Correlation, path coefficient and principal component analysis of yield components in mung bean [*Vigna radiata* (L.) Wilcezk] accessions

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Adequate knowledge on the identification of the most important yield contributing traits would help in improving seed yield of mung bean by using appropriate selection indicators. Thus, this research work aimed at studying relationships among yield contributing traits and estimating the direct and indirect effects of these traits on seed yield of 20 mung bean accessions evaluated at three major agro–ecologies (forest, derived savanna and savanna) in southwest Nigeria. Results obtained from correlation analysis revealed that significant and positive relationship existed between pairs of seed yield/ha with days to first flowering (r=0.27), number of pods/plant (0.32**), number of seeds/pod (0.14*) and pod yield/plant (0.91***). Path analysis showed that pod yield/plant had the highest positive direct effect on seed yield/ha (0.91), followed by pod length (0.40), days to 70% maturity (0.12), days to 50% podding (0.10), days to first flowering (0.04) and number of pods/plant (0.01). Similarly, pod yield/plant exhibited positive indirect effect through days to first flowering, days to 50% flowering, days to 50% podding, number of pods/plant, days to 70% maturity and pod length. Principal component analysis revealed five component axes that accounted for 89.45% of the total variation. The first three components had eigenvalues greater than 1.0 and accounted for 70.48% of the total variation. The first principal component was associated with days to first flowering, days to 50% flowering and days to 50% podding with negative loadings. The traits that contributed the most positive loadings to the second component were seed yield/ha and number of pods/plant. The third component was associated with pod length and number of seeds/pods with positive loadings. Identified relationships could assist plant breeders in genetic improvement of seed yields of mung bean.**

Keywords: Mung bean, seed yield, correlation, path analysis, principal component analysis

Mungbean is one of the most important food legumes grown worldwide. It is also one of the most common crops in tropical and sub–tropical regions (Allahmoradi et al. 2011). The importance of this legume is related to desirable characteristics such as high protein content, broad adaptation, low need for agricultural inputs and high ability to increase soil fertility (Makeen et al. 2007). Mung bean is regarded as one of the under–utilized legumes in many countries in Sub–Saharan Africa. Hence, it is not always included in national statistics, especially in Nigeria. Some of the yield data from research activities at National Agricultural Research Institutes and Universities in Nigeria, showed that mung bean seed yields were extremely low (below 1.5 t/ha). Idoko and Avav (2013) obtained seed yields of 1181.67 kg ha^1 in early season and 995.60 kg ha^{-1} in late season for some mung bean cultivars evaluated in the Southern Guinea Savanna of Nigeria. Similarly, Agugo (2017) obtained seed yields of 620 kg ha^{-1} in early season and 415 kg ha^{-1} in late season in some mung bean genotypes evaluated in the lowland rainforest in south eastern Nigeria. Therefore, to achieve consistent yields, there is a need to identify yield contributing traits, rather than focusing only on seed yield for mung bean improvement. To achieve this improvement, availability and tracking of genetic variation among mung bean germplasm is important.

Genetic variation is a prerequisite for a successful crop improvement programme. Knowledge of genetic variation and relationships among accessions or genotypes is important to understand the available variability and its potential for use in breeding programmes (Yoseph et al. 2005; Akinyosoye et al. 2017). However, grain yield is a complex quantitative trait and is governed by several genes which are influenced by environmental factors (climatic

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and edaphic) (Akinyosoye et al. 2018). In order to increase grain yield, knowledge of correlations between yield and its component characters and among the component characters is essential for yield improvement (Vidya and Oommen 2002). Yield improvement is easier when a positive correlation exists among major yield characters, however, when these characters are negatively correlated, it becomes necessary to exercise simultaneous selection (Nemati et al. 2009).

Path analysis is a statistical technique that partitions correlations between dependent variables and independent ones into direct and indirect effects and distinguishes between correlation and causation, whereas, in general, correlation measures the extent and direction (positive or negative) of the relationship between two or more variables (Saed–Moucheshi et al. 2013). Therefore, there is need to consider other contributing traits when selecting for yield. Similarly, there is need to study the contributions of the yield components that have direct or indirect effects on yield, since these have been poorly understood in mung bean breeding. Therefore, this study aimed at studying relationships among yield contributing traits and estimating the direct and indirect effects of these on grain yield of 20 mung bean accessions evaluated at three major agro–ecologies (Forest, Derived Savanna and Savanna) in southwest Nigeria.

Materials and methods

Twenty mungbean accessions (TVr–9, TVr–20, TVr–21, TVr–22, TVr–25, TVr–27, TVr–33, TVr–45, TVr–50, TVr–61, TVr–64, TVr–70, TVr–71, TVr–73, TVr–78, TVr–86, TVr–95, TVr–98, TVr–102, TVr–106) collected from the Genetic Resources Unit of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, were evaluated across three major agro–ecological zones in the southwest of Nigeria. The agro–ecological zones are: Ibadan (forest–savanna agro–ecology; latitude 7.38‘N, longitude 3.84‘E, 160 m asl), Ile–Ife (rainforest, agro–ecology; (latitude 7.55’N, longitude 4.56’E, 280 m above sea level) and Kishi (Southern Guinea Savanna agro–ecology; latitude 8.98'N, longitude 3.94'E, 380m asl). The experiment was repeated over two cropping seasons (2019 and 2020). The experiment was laid out in a randomised complete block design with three replications at each location. Plot size at each site was 2 m by 1.5 m with spacing of 0.5 m by 0.5 m between and within the rows, respectively. All plots were hand weeded as and when due till maturity. Insecticide, Magic force$^{(R)}$ (Lambda–cyhalothrin 15% + Dimethoate 300 g/L) was used for the control of field insect pests at both vegetative and reproductive stages as recommended by the manufacturer (Anhui Zhongshan Chemical Industries Co. Ltd, China). Data were collected on yield and its components. Number of days to first flowering was determined by counting the number of days from emergence to when flower was first noticed in a plot. Numbers of days to 50% flowering and podding were calculated by counting the number of days from emergence to when 50% of the plants had flowered and 50% of the plants developed pods in a plot, respectively. Number of days to 70% physiological maturity was determined when all the plants in a plot reached 70% physiological maturity after planting. Pod length was measured by randomly selecting five of the longest pods and five of the shortest pods among the harvested pods from the tagged plants and measured in cm. Number of seeds per pod was counted by randomly selecting ten pods, where number of seeds in each pod were recorded. Pod yield/plant was calculated by dividing total pods weight in a plot by number of plants at harvest in a plot.

Data analysis

Relationships between seed yield and yield contributing traits and their contributions to total variation were determined via simple correlation and principal component analysis using the Statistical Tool for Agricultural

Research (STAR) Version 2.0.1 Nebular 2017. Path coefficient analysis was calculated using the method of Akintunde (2012), so as to estimate the direct and indirect effects of yield contributing traits on seed yield of 20 mung bean accessions evaluated across three locations.

Results and discussion

Correlation

Pearson correlation coefficients between seed yield and other agronomic traits showed that significant and positive relationships existed between seed yield and days to first flowering (r=0.27**), number of pods/plant (0.32**), number of seeds/pod (0.14*) and pod yield/plant (0.91***) (Table 1). This suggests that increase in days to flowering, number of pods/plant and pod yield/plant contributed to higher yield. Thus, any of these traits could be used to select indirectly for yield. Baisakh et al. (2015) reported that number of pods/plant, pod length and number of seeds per pod showed significant positive correlation with yield in mung bean. There was a positive and highly significant association between days to first flowering and days to 50% flowering (0.70***) and these same traits were positively and significantly correlated with days to 50% podding (0.70***, 0.88***) and pod yield/plant (0.34**, 0.21*), respectively (Table 1). This suggests that if days to first flowering increased, then 50% flowering, 50% podding, and pod yield/plant would also increase. Positive and significant relationship existed between number of pods/plant and pod yield/plant (0.29**). Also, pod length and number of seeds/pod were positively and significantly correlated (0.52***). Positive and significant correlations recorded between pair of aforementioned agronomic traits, indicates that pairs of these traits may either be controlled by the same or similar genes or by genes with pleiotropic effect on these traits or may be controlled by closely linked genes (Brown and Caligari 2008).

Table 1: Pearson correlations between seed yield and other agronomic traits of 20 mung bean evaluated across locations in Nigeria in 2019 and 2020

	Days to first flowering	Days to 50% flowering	Days to 50% podding	Number of pods/plant	Days to 70% maturity	Pod length (cm)	Number of seeds/ pod	Pod yield/ plant (g)
Seed yield(kg/ha)	0.27**	0.04	0.02	0.32**	0.01	0.06	0.14*	0.91***
Days to first flowering	–	0.70***	0.70***	0.00	–0.11	0.20**	–0.07	0.34**
Days to 50% flowering		–	0.88***	–0.18*	–0.14	–0.09	–0.1	0.21*
Days to 50%podding			–	–0.14*	–0.17*	0.13*	–0.13	0.10
Number of pods/plant				–	0.00	0.00	–0.02	0.29**
Days to 70%maturity					–	–0.11*	–0.05	0.02
Pod length (cm)						–	0.52***	0.05
Number of seeds/pod							–	–0.01
Pod yield/ plant (g)								–

Path analysis

As simple correlation between pairs of yield contributing traits cannot provide substantial reasons for cause/effect phenomenon, path coefficient analysis for determination of direct and indirect effects is very essential (Bello et al. 2010). The path coefficient analysis not only specifies the effective measure of direct and indirect causes of association, but also depicts the relative importance of each factor to the final yield (Bello et al. 2012). The direct and indirect effects of yield related characters on grain yield are presented in Table 2. Pod yield per plant had the highest positive direct effect on seed yield (0.91), followed by pod length (0.40), days to 70% physiological maturity (0.12), days to 50% podding (0.10), days to first flowering (0.04) and number of pods/plant (0.01). Pod yield per plant exhibited positive indirect effect with days to first flowering, 50% flowering, days to 50% podding, number of pods/plant, days to 70% physiological maturity, and pod length. Apart from number of seeds/pods, this result suggests that an increase in any of yield contributing traits may directly contribute significantly towards higher seed yield in mungbean evaluated in this study. The result obtained is in agreement with findings of Kumar et al. (2018) who reported that pod length, number of pods per plant, days to 50% flowering were among the agronomic traits that contributed directly towards seed yield in mung bean genotypes. Other researchers reported that some agronomic traits had highest positive direct effect on seed yield in mungbean, which could contribute toward its yield improvement, (Rahim et al. 2010; Jeberson et al. 2017), biological yield and days to flowering (Canci and Toker 2014), number of pods per plant and days to maturity (Parsanna et al. 2013).

Table 2: Direct and indirect effect of some yield contributing characters on seed yield of 20 mung bean accessions evaluated across locations in Nigeria in 2019 and 2020

		Indirect effects							
	Direct effect on seed yield	Days to first flowering	Days to 50% flowering	Days to 50% podding	Number of pods/plant	Days to 70% maturity	Pod length (cm)	Number of seeds/ pod	Pod yield/ plant (g)
Days to first flowering	**0.04**		0.00	0.00	0.01	0.00	0.01	0.01	0.02
Days to 50% flowering	**–0.26**	–0.25		0.00	–0.06	0.00	–0.04	–0.03	–0.13
Days to 50% podding	**0.10**	0.09	0.10		0.09	0.00	0.07	0.06	0.06
Number of pods/plant	**0.01**	0.00	0.00	0.00		0.01	0.00	0.00	0.01
Days to 70% maturity	**0.12**	0.07	0.08	0.09	0.02		0.08	0.08	0.06
Pod length (cm)	**0.40**	0.13	0.13	0.03	–0.32	–0.04		0.00	0.07
Number of seeds/pod	**–0.27**	–0.09	–0.10	–0.04	0.17	0.03	–0.24		–0.01
Pod yield/ plant (g)	**0.91**	0.14	0.14	0.10	0.11	0.16	0.29	0.41	

Principal component analysis

The results of principal component of yield and its components in 20 mung bean accessions revealed that the first five principal components axes accounted for 89.45% of the total variation. The first three components had Eigen values greater than 1.0 and accounted for 70.48% of the total variation. Eigen values of 2.72, 2.09, 1.53, 0.96, 0.74, with corresponding contributions of 30.25%, 23.23%, 17.01%, 10.71% and 8.25%, to the total variations were recorded for the first five principal components (Table 3). Similar results were reported by others (Pandiyan et al. 2012; Divyaramakrishnan and Savithramma 2014; Titumeer et al. 2014; Jeberson et al. 2017) in mungbean.

Table 4 shows that the first principal component was associated with days to first flowering, days to 50% flowering and days to 50% podding) with negative loadings. The traits that contributed the most positive loadings to the second principal component were seed yield/ha and pod yield/plant. The third principal component accounted for pod length and number of seeds/pod with positive loadings, whereas the fourth and fifth components accounted for days to 70% physiological maturity and number of pods/plant with positive loadings, respectively. Thus, the first principal component relates to early flowering and podding. The second principal component connotes high yield, the third principal component is associated with pod length and number of seeds/pod whereas, fourth and fifth depict longer days to reach 70% physiological maturity and increase in number of pods per plant, respectively.

Principal component analyses are very useful in crop breeding programmes for selecting not only potential parents for crossing to improve the characters of interest for productivity in quantity and quality but also in identifying the phenotypic characters that contribute higher genetic variations among the genotypes studied (Abna et al. 2012; Basnet et al. 2014). Thus, genetic variation among genotypes for the traits of interest is important for precise selection in crop improvement programmes.

Table 3: Eigen values and variability explained by each component of 20 mung bean accessions evaluated across locations in Nigeria in 2019 and 2020

Principal component	Eigen value	Standard deviation	Variance (%)	Cumulative (%)
First	2.72	1.65	30.25	30.25
Second	2.09	1.44	23.23	50.48
Third	1.53	1.24	17.01	70.48
Fourth	0.96	0.98	10.71	81.19
Fifth	0.74	0.86	8.25	89.45

Table 4: Principal component (PC) contributions of yield and yield contributing traits towards total variation in 20 mung bean accessions evaluated across locations in Nigeria in 2019 and 2020

	PC 1	PC 2	PC 3	PC 4	PC 5
Seed yield (kg/ha)	–0.25	0.58*	–0.12	0.06	–0.29
Days to first flowering	–0.53*	–0.02	0.13	0.08	0.20
Days to 50% flowering	–0.52*	–0.26	0.05	0.07	0.07
Days to 50% podding	–0.52*	–0.27	0.01	0.01	0.10
Number of pods/plant	0.00	0.39	–0.20	–0.39	0.79*
Days to 70% maturity	0.12	0.06	–0.25	0.90*	0.33
Pod length (cm)	0.00	0.20	0.67*	0.08	0.19
Number of seeds/pod	0.07	0.21	0.63*	0.15	0.00
Pod yield/plant (g)	–0.30	0.53*	–0.17	0.06	–0.28

Conclusion

This study revealed that pod yield per plant, pod length, days to 70% physiological maturity, days to 50% podding, days to first flowering and number of pods/plant were the most important quantitative characters that could facilitate direct selection for seed yield. Whereas, occurrence of significant and positive correlation between seed yield with its components such as days to first flowering, number of pods/plant, number of seeds/pod and pod yield/plant, could aid in identifying traits that could be used for indirect selection for the seed yield, due to the complexity of genes associated with yield, coupled with environmental influence. Similarly, high variation existed among the mung bean genotypes evaluated across location, where the first three components accounted for 70.48% of the total variation. Identified relationships could assist plant breeders in genetic improvement of seed yields of mung bean.

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