluminum sub-lethal doses, Bragantia 63:13-24.

Minja, E.M. (2000). Yield losses due to field pests and integrated pest management strategies for pigeonpea- a synthesis. P.48-53 In Silim, S.N., G. Mergeai and P.M. Kimani (eds.) status and potential of pigeonpea in Eastern and Southern Africa. Proceedings of a regional workshop, Nairobi, Kenya, 12-15 September.

Oseni, T.O. (1994). Correlation and path-coefficient Analysis of height components on grain yield of cowpea (Vigna unguiculata (L.) Walp) Samaru J. Agri. Res., 11:45-47.

Patel, N.R., A.N. Mehta, and A.M, Shekh (2001). Canopy temperature and water stress quantification in rainfed pigeon pea (Cajanus cajan (L.) Millsp.) Agriculture and Forest Meteorology 109:223-232.

Ray, C.L., E.R. Shipe, and W.C. Bridges (2008). Planting date influence on soyabean agronomic traits and seed composition in modified fatty acid breeding lines. Crop Sci. 48:181-188.

Runge-Metager, A, and L. Diehl (1993). Farm household systems in northern Ghana. A case study in farming systems oriented research for the development of improved crop production systems. NyankpalaAgricl. Res. Rep; 9:249.

Sharma, D., L. J., Reddy., J. M. Green, and K. C. Jain (1980). International Adaptation of Pigeonpeas. Proceedings of the International Workshop on Pigeonpeas (1). ICRISAT Centre Patancheru, India 15-19 December . 71 – 81.

Whiteman, P. C., D. E. Byth, and E. E. Wallis (1985). Pigeonpea (*Cajanuscajan*(L.) Millsp) In: Grain Legume Crops (eds. Summerfield, R. J. Roberts, E. H.). First Edition. Collins Professional and Technical Books.658-698p.