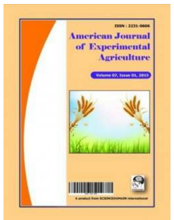

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Evaluation of Selected Pigeonpea (*Cajanus cajan* (L.) Millsp.) Genotypes for Resistance to Insect Pest Complex in Dry Areas of North Rift Valley, Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author JJC designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors PKK, MGK and OKK reviewed the experimental design and all drafts of the manuscript. Authors JJC, JJK and SCK managed the analyses of the study. Authors JJC, BKT and NVPRG identified the plants. Authors JJC and SK performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Pigeonpea is an important pulse crop that has gained importance in semi-arid tropics, although its yield potential has not been fully realized due to biotic and abiotic stresses that limit its production. Insect pest complex of pod borer (*Helicoverpa armigera)*, sucking bug (*Clavigralla tomentosicollis*) and pod fly (*Melanagromyza cholcosoma*) are the major limiting factors to its production causing up

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to 100% yield loss. The objective of this study was to evaluate resistant genotypes to insect pest complex in dry parts of North Rift Valley Kenya. The study was carried out in three sites (Kenya Agricultural Livestock Research Organization- Marigat, Agricultural Training Centre-Koibatek and Fluorspar-Chepsirei) for one season during long rain of April-November 2014 growing season. Sixteen ICRISAT elite genotypes were evaluated in randomized complete block design (RCBD) with 75cm inter and 25 cm intra spacing. Significant (P≤0.05) differences in grain yield performance, incidence and severity of the insect pests were revealed in all sites. The damage was more severe in Marigat (Pod borer-37.2%, Sucking bug-39.3% and pod fly-5.9%) than ATC-Koibatek (Pod borer-1.9%, Sucking bug-8.4% and pod fly-5.9%) and Fluorspar (Pod borer-3.6%, Sucking bug-6.8% and pod fly-2.9%). Genotypes ICEAPs 00850^R, 00902, 01541 and 1154-2 showed potential levels of resistance to the insect pest complex and high yields. Grain yield associated negatively (P≤0.05) with pod borer and sucking bug damage correlated non-significantly with pod fly damage. The potential genotypes identified in this study need to be further evaluated in two seasons and in other multi-locations to validate these findings to be used in breeding.

Keywords: Pigeonpea; insect pest complex; resistance; yield potential; yield loss.

1. INTRODUCTION

Pigeonpea (*Cajanus cajan* (L) Millsp.) is an important pulse crop of semi-arid tropics. Many reasons account for the increased interest in the crop but the most important is its high nutritional value comprising of proteins, essential amino acids, vitamins and minerals making it the best solutions to protein-calorie malnutrition in the developing world and a source of dietary protein mainly in vegetarian based diets [1]. It grows well even on less fertile soil due to its ability of fixing about 40kg of nitrogen per season [2] to the soil and access bound phosphorus in the soil due to presence of piscidic acid exudates that solubilize phosphorus in the rhizosphere [3]. Despite these importance, the average global productivity of pigeonpea has remained static over the last three decades [4]. The yield gap observed between the potential yield and on-farm yield is mainly due to prevalence of various abiotic [5] and biotic factors [6].

Insect pests are major constraint to pigeonpea production in the - semi-arid tropics [7] including East Africa [6]. These pests include pod borer (*Helicoverpa armigera),* pod sucking bugs (*Clavigralla tomentosicollis)* and pod fly (*Melanagromyza chalcosoma)*. They cause damage to the crop from flowering to maturity stage by causing flower abortion, feeding on the pods and seeds hence not good for consumption and will not germinate when planted [8]. Several strategies including utilization of resistant cultivars and the use of environment-friendly solution to manage these insect-pests [4] have been suggested. However, chemical pesticides remain the primary means of pest management among farmers.

Research on losses and damage from insect pests are limited in east Africa particularly Kenya. There is also limited information on incidence, distribution and reaction of commercial and improved varieties against the insect pest complex. However, total seed damage by sucking bug-(73%); pod borer (18%) and pod fly (9%) have been reported in Kiboko. Also, seed damage by sucking bug (69%), pod borer (16%) and pod fly (15%) in Kabete have been reported [6] while no statistics have been reported from dry parts of North Rift Valley. The identification of pigeonpea genotypes which are resistant to insect pests would be of particular importance to most farmers in Kenya who are unable to access inputs like conventional pesticides. Therefore, a variety possessing inbuilt resistance to the pest will be preferred for its manifold advantage like low input cost, through avoidance of pesticide cost besides eliminating residue problem and environmental pollution [9]. The study was therefore carried out to evaluate pigeonpea genotypes for resistance to insect pest complex in dry parts of North Rift Valley, Kenya.

2. MATERIALS AND METHODS

2.1 Study Sites

The experiments were carried out in three varied sites; (KALRO Perkerra-Marigat, ATC Koibatek in Baringo County and Fluorspar in Elgeyo Marakwet County during the long rains of April-October 2014 cropping season. Kenya Agricultural and Livestock Research Organization (KALRO) Perkerra– Marigat is situated at 0°28'N, 36°1'E with an altitude of 1067 m above sea level and an average annual rainfall of 654 mm . The average temperature of the area ranges from 16-34°C and the soil type is fluvisols.

National Youth Service (Chepsirei) is located at an altitude of 1200 m above sea level with temperature range of 16 -30°C and receiving rainfall ranging from 400 to 800 mm per annum but the rainfall is usually erratic and unreliable. The soil type is sandy loam.

Agricultural Training Centre Koibatek is located 1°35'S, 36°66'E at an elevation of 1890 m.a.s.l and receives an average annual rainfall of 767 mm. Mean minimum and maximum temperatures are 10.9°C and 28.8°C respectively. Soils are Vitric andosols with moderate to high soil fertility, [10].

2.2 Plant Germplasm, Field Layout and Experimental Designs

Sixteen medium duration elite lines of pigeonpea sourced from ICRISAT were evaluated during the long rains of April- October 2014 cropping season (Table 1). Two among the 16 genotypes resistant ICEAP 00850 and susceptible KAT 60/8 are commercial varieties and were used as checks. The test entries were evaluated in a randomized complete block design (RCBD), in three replicates. Each plot consisted of 5 rows measuring 5 m in length, spaced 75 cm between the rows (inter-row) and 25 cm between the plants (intra-row). The evaluation was done under open field using natural pest population and rain fed conditions.

2.3 Data Collection

2.3.1 Larval and egg counts of pod borer (*Helicoverpa armigera*)

Larval population and eggs were counted on five random plants in each plot at 50% podding. Pod borer eggs were identified by their spherical shape, white colour and are laid singly on buds, leaves and flowers. The larvae were identified with green, yellow and brown colour due to their camouflaging nature.

2.3.2 Pod Damage by pod borer (*H. armigera*) and pod fly (*Melanagromyza chalcosoma*)

Pod- damage assessment was carried out at physiological maturity when the pods have

Table 1. List of 16 medium duration pigeonpea genotypes used in the study during long rains of April- October 2014 cropping season indicating their source, status and pedigree

Germplasm name	Source	Status	Pedigree
ICEAP 01147	ICRISAT	Pre release	ICPL 87091 X ICEAP 00020
ICEAP 01179	ICRISAT	Pre release	ICPL 87091 X ICEAP 00020
ICEAP 1147-1	ICRISAT	Pre release	ICPL 87091 X ICEAP 00020
ICEAP 01159	ICRISAT	Pre release	ICPL 87091 X ICEAP 00040
ICEAP 00554	ICRISAT	Pre release	Improved
ICEAP 01541	ICRISAT	Pre release	ICEAP 00779 X ICP 6927
ICEAP 00540	ICRISAT	Pre release	Land race
ICEAP 00911	ICRISAT	Pre release	Improved
ICEAP 00902	ICRISAT	Released	Improved
ICEAP 01150	ICRISAT	Pre release	ICPL 87091 X ICEAP 00020
ICEAP 00068	ICRISAT	Released	Improved
ICEAP 00557	ICRISAT	Released	Improved
ICEAP 00850-Resistant check	ICRISAT	Released	Improved
ICEAP 0079-1	ICRISAT	Pre release	ICPL 87091 X ICEAP 00068
ICEAP 1154-2	ICRISAT	Pre release	ICPL 87091 X ICEAP 00020
KAT60/8- Susceptible check	ICRISAT	Released	Improved

turned colour from green to brown but not dry. Pods from 5 randomly tagged plants in the three middle rows of each plot were examined. Pod damage by pod borer was identified by the presence of round, large bored holes in pods and a pin shaped hole and immature drying for pod fly. Severity of damage and incidences of the insect based on symptoms and number of pods affected was established. The percentage pod damage was calculated based on the following formula,

% Pod damage = (Number of pods damaged / Total number of pods examined) x 100

2.3.3 Seed damage by sucking bug, pod fly and pod borer

Ten pods from each 5 plants from the three inner rows were harvested randomly, threshed and carefully cleaned. Seeds damaged by insect pests and wholesome seeds were separated, counted, recorded and percentage seed damage was calculated per plot. Seeds damaged by sucking bug become shriveled and develop dark patches, the injury being similar to that of drought stress. Seeds damaged by pod fly show presence of white maggots and a brown puparium formed between the remnant of the seed and the pod wall and those damaged by pod borer can be identified by presence of round large holes on the seeds. The percentage seed damage was calculated using the formula below,

% Seed damage = (Number of seeds damaged / Total number of seeds examined) x 100

2.3.4 Insect pest scoring

The pest resistance rating was carried out based on the formula below (Lateef and Reed, 1990) and the resistance percentage was converted to 1 to 9 scale (Table 2).

Pest resistance rating (%) = {(P.D. rating of check – P.D rating of test entry) x 100 / P.D rating of check}

P.D = Mean of % seed damage

2.3.5 Determination of grain yield

Grain yield (Kg ha-1) was determined at maturity by harvesting and threshing the pods from the 3 middle rows of each plot and converted to t/ha.

2.3.6 Correlation between grain yield and damage by insect pest complex

Association between grain yield and damage severity was determined to assess factors that contributed either positively or negatively to yield performance among the genotypes.

2.4 Data Analysis

Data from field evaluation was transformed using log transformation method then subjected to analysis of variance using SAS version 9.2 [11]. Treatment means were separated using Fishers, leased significant difference (LSD) test at $P \leq 0.05$ and simple correlation coefficient (r) was carried out using Pearson's correlation to determine association among parameters measured.

Table 2. A quantitative 1-9 rating scale for resistance to insect pest complex among the genotypes

Pest resistance (%)	Resistance/Susceptibility rating		
100	1	↑	Increasing resistance
75 to 99	2		
50 to 75	3		
25 to 50	4		
10 to 25	5		
-10 to 10	6		Equal to check
-25 to -10	7		
-50 to -25	8		
-50 to less	9	↓	Increasing susceptibility

3. RESULTS

The three sites received different amount of rainfall and temperature during the study period. Koibatek recorded higher amount of rainfall (245 mm), Marigat (128.3 mm) while Fluorspar recorded the lowest amount of 115.9 mm (Table 3).

3.1 Number of Pod Borer Eggs and Larvae per Plant

The incidence of pod borer based on number of eggs and larvae varied significantly *(P*≤0.05) among the genotypes in all the sites. In Marigat, the number of eggs ranges from 2 to 4 with a mean of 3.9., however the number was low in Koibatek and Fluorspar recording a mean of 0.79 and 0.3 respectively. Similarly, number of pod borer larvae was high in Marigat (0.58) compared to Koibatek (0.06) and Fluorspar (0.03) (Table 4).

3.2 Pod and Seed Damage by Insect Pest Complex

Mean pod damage by pod borer was high (11.5%) compared to pod fly (9.82%). The damage by pod borer was significantly high in Marigat compared to Koibatek and Fluorspar. However, pod fly damage was high in Fluorspar (9.8%) compared to Marigat (4.5%) and Koibatek (3.9%).

Seed damage among the genotypes was significantly higher in sucking bug (16.86%) and pod borer (6.2%) but lower in pod fly (6.2%). The damage by these pests was high in Marigat except for pod fly which caused high damage in Fluorspar with a mean damage of 6.8% (Table 5).

3.3 Insect Pest Scoring

Pigeonpea is among the crops attacked simultaneously by several insect pests. The resistance to one particular insect may enhance the population of the other pests and cause enough damage to negate the effect of resistance**.** For instance, two genotypes (ICEAPs 01179 and 00068) are tolerant to pod borer but susceptible to sucking bug. Similarly two genotypes (ICEAPs o1147 and 0979-1) revealed resistance to sucking bug but susceptible to pod borer. All the genotypes were attacked by the insect pests though at different rates. Most of the genotypes were more susceptible to both pod borer and sucking bug but less to pod fly. Three genotypes (ICEAPs 00902, 01541 and 1154-2) recorded consistent results of resistance to the three insect pests across the three sites (Table 6).

Table 3. Monthly rainfall (mm) and temperature (℃) records for the study sites during 2014 period of the study

Month	Marigat		Fluorspar		Koibatek	
	Rainfall	Temp	Rainfall	Temp	Rainfall	Temp
Jan	100	33	14.00	30.2	100	27
Feb	90	34	25.90	26.46	60	28
Mar	150	34	87.80	29.89	80	28
Apr	200	32	46.80	28.25	180	26
May	145	33	130.00	21.88	220	25
Jun	120	32	83.20	30.6	300	25
Jul	115	31	243.80	25.12	200	24
Aug	160	31	170.60	27.2	250	24
Sep	90	33	65.10	34.45	360	26
Oct	145	33	314.80	26.79	330	25
Nov	100	32	123.70	28.22	410	25
Dec	125	33	85.00	29.36	550	26
Total	1540	391	1390.7	328.42	2940	309
Average	128.3	32.58	115.89	27.37	245	25.75

Source: weather-average/rift valley/ke.aspx

Table 4. Means for number of pod borer eggs and larvae per plant at 50% podding for three sites during April-October 2014 cropping season

Genotype	No. of pod borer eggs			No. of pod borer larvae		
	Marigat	Koibatek	Fluorspar	Marigat	Koibatek	Fluorspar
ICEAP 01147	7a	1ab	0.0d	0.3b	0a	0.0b
ICEAP 01179	5b-d	0b	0.7dc	0.7b	0a	1ab
ICEAP1147-1	2i	0b	0.0d	0.3b	0.3a	0.0b
ICEAP 01159	4.7c-e	0b	3.3b	0.7b	0a	0.7ab
ICEAP 00554	3f-i	1.3ab	0.0d	0.3b	0a	0.0b
ICEAP 01541	3.3e-i	0b	0.0d	0.3b	0a	0.0b
ICEAP 00540	2i	0b	0.0d	0.3b	0a	0.0b
ICEAP 00911	3f-i	0b	0.0d	0.0b	0a	0.0b
ICEAP 00902	4.3e-f	0.7ab	0.0d	1ab	0.3a	0.0b
ICEAP 01150	6.3ab	0b	1.7c	0.3b	0a	0.7ab
ICEAP 00068	2.3ih	0b	0.0d	0.3b	0a	0.0b
ICEAP 00557	6a-c	0.7ab	0.0d	1ab	0a	0.0b
KAT 60/8^S	4d-g	1.7a	5.3a	0.3b	0a	1.7a
ICEAP 00850^R	3.7d-h	0b	0.0d	0.0b	0.3a	0.0b
ICEAP 0979-1	2.7g-i	0b	1.7c	2.7a	0a	1.7a
ICEAP 1154-2	4d-g	0b	0.0d	0.7b	0a	0.0b
Genotype	**	*	**	*	NS	*
Grand mean	3.9	0.3	0.79	0.58	0.06	0.35
CV%	22.65	271.7	95.5	169.5	400	197.1
LSD	1.49	1.51	1.26	1.65	0.42	1.16

Mean in the same column followed by the same letter are not significantly different by Fisher least significant difference test at P =0.05

Table 5. Mean percentage pod damage and seed damage for pod borer, sucking bug and pod fly in all study sites

Sites	% pod damage		% seed damage		
	Pod borer	Pod fly	Pod borer	Sucking bug	Pod fly
Marigat	21.6	4.5	37.2	39.3	5.9
Koibatek	0.4	3.9	1.9	8.4	5.9
Fluorspar	11.6	9.8	3.6	2.9	6.8
Mean	11.2	6.1	14.2	16.9	6.2
CV%	26.3	23.3	30.2	15.1	19.5

3.4 Grain Yield

There were significant ($P \leq 0.01$) differences among the genotypes in yield performance in all sites. The interaction between the genotypes and the environment (sites) also affected the grain yield production of the test genotypes. Grain yield was higher in Koibatek (2.5 t/ah) than Marigat (0.4 t/ha) and Fluorspar (0.2t/ha). However, seven genotypes (ICEAPs 01147, 01147-1, 01159, 00911, 00850^R, 0979-1 and 1154-2) recorded higher yields. Most of these genotypes were resistant to the insect pest complex except for some few like ICEAP 01147-1 which recorded the highest yield (1.27 t/ha) across all the sites and was susceptible to pod borer and sucking bug. Its performance was contributed to its high number of branches yielding higher number of pods so that the damage could not be significant to its performance (Table 7).

Table 6. Percentage resistance of insect pest complex among 16 pigeonpea genotypes and rating based on 1-9 resistance scale (1-increasing resistance, 6-check and 9-increasins susceptibility)

Genotype	Pod borer	Sucking bug	Pod fly	Mean	Overall rating
ICEAP 01147	-10.4	19.8	17.3	8.9	6
ICEAP 01179	7.7	-7.7	7.5	7.5	6
ICEAP1147-1	-14.8	-373.2	58.6	-109.8	9
ICEAP 01159	-71.2	-19.5	56.1	-11.5	7
ICEAP 00554	-4.7	-387.1	30.2	-120.5	9
ICEAP 01541	18.7	47.6	84.5	37.8	4
ICEAP 00540	-18.1	42.8	-58.2	-27.6	8
ICEAP 00911	18.7	-102.5	72.5	-3.8	6
ICEAP 00902	23.7	47.3	79.1	50.0	4
ICEAP 01150	-26.7	-34	72.3	-26.5	8
ICEAP 00068	20.2	-33.9	72.3	-42.1	8
ICEAP 00557	0.6	49.3	-60.6	-36.8	8
KAT 60/8^S	-65.6	-78.3	38.1	-35.3	8
ICEAP 00850^R	0	0	0	0.0	6
ICEAP 0979-1	-39.8	36.1	71.7	9.3	6
ICEAP 1154-2	11.3	36.9	73.2	40.5	4
Grand mean	-11.7	-36.6	53.3	1.7	
Genotype	***	**	**		

Table 7. Table of means for grain yield (t/ha) for 16 pigeonpea genotypes in each site during April- October 2014 cropping season

Genotype	Marigat	Koibatek	Fluorspar	Mean
ICEAP 01147	0.8a	2.1e-h	0.2cd	1.03 a-d
ICEAP 01179	0.7b	1.7h	0.2bc	0.87 d
ICEAP1147-1	0.6b	2.9a-c	0.3ab	1.27a
ICEAP 01159	0.3c-e	2.7a-e	0.4a	1.13 a-c
ICEAP 00554	0.2e	2.6a-f	0.1d	0.98b-d
ICEAP 01541	0.2e	2.6a-f	0.1d	0.98b-d
ICEAP 00540	0.3c-e	2.3c-h	0.1d	0.9cd
ICEAP 00911	0.4c	2.9ab	0.1d	1.17ab
ICEAP 00902	0.3cd	2.2d-h	0.1d	0.89 cd
ICEAP 01150	0.3de	1.9gh	0.2bc	0.81d
ICEAP 00068	0.4c	2.1f-h	0.1d	0.87d
ICEAP 00557	0.3c-e	2.5b-g	0.1d	0.98 b-d
KAT 60/8^S	0.6b	1.7h	0.2bc	0.86d
ICEAP 00850^R	0.3cd	2.9a-c	0.4a	1.21ab
ICEAP 0979-1	0.4c	2.8a-d	0.4a	1.18ab
ICEAP 1154-2	0.2de	3.2a	0.1d	1.18ab
Genotype	**	**	**	**
Grand mean	0.4	2.45	0.2	1.02
CV%	16.9	16.2	24.08	27.1
LSD	0.11	0.66	0.08	0.25

Mean in the same column followed by the same letter are not significantly different by Fisher least significant difference test at P =0.05

3.5 Correlation Analysis of Grain Yields and Severity of Insect Pest Complex

The different insect pest complex parameters were correlated to establish any possible significant relationship with yield. There was significant correlation in some traits (<0.01) but not in others. Seed damage by pod fly (r=-0.08) showed a negative correlation with yield but not significant. In contrast, number of pod borer eggs at 50% podding (r=-0.35***), pod borer damage on pods at 50% podding (r=-0.53***), seed damage by sucking bug (r=-0.24**) and seed damage by pod borer (r=-0.41***) were negatively correlated to yield (Table 8).

4. DISCUSSION

4.1 Rainfall and Temperature

Genotypes responded differently to the insect pest complex depending on the sites. A significant variation was observed in number of pod borer eggs per plant, number of larvae per plant, pod damage and seed damage. The variations in incidence and severity among the genotypes may be attributed to the genetic makeup of the plant and environmental factors favoring the distribution and existence of the pests in different environments [6]. The variations can also be attributed to differences in amount of rainfall and temperature during this time of pest build up. Koibatek received high amount of rainfall during the cropping season which may have washed away pod borer eggs. On the other hand, Fluorspar received low rainfall and exhibited high temperatures that could not allow survival of the eggs. The high pest pressure in Marigat (warm) compared to Koibatek (cool) and Fluorspar (dry) may be explained by preference of pod borers in warm areas compared to cool areas since they undergo diapause during cool and dry weather conditions [6]. Pod damage by pod fly (4.46%) was low compared to that of pod borer (21.64%) in Marigat.

4.2 Oviposition Preference

The variations in number of eggs and larvae among the test genotypes may be attributed to oviposition preference of the pod borer on some -genotypes and not others. The preference may be contributed to the type of trichomes, flower colour and flower orientation. Non-glandular trichomes act as physical barrier to feeding by young larvae. It also affects locomotion, attachment, shelter and survival of insects. Pod borer is attracted by yellow colour hence having preference to genotypes with yellow flowers compared to red. This concurs with [12] who found significant differences in response to pest damages during flowering and maturity stages across seasons.

4.3 Tolerance

Some genotypes were susceptible to the insect pest complex but were still giving high grain yields. This ability may be contributed by the genetic components of the plant like ability of producing higher number of pods that lead to higher number of seeds hence higher yields. This trait was revealed by ICEAP 1147-1 which was susceptible to the insect pest complex but yielded the highest yield across the study sites.

Table 8. Correlation analysis for grain yields and incidence/severity of insect pest complex

	Grain yield	Pod borer damage	Pod fly damage	Seed damage by pod fly	Seed damage by sucking bug	Seed damage by pod borer
Grain yield	1					
Pod borer damage	-0.53***	***1***				
Pod fly damage	*-0.46****	0.12ns	***1***			
Seed damage by pod fly	-0.08*ns*	-0.10ns	0.05ns	***1***		
Seed damage by sucking bug	-0.24**	0.47***	-0.36***	0.09ns	***1***	
Seed damage by pod borer	-0.41***	0.55***	-0.26**	-0.05ns	0.85ns	***1***

Correlation significance at p=.05=; p<.01=** and p<.001=***; ns= not significant*

5. CONCLUSION

Genotypes revealed different levels of resistance / susceptibility to the insect pest complex at different locations. Some genotypes showed tolerance to pod borer, but were highly susceptible to pod fly and sucking bug. This suggests that tolerance does not hold against other insect groups. The sites varied significantly in incidence and severity of the insect pests, with Marigat showing high incidence of pod borer and sucking bug, Koibatek incidence of pod fly and sucking bug while Fluorspar had incidence of pod fly and pod borer. Three promising genotypes (ICEAPs 00902, 01541 and 1154-2) have been identified with potential of tolerance to insect pest complex across the three sites by having large number of branches and number of pods per plant. These sources of resistance can be explored and used in breeding programs for development of resistant lines.

6. RECOMMENDATIONS

Mechanisms of resistance to this insect pest complex need to be identified to aid in breeding for resistance to insect pests in Pigeonpea.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Chitra U, Singh U, Rao PV. Phytic acid, in vitro protein digestibility, dietary fiber, and minerals of pulses as influenced by processing methods. Plant Foods Hum Nutr. 1996;49:307–16.
   DOI: 10.1007/BF01091980
2. Saxena KB, Kumar RV, Rao PV. Pigeonpea nutrition and its improvement. J Crop Prod. 2002;5:227–60.
   DOI: 10.1300/J144v05n01_10
3. Rao KJVDK, Johansen C, Chauhan YS, Jain VK, Jain KC, Talwar HS. An analysis of yield variation among long-duration pigeonpea genotypes in relation to season, irrigation and plant population. J Agric Sci. 2001;136:291–9.
   DOI: 10.1017/S0021859601008747
4. Choudhary AK, Raje RS, Datta S, Rafat Sultana, Timanna Ontagodi. Conventional and molecular approaches towards genetic improvement for insects resistance in pigeonpea. American J Plant Sci. 2013;4: 372-385.
5. FAOSTAT. Pigeonpea production in Kenya 1993-2013; 2015.
   Available:http://faostat3.fao.org/browse/Q/QC/E. August
6. Minja EM, Shanower TG, Songa JM, Ong'aro JM, Kawonga WT, Mviha PJ, et al. Studies of pigeonpea insect pests and their management in farmers' fields in Kenya, Malawi, Tanzania, and Uganda. African Crop Sci J. 1999;7:1–10.
   DOI: 10.4314/acsj.v7i1.27778
7. Lateef SS. *Heliothis* management: Current Status and Future Strategies; 1990.
8. Shanower TG, Romeis J, Minja EM. Insect pests of pigeonpea and their management. Annu Rev Entomol. 1999;44:77–96.
   DOI: 10.1146/annurev.ento.44.1.77
9. Joshi S. Pestcide treadmil. Appropr Technol. 2006;33:22–4.
10. Jaetzold R, Schmidt H. Farm management handbook of Kenya vol. II - natural conditions and farm management information. Vol II/B Central Kenya (Rift valley and Central province); 1983.
11. SAS Institute Inc. SAS/STAT® 9.2 User's Guide. Cary, NC: SAS Institute Inc; 2008.
12. Khaki N. Evaluation of Malawi pigeon pea (*Cajanus cajan* L) accessions for tolerance to moisture stress and superior agronomic traits in Uganda; 2014.

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