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Research Article
Effects of Genotypes and Potassium Rates on Some of Cowpea Traits Heritability

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Abstract

Background: Introduction is considered one of important plant breeding methods to develop new cultivars. Cowpea cultivars have high performance under optimum potassium level because of their positive effects on photosynthesis and physiological as well as chemical processes in plant. **Methodology:** Two cowpea cultivars (byader and bonanza) and their F_5 progenies were planted at Abu-Ghraib station located in Baghdad in the middle of Iraq in the autumn season, 2014. Split plots in randomized completely block design was used. Potassium rates were control (without application), 50 and 100 kg K ha^{-1} were assigned to main plots while genotypes occupied the sub-plots. Statistical analysis of variance to test the significance and to measure the least significant differences between means was carried out. **Results:** Byader was superior in 100 seeds weight, pod length and seeds number per pod. Byader F_5 recorded lowest mean in days to flowering, number of pods per plant and seed yield. Bonanza F_5 and byader had the highest mean in seeds number per pod. Plants grown at 100 kg K ha^{-1} took the shortest period to flowering. Byader F_5 grown at 100 kg K ha^{-1} was the best for early flowering. In addition, it was the highest in pod length, pod number per plant and seed yield. Bonanza F_5 was the best in seeds number per pod. Strongest positive correlation relationship was r = 0.919 between seed yield and pods number per plant, therefore, it considers as a strongest indirect selection index to improve seed yield. High heritability value was 80% for 100 seed weight because of strong genetic control on it. Similarly, it was observed with inheritance of days to flowering. Small differences between genotypic coefficient correlation (GCV) and phenotypic coefficient correlation (PCV) was recorded, indicating high homogeneity between plants. **Conclusion:** Selection in early generation for pods number per plant led to high seed yield in cowpea progenies F_5 especially when planted at optimum rate of potassium fertilization.

Key words: Progenies, seed yield, correlation, generation, heritability, cowpea, interaction, pods number

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Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cowpea (*Vigna unguiculata* L.) is a leguminous crop with multipurpose usage. Yield of fresh pods per hectare is 5.2 t ha^{-1}. Dry seed yield above 7000 kg ha^{-1} had been achieved in large field plot with guard rows in Southern San Joaquin valley of California[1] where growers often obtained yields above 4000 kg ha^{-1}. East and middle of Africa produce more than 60% from total world production[2]. Cowpea seed contains high percent of protein and reach as high as 25 and 64% of carbohydrates[3]. In addition, their leaves and stems are a good fodder for livestock. Cowpea being a fast growing crop, Iraqi farmers prefer planting it in crop rotation before cereals such as wheat. Cowpea improves soil fertility because it has ability to fix atmospheric nitrogen on their root with some strains of rhizobia through symbiosis. Moreover, its residues decay in soil. Iraqi environment needs high yielding cultivars, therefore, program was designed to introduce cultivars and then selecting the best in productivity and adaptability.

Potassium is the most important cation for plant growth and its development. It has multifunction at levels of physiology and biochemistry particularly those related to enzymes activity that take part in photosynthetic reactions and metabolism of carbohydrates. Potassium constitutes up to 10% of plant dry matter by weight[4]. There are many physiological processes in plant such as osmotic regulation, transporting carbohydrates and anion-cation balance respond to potassium concentration in plant tissues. Although, the plants can absorb K^+ from the soil solution, the majority of K^+ in soil is unavailable, existing in fixed and lattice forms[5]. The increase of potassium intake leads to a positive effects on photosynthesis, leaf area index, growth, enhancement of ATP, NADPH synthesis, increase of mobilization of nitrogenous materials to grain in cereals, regulation of stomata opening and closure and decrease of transpiration[6]. Either efficient species have certain morphological characteristics that increase uptake of utilization of nutrients or they are able to improve the availability of nutrients[7]. The high water use efficiency (production of unit dry matter per unit water transpired) at optimum K^+ nutrition results from closely controlled opening and closure of stomata[8]. Potassium not only promotes the translocation of newly synthesized photosynthates but also has beneficial effect on the mobilization of stored material. Timko and Singh[9] reported that early flowering cowpea genotypes could produce a crop of dry seeds in 60 days while longer season genotypes may require more than 150 days to maturity depending on photoperiod. Msaakpa *et al.*[10] found a large variation among varieties of cowpea in pod length and pod weight where the variety IT89KG-288 was superior. The objective of this study was to determine the effectiveness of selection of cowpea progenies and their parents under potassium fertilization at the middle of Iraq.

MATERIALS AND METHODS

Field trial was conducted at the College of Agriculture field station that is located near Baghdad in autumn season, 2014. Split plots experiment in Randomized Completely Block Design (RCBD) with three replications was followed. The main plots were assigned for potassium rates while sub-plots were for genotypes. The genotypes were two cowpea cultivars (byader and bonanza) with their progenies (F_5) that were selected depending on their high performance in pods per plant. Three potassium rates were added, K_0 (control, without application), K_{50} (50 kg K ha^{-1}) and K_{100} (100 kg K ha^{-1}). The DAP fertilizer that contains nitrogen and phosphorus was applied before planting. Therefore, DAP was part of nitrogen source that was added at 50 kg N ha^{-1}. It provided the total source of phosphorous fertilization that applied at 100 kg P ha^{-1}. Potassium source was potassium chloride (41% K). All quantity of P and K^+ was added in one batch before planting while nitrogen was applied at two dates, the first came from DAP and the second batch was added as urea form (46% N) at flowering stage. Available nitrogen, phosphorus and potassium were taken into accounts when adding fertilizers to required rates (Table 1). Seeds were planted at upper third of furrow in holes spaced 30 cm and spacing between furrows was 75 cm. Insects were controlled by nogoze insecticide. All agronomic practice such as weeding, irrigating and fertilizing were done as recommended. Random sample of 10 plants for each treatment were taken to calculate yield and its components. Total pods yield were gathered three times in the season for each sample.

Yield calculation: Progress in yield performance for each variety and its progeny was calculated by following equation:

$$\text{Yield performance} = \frac{\text{Yield mean at } F_5 \text{ generation-yield mean at parent generation}}{\text{Yield mean at parent generation}}$$

Table 1: Pre-study soil characteristics at test plots measured to a depth of 20 cm

Soil characteristics	Value
Available nitrogen (mg kg^{-1})	10
Available phosphorous (mg kg^{-1})	8
K^+ (cmol kg^{-1})	0.45
Organic matter	1.2%
pH	7.3
EC	1.77
Soil type	Loamy clay

Potassium Use Efficiency (KUE): It was determined for each treatment by using Agronomic Efficiency (AE) and the Partial Factor Productivity (PFP) indices according to Dobermann[11] who calculated it for nitrogen fertilizer:

$$AE = (Y\text{-}Y0)/F \text{ and } FP = Y/F \text{ or } PFP = (Y0/F)+AE$$

$$\text{KUE-AE} = \text{GY increase over control per kilogram K applied}$$

$$\text{KUE-PFP} = \text{GY per kilogram K applied}$$

where, F is amount of (fertilizer) nutrient applied (kg ha^{-1}), Y is crop yield with applied nutrients (kg ha^{-1}) and Y0 is crop yield (kg ha^{-1}) in a control treatment.

Agronomic efficiency: Expressed by relative yield increase per units of potassium applied and partial factor productivity expressed as crop yield per unit of K applied.

Statistical analysis: Data were analyzed statistically according to the analysis of variance (ANOVA) procedures by GenStat discovery (version 12) to test the significant ($p< 0.05$) for single factors and interactions for split plots design. Curves and bar charts were plotted by Minitab (version16.1).

Estimation of genetic parameters: Estimation of the genetic varaibility among genotypes for each traits under study was according to following formula. Expected mean square for potassium rates is considered as a fixed factor while for genotypes was a random:

$$\text{Genotypic variance } (б^2g) = \frac{\text{MS genotypes-MS (Error b)]}}{k \times g}$$

$$\text{Phenotypic variance } (б^2p) = б^2g\text{+MS (Error b)}$$

$$\text{Genotypic coefficient of variability (GCV\%)} = [бg/\overline{X}]\times 100$$

$$\text{Phenotypic coefficient of variability (PCV\%)} = [бp/\overline{X}]\times 100$$

Where:

бg = Genotypic standard deviation

бp = Phenotypic standard deviation

$\overline{X}$ = General mean of the character

Sivasubranian and Menon[12] classified the values of GCV and PCV% as follows:

0-10%: Low, 10-20%: Medium, 20% and above: High

$$\text{Hertability (\%) in broad sense } (H^2b.s) = [б^2g/б^2p]\times 100$$

Heritability in broad sense was computed as the ratio between the genetic variance to the total phenotypic variance as suggested by Hanson *et al.*[13].

RESULTS AND DISCUSSION

Effects of genotypes and their F_5 progenies on cowpea traits: Results in Fig. 1 show that there were significant differences between genotypes within each trait except in seed number per pod. Byader and its progeny flowered first compared to bonanza and its progeny. Byader F_5 took time to flowering 1% less than its parent. Similarly, bonanza F_5 recorded 2.6% less days to flowering compared to its parent. Early flowering is a desirable character because it is highly related to early maturity that lead to save enough time to prepare the land for planting successive crop such as wheat especially in autumn season (under Iraqi environment). Many selection cycles lead to reducing days to flowering in both progenies because of increasing gene frequency controlling flowering. The flowering mechanism is genetically very complex. It controls seed number and total seed yield. Photoperiod is the most important environmental variable affecting time to flowering in cowpea. Short cycle durations cowpeas take less than 60 days and are ideal for short gowning season. Obadoni *et al.*[14] and Ichi *et al.*[15] reported that cowpea varieties varied significantly in days to flowering. Al-Temimi[16] found that S_4 progeny was superior on other previous generations. It took 40 days to flowering in autumn season.

Furthermore, pod length is considered as a favorable trait for consumers, but if there is high abortion of ovules, it becomes useless. Byader came first in pod length while the lowest was bonanza. This may be attributed to the fact that selection for one trait leads to reduction of the mean of another trait. Idahosa *et al.*[17] reported of pod length was 14.93 cm, while another report by Cobbinah *et al.*[18] found it to be 15.77 cm. Ehlers and Hall[19] stated that pod length in some varieties that have succulent pods which are eaten in fresh form as vegetable might reach between 35-75 cm. Al-Temimi[16] found that selected S_5 gave highest pod length reaching 15.88 cm in spring season while in autumn seasons was 15.3 cm. Al-Assafi and Abed[20] stated that there was a successive increase in pod length by progressing of selection cycles.

Pods number per plant is one of the main yield components. It is affected by environmental conditions such as high temperature that causes death of pollen grains and then failure to fertilization. Consequently, seeds set will be at minimum range; this in turn reduces pods formation. The F_5 progenies for two cultivars gave highest values compared to their parents. Byader F_5 gave the highest mean but there was

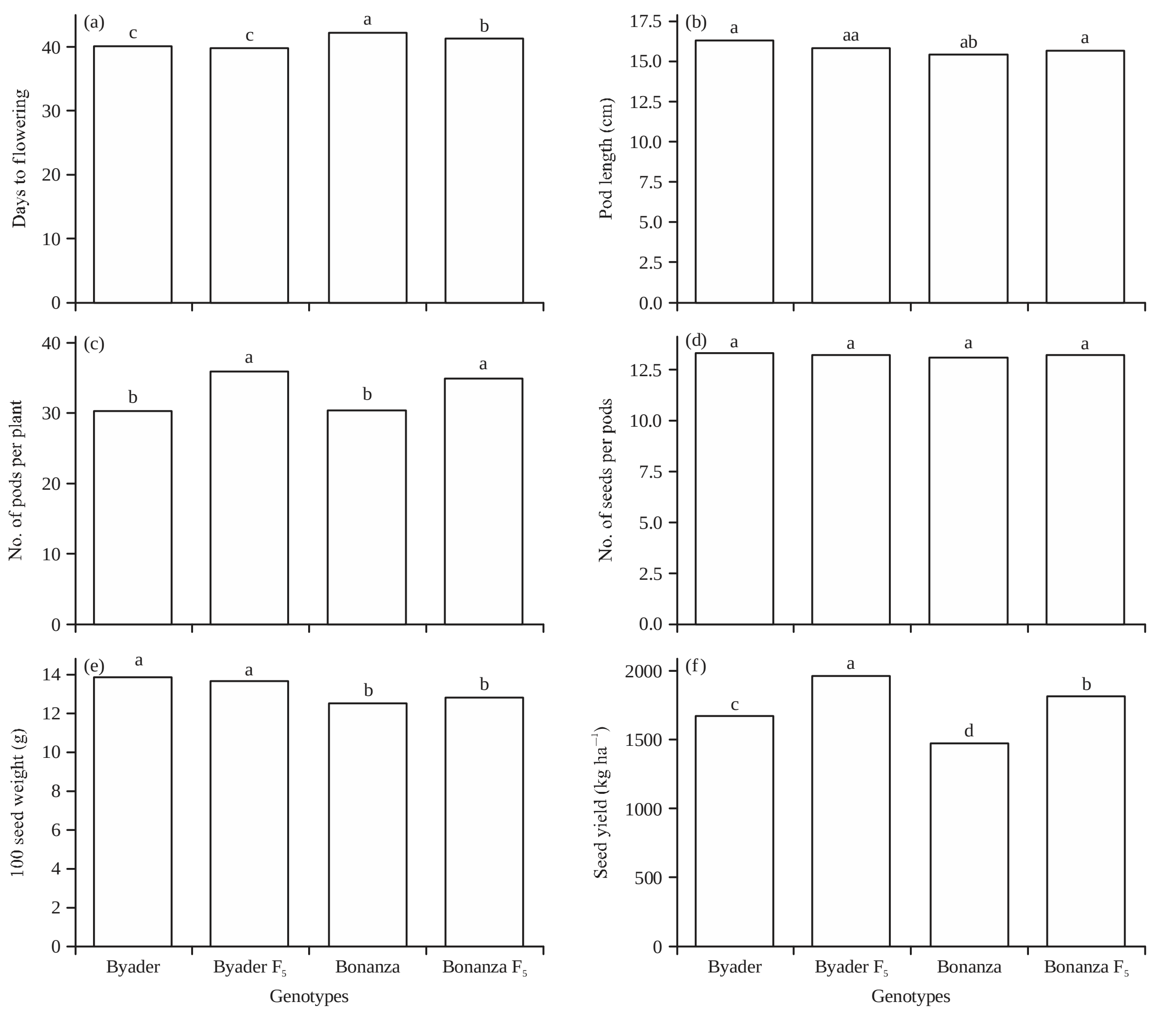

Fig. 1(a-f): Means of traits studied for cowpea genotypes

no significant difference with bonanza F_5. There were considerable increases that reached 15.2 and 12.7% between F_5 progenies of byader and bonanza and their parents, respectively. Cobbinah *et al.*[18] found pods per plant to range from 22.7-26.3. There were no significant differences between genotypes in seed number per pod. Small increases between both parents in, byader and bonanza and their F_5 progenies were 3.3 and 1.2%, respectively. The inheritance of 100 seed weight is associated strongly with genotypic factors of cultivar. It is affected by the duration from flowering to maturity (long seed filling period). Parental byader gave the highest 100 seed weight while the lowest mean came from parental bonanza. The reason behind superiority of byader in 100 seed weight was early flowering that led to prolonged reproductive phase. The reduction in this trait between parental byader and its F_5 progeny was -1.7%, while there was small increase (no significance) between parental bonanza and its F_5 progeny. The increase of seeds number per pod and pods per plant in byader F_5 led to reduced 100 seeds weight according to compensation principle. This result is in disagreement with the result of Abed[21] who found in advanced progenies, 100 seeds weight increased by about 5.4% because of increasing gene frequency. Ehlers and Hall[19] found variation for seeds sizes ranged between less than 10 g per 100 seeds and approximately 30 g.

Seed yield is considered most stable agronomic criteria to evaluate the performance of variety. Both genotypic and environmental factors might affect seed yield negatively or positively. Seed yield is the product of components including number of pods per plant, number of seeds per pod and seed weight. There was considerable increase between byader F_5 and its parent, reaching 14.7% while the increase was 18.9% between bonanza F_5 and its parent. Selection and adaptation for both progenies at Iraqi environment led to increase in seed yield. Generally, byader F_5 was more than parental byader, the same trend for bonanza F_5. Planting cultivar under the

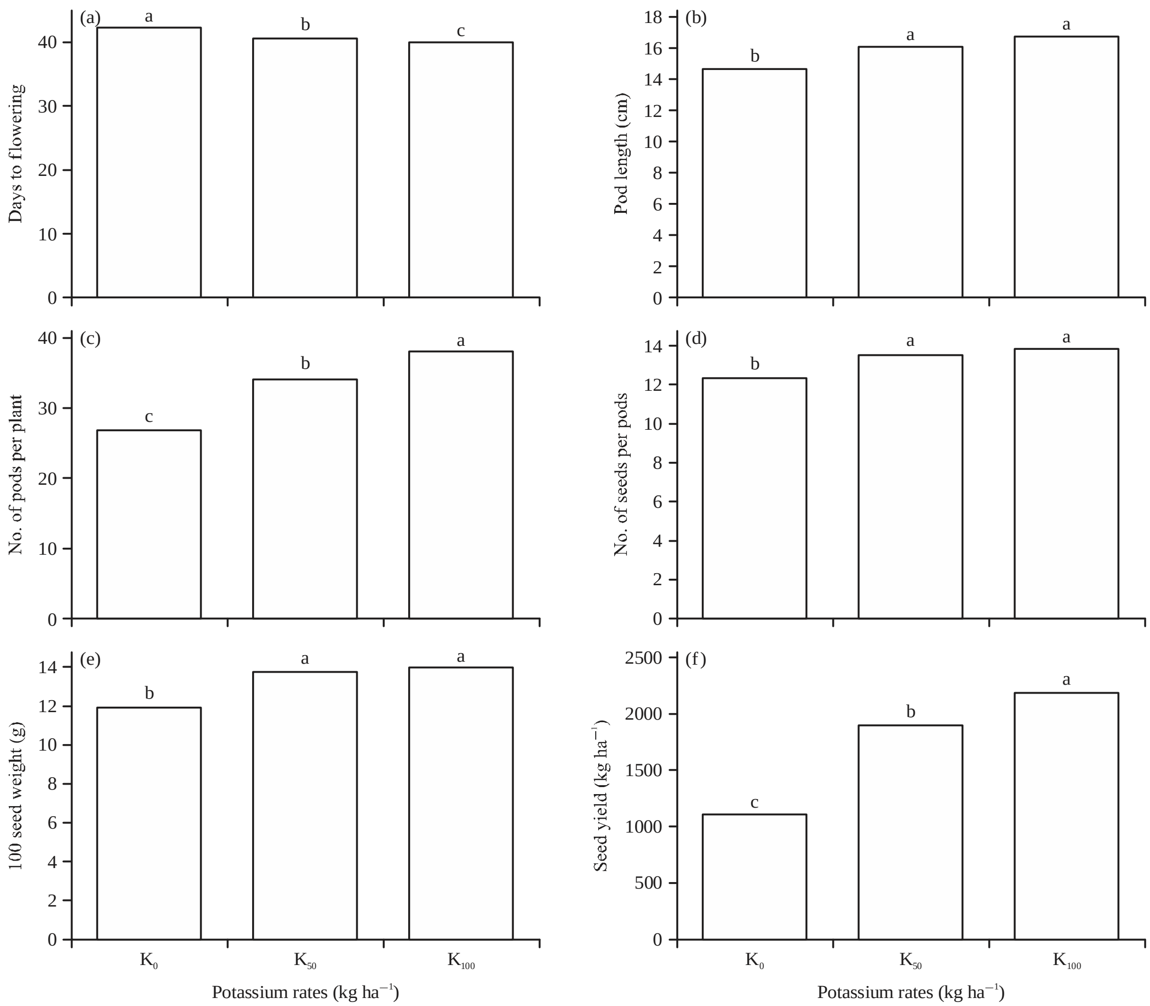

Fig. 2(a-f): Means of cowpea traits studied at potassium rates

same environmental sites from year to year lead to activation of some sets of genes to be more convenient in target environment. This result is in agreement with the result of Al-Assafi and Abed[20] who found the selection for pods number per plant to influence on increased seed yield.

Effects of potassium fertilization on cowpea traits: Results in Fig. 2 show a big role for potassium within each trait. For days to flowering, K_{100} gave the lowest period to flowering while K_0 was the highest. This can be associated to the role of potassium in accelerating photosynthesis, internal physiological and biochemical processes. Therefore, the plants grow up to form reproductive organs faster compared to plants with poor potassium fertilization. In pod length, K_{100} gave the highest mean. Increases in pod length at K_{50} and K_{100} rates compared to control treatment were 9.6 and 13.6%, respectively. Kanaujia *et al.*[22] found significant increase in pod length of french bean due to application of potassium fertilizer. High photosynthesis activity and source strength that supported assimilates for pods may have partially contributed in lengthening the pods. The K_{100} recorded the highest mean in seed per pods, number of pods per plant, 100 seeds weight and seed yield. Increasing seeds per pod at K_{50} and K_{100} rates compared to control were 8.6 and 10.8%, respectively. We observed a big increase in pods number per plant between K_0 and K_{50} which was 21.3% as compared to increase between K_{50} and K_{100} of 10.1%. Geetha and Varughese[23] reported that N and K fertilizers by increasing the number of pods and seeds per plant improved seed yield of cowpea. According to Mengel and Kirkby[8], potassium is mobile in xylem and phloem can be recycled in plant, i.e., transport from roots and from here again to shoots. So that, high rates of potassium fertilization increase availability of material assimilated to seed and eventually reduce abortion of ovules. Similarly, 100 seed weight was superior at K_{100}. The amount of increase in 100 seed weight between (K_0 to K_{50}) and between (K_0 to K_{100}) were 16 and 17.5%, respectively, while there was small increase between K_{50} and K_{100} about 1.2%.

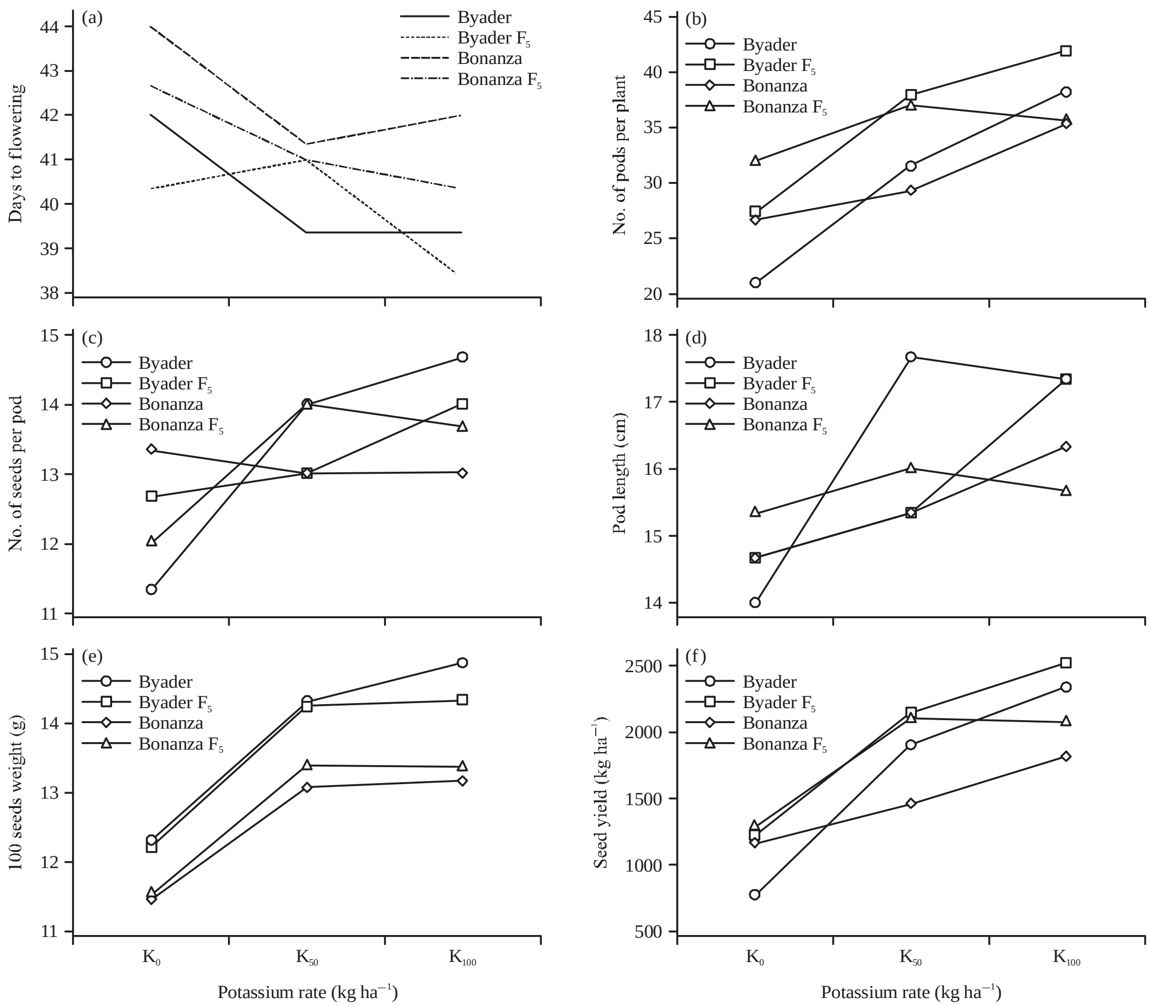

Fig. 3(a-f): Interactions between genotypes of cowpea and potassium rates for some traits

Results in Fig. 2 indicates that potassium fertilization has a major role in high seed yield. The K_{100} gave high mean of seed yield compared to K_{50} and K_0. Increases in seed yield at K_{50} and K_{100} compared to control were 41.8 and 97.9%, respectively. Therefore, it is necessary to provide the plants with optimal concentration quantity of potassium to get high yield. Potassium has multidimensional effects on plant growth. Lopez *et al.*[24] reported that potassium has an important role in increase seed yield of cowpea. Haghparast *et al.*[25] found the highest amount of seed yield (1556 kg ha^{-1}) was recorded by application of 30 kg N and K ha^{-1}. Padi and Ehlers[26] found that F_4 lines derived from highest 10% F_3 individuals were no higher yielding than F_4 lines derived from the remaining F_3 individuals, indicating that early generation selection for yield was ineffective. Potassium regulates cell growth, such as root hair[27] and pollen tube growth[28]. Plants growing under K^+ limited conditions are stunted and poorly developed.

Interactions between genotypes and potassium rates: Results in Fig. 3 indicate there are significant interactions between genotypes and potassium rates for traits studied except in 100 seed weight. Byader F_5 planted at K_{100} took shorter period to flowering, this indicates importance of selecting genotypes at optimum potassium level to shortening days to flowering. Byader showed a high response in pod length at K_{50} and K_{100} compared to K_0 while there was no response by increasing potassium rate from K_{50} to K_{100}. For seeds per pod, parental bonanza was more tolerated to potassium shortage compared to parental byader. Bonanza F_5 planted at K_{100} gave the highest mean seeds per pod while byader planted at control was the lowest mean. That indicated bonanza showed higher responsive in seeds per pod for potassium fertilization than byader. The highest mean in pods number per plant came from byader F_5 planted at K_{100} while parental byader at control treatment gave the lowest mean.

Table 2: Simple correlation coefficient between all traits studied

Traits	100 seed weight	No. of pods	No. of seeds	Days to flowering	Pod length
No. of pods	0.668				
No. of seeds	0.532	0.681			
Days to flowering	-0.752	-0.491	-0.347		
Pod length	0.671	0.607	0.541	0.574	
Seed yield	0.817	0.919	0.767	-0.633	0.762

Bonanza F_5 planted at K_{50} was higher mean than plants at K_{100}. Al-Temimi[16] found the S_5 planted in autumn season gave 23 pods plant^{-1}. Byader F_5 planted at K_{100} gave highest seed yield while its parent (byader) recorded the lowest seed yield mean.

Correlations between traits: Table 2 showed simple correlation coefficients between traits studied. The relationship between pods number per plants and seed yield recorded highest simple correlation coefficient reached 0.919. This is considered a good indicator for improving yield based on pods number per plant. Many researchers reported high positive correlation between pods number per plants and seed yield[29,30]. Also 100 seed weight gave a higher correlation coefficient with seed yield which reach 0.817. There were negative correlation between days to flowering and seed yield, seed weight, pod number per plant, seed number per pods but it has a positive correlation with pod length. This lead to prolonging of reproductive period for early cultivar flowering. Negative significant correlation between days to flowering and seed yield was found by Alidu *et al.*[29] but highest and lowest positive direct effects on seed yield were observed for seed weight per pod and plant height while days to 50% flowering recorded negative direct effect on seed yield per plant[31].

Agronomic Efficiency (AE): Expressed by relative yield increase per units of potassium applied and partial factor productivity expressed as crop yield per unit of K applied[32] are indicative of the degree of economic and environmental efficiency in use of nutrient input. Figure 4 shows that K_{50} gave highest value for agronomic efficiency compared to K_{100} except for bonanza. The highest value was 22.9 kg seed for each potassium up to control treatment came from byader planted at K_{50}. This indicates high response for nutrient at low levels of fertilization and then decrease gradually.

Genetic parameters: Results in Table 2 for genetic analysis of days to flowering revealed a magnitude of genotypic variance $\sigma^2 g$ out of phenotypic variances $\sigma^2 p$. This indicated less environmental impacts controlling on flowering. Heritability value was 58%, this is considered a good value to design

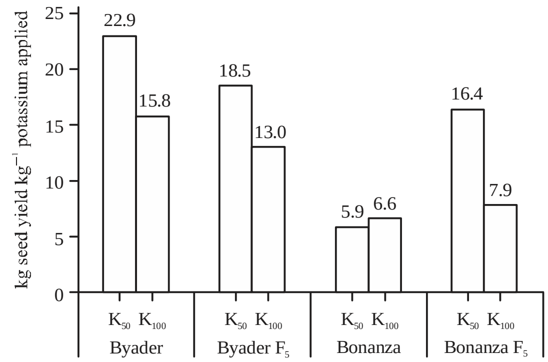

Fig. 4: Agronomic efficiency percentage of cowpea genotypes at K_{50} and K_{100}

active selection program to improve earliness. Poehlman and Sleper[33] stated that days to flowering had high heritability value. Ishiyaku *et al.*[34] estimated a narrow sense heritability about 86% and seven pairs of major genes which control time to flowering in one of crosses. Omoigui *et al.*[35] found considerable variation among cultivars for duration of reproductive phase. Also, PCV% was high for days to first flower, 100 seed weight and H^2 bs was 84%. Shimelis and Shiringani[36] estimated heritability in broad sense of cowpea in this character, which was up 50% while[16] found values for heritability of cowpea planted at two seasons to range between 71-75%. Earliness in cowpea was under polygenic control and highly heritable[37]. Genotypic coefficient value and phenotypic coefficient value for this trait were 2.38 and 3.10, respectively. Both values are closer from each other indicating high uniformity between genotypes. This result is in agreement with findings of Sattelmacher *et al.*[7] who stated PCV and GCV% were 3.18 and 2.94%, respectively.

Genotypic and phenotypic variance values for pod length were 0.0717 and 0.4976 reflecting poor heritability value was 14%. This indicates small part of total variance was genotypic source, therefore, the selection as a way to improve this trait could be viable. The GCV and PCV% were 1.7 and 4.4%, respectively. The small gap between GCV and PCV% refers to high homogeinty among the plants in this triat. This result is in agreement with findings of Al-Temimi[16], Al-Assafi and Abed[20] and Shanko *et al.*[38].

Genetic variation $б^2g$ and $б^2p$ values for this trait were 0.0945 and 0.2844, respectively. This could have led to less than medium heritability value of 33%. Therefore, more selection cycles are needed to accumulate the additive genes that increase seeds per pod. The GCV and PCV% were 2.2 and 3.9%, respectively. The small gap between GCV and PCV refers to high homogeneity among plants in this triat. This result was in agreement with the results of Al-Assafi and Abed[20] and Shanko *et al.*[38].

Heritability for pods number per plant was more than medium value of 59.3%, given that the selection trial for this trait was performed in early generations. Therefore, this trait can be selected efficiently because it has high genotypic variance. Values of GCV and PCV% showed that there were considerable differences between them. This means that some heterogeneity between genotypes in this trait exist. Ajibade and Morakinyo[39] found low heritability value (20%) for this trait while Omoigui *et al.*[35] estimated it between 0-19%. Heritability in broad sense for 100 seed weight was of high value about (80%). This explains that seed weight was under high control of genetic factors. Five genes with high heritable reaching 68% are governed seed weight[40]. The difference between GCV and PCV% was very small, indicating the genotypes were vey homogenous in this trait.

For seed yield, $б^2g$ was 31002 and $б^2p$ was 48326 resulting in heritability value more than medium of 64%. This is considered a high value over expectation. The reason behind that, byader F_5 and bonanza F_5 were subjected to selection in early generation leading to accumulation of the favorable genes. The GCV and PCV were 8.99 and 11.23%, respectively. It is considered medium values according to Sivasubranian and Menon[12] indicating some homogeneity among genotypes.

CONCLUSION

Results from this expirement explain the relationship between seed yield and traits or factors affecting it. The easy way to design an effecitive selection programm to improve cowpea seed yield is by supporting the plants with optimum factors that contribute increasing it. Performance of genotypes at varous of potassium fertilization was different and the best agronomic efficiency was at K_{50}. Pods number per plant was most positively correlated with seed yield. Therefore, it can be used as an indirect selection index to improve seed yield.

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