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CROP IMPROVEMENT AND ITS YIELD ATTRIBUTES IN RABI PIGEONPEA (*Cajanuscajan*L. Millsp.)

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Abstract

Cajanuscajan is commonly known as '*Arhar*' or '*Tur*', generally used in preparing *dal*, which is fairly rich in protein and minerals and eaten almost by all the Indians. The present study recorded the highest heritability for the character seed yield Kg/ha followed by number of pods per plant, days to 50% flowering, days to flower initiation, protein content, number of secondary branches per plant, plant height, seed yield per plant and days to maturity. Results of variability analysis revealed that sufficient variability present among all the characters. High heritability coupled with high genetic advance was found for seed yield per plant, number of secondary branches per plant, number of pods per plant. Correlation coefficient studies revealed that seed yield (Kg/ha) showed the highest significant positive correlation with number of seed per pod followed by number of secondary branches per plant, seed yield per plant, plant height and 100 seed weight. Path coefficient analysis revealed that number of secondary branches per plant exhibited maximum positive direct effect on seed yield followed by seed yield per plant, 100 seed weight, number of primary branches per plant, plant height, pod length cm, days to 50% flowering and days to flower initiation.

Key words: Variability analysis, heritability, Path coefficient, protein content, genetic advance

Introduction

Pigeonpea [*Cajanus cajan* (L.) Millsp] is an important seed legume mostly being cultivated in Africa, Asia and America. Pigeonpea is mostly consumed as dry split "daal" besides several other uses of various parts of pigeonpea plant. It is an excellent source of protein (20-22%), supplementing energy rich cereal diets in a mainly vegetarian population. In India, pigeonpea share percentage of total production 19.11% and yield of 4.23 million tonnes during 2016-17 (Directorate of Economics and Statistics). The *rabi* pigeonpea enhance the double cropping area in Chhattisgarh. The Perennial pigeonpea is receiving considerable attention in India as a multi-purpose species for agroforestry systems. Its multiple uses include food, fodder, manure and firewood.(Denial *et al*.,1990). Pigeonpea is a rich source of protein, carbohydrates and certain minerals (Goplan *et al.*, 1971). Protein content of commonly grown pigeonpea cultivars ranges between 17.9 and 24.3 g per 100 g for whole grain samples and between 28.1 g per 100 g for split grains (Salunkhe *et al.,* 1986).

The productivity of Pigeonpea was found to be very low under rainfed condition. However, the demand for Pigeonpea dal is increasing with premium price. Introduction of Pigeonpea under *Rabi* situation is compelled to initiate an experiment on Pigeonpea to study the feasibility of Pigeonpea cultivation during *Rab*i. Several workers reported that the yields of *Rabi* Pigeonpea are high as compared to *Kharif* Pigeonpea. However, the flowering in Pigeonpea should not coincide with hot weather as this may lead to severe flower drop resulting in

low yields. Hence, this study is envisaged to find out optimum time of sowing and suitable Pigeonpea variety for *Rabi* cultivation. Success of yield improvement largely depends upon the magnitude and nature of genetic variability present in the existing material. It is the pre-requisite for the progress of plant breeding programme.

Material and methods:

The present study entitled "Genetic analysis for seed yield and its components in *rabi* pigeonpea (*Cajanus cajan* L. Millsp.)" was conducted during the *rabi*- season of 2016-17. The experimental details, prevailing weather conditions, materials used and techniques adopted during the course of the investigation was briefly narrated in this chapter.

Location of experimental site

The field experiment was laid out at the experimental area of department of Genetics & Plant Breeding at Research cum Instructional Farm, Indira Gandhi Krishi Viswavidyalaya, Raipur during *rabi* 2016-17. Raipur is situated in Eastern Central part of Chhattisgarh at latitudes of 210.16' N, longitude of 810.36' E and an altitude 289.5 m above Mean Sea Level.

Climate

The general climatic condition of Raipur is classified as sub-humid with hot summer and cold winter. The average annual rainfall of the region is 1200-1400 mm, most of the rainfall (85%) occurs from June to September. At Raipur the average maximum and minimum temperatures during crop period was 35.7^0 C and 7.3^0 C, respectively while, the hottest and coldest months are May and December, respectively. Weather during the crop period was favourable for pigeonpea. Weekly average meteorological data during the period of experimentation (November 01, 2016 to March 27, 2017), as recorded at Observatory of Department of Agricultural Meteorology, College of Agriculture, IGKV, Raipur.

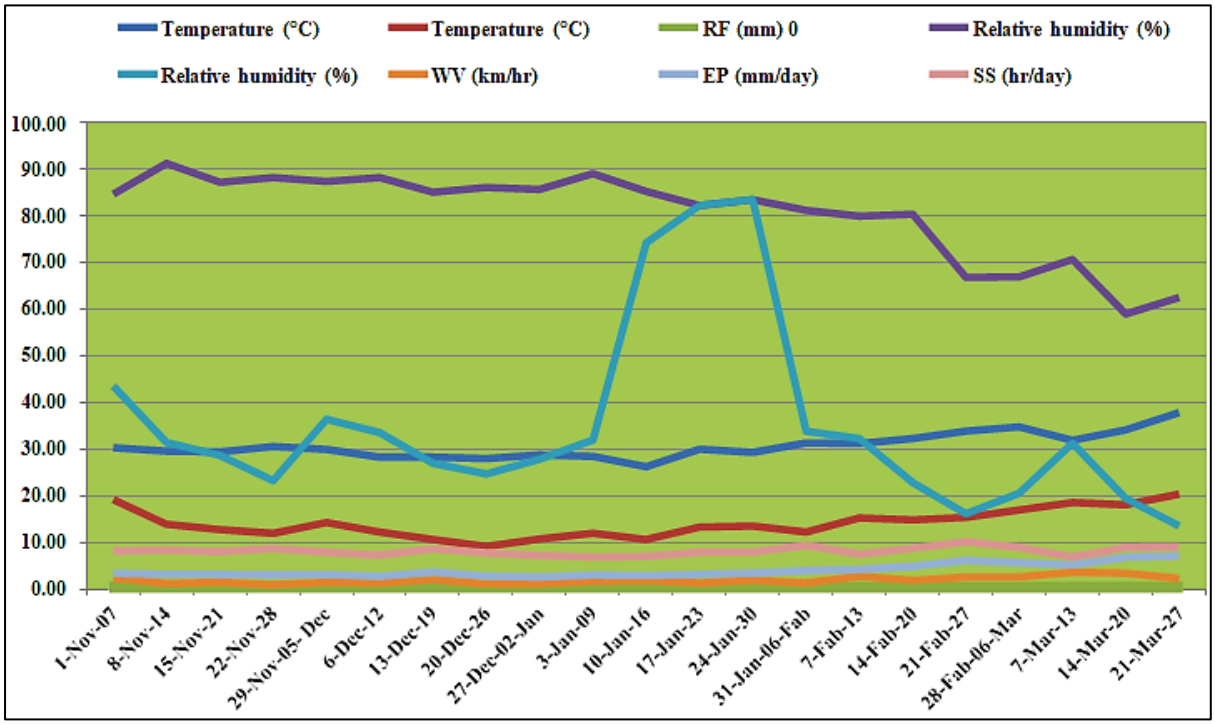

Fig: Weekly meteorological data during crop growth period (November 01, 2016 to March 27, 2017)

Experimental Detail

The experimental material consist of 20 genotypes in which 9 (Rajeevlochan, JKM-189, BDN-2, TJT-501, UPAS-120, ICPL-87, LAXMI, ICPL-88039 and ICPL-

87119) were released variety. The experiment was laid out in Randomized Complete Block Design (RBD) in three replications during *rabi*- 2016-17. Experimental site has heavy soil (Vertisol). A fertilizer dose of 20N: 50P: 20K kg / ha. was applied. Each entry was sown in two rows of four meter length keeping 30 cm between rows and 10 cm between plants spacing. All the recommended package of practices were adopted to raise a good crop.

Table 3.1 List of genotypes

S.N.	Genotypes	Place of origin
01.	RPS 2007-10	IGKV, Raipur (C.G.), India
02.	Rajeevlochan	IGKV, Raipur (C.G.), India
03.	JKM-189	Khargone (M.P.), India
04.	BDN-2	ARS, Badnapur (M.P.), India
05.	TJT-501	BARC & Khargone (M.P.), India
06.	UPAS-120	GBPAU & T, Pantnagar (U.K.), India
07.	Pragati (ICPL-87)	ICRISAT, Hyderabad, India
08.	Laxmi (ICPL-85063)	ARS, Lam, Guntur, India
09.	(ICPL-88039)	IGKV, Raipur (C.G.), India
10.	Asha (ICPL-87119)	ICRISAT, Hyderabad, India
11.	RPS 2008-5	IGKV, Raipur (C.G.), India
12.	RPS 2008-4	IGKV, Raipur (C.G.), India
13.	RPS 2007-109	IGKV, Raipur (C.G.), India
14.	RPS 2007-106	IGKV, Raipur (C.G.), India
15.	RPS 2007-105	IGKV, Raipur (C.G.), India
16.	RPS 2015-25	IGKV, Raipur (C.G.), India
17.	RPS 2015-22	IGKV, Raipur (C.G.), India
18.	RPS 2015-13	IGKV, Raipur (C.G.), India
19.	RPS 2015-28	IGKV, Raipur (C.G.), India
20.	RPS 2015-29	IGKV, Raipur (C.G.), India

3.4. Observations Recorded

Observations on metric traits were recorded on single plant basis from five randomly selected competitive plants from each genotype separately. Observations on flowering and maturity were recorded on plot basis as per the descriptors developed by IBPGR and ICRISAT for pigeonpea.

Days to flower initiation

This was noted in terms of days from the date of sowing to the opening of first flower.

Days to 50 % flowering

It was noted in days from the date of sowing to the opening of first flower on approximately 50 % plants in each plot.

Days to maturity

It was noted in terms of days from the date of sowing to the stage when over 90 % pods have matured.

Plant height (cm)

The height of plant was measured in cm from ground level to the tip of main axis of physiologically matured plants.

Number of primary branches plant-1

Total numbers of primary branches were counted at physiological maturity.

Number of secondary branches plant-1

Total numbers of secondary branches were counted at physiological maturity.

Number of pods plant-1

All the effective pods were counted from each selected plant at physiological maturity.

Pod length (cm)

It was measured in cm from petiole end to tip of the pod of physiological matured plants.

Number of seeds pod-1

Total number of seeds from the effective pods from each selected plant was counted at physiological maturity.

100 seed weight (g)

Test weight of dried 100 healthy seeds at 10 per cent (air dry) moisture content was recorded in grams.

Seed yield plant-1 (g)

The selected plants were harvested, threshed and winnowed separately. Finally the seeds were weighed in grams after drying them to appropriate moisture level.

Seed yield (Kg/ha)

Seed yield per plot used to calculate the seed yield per hactare

Protein content %

The protein content in dry seeds was determined by estimating the organic nitrogen by adopting the micro-Kjeldahl method.

Pod borer incidence score

Number of pods affected per plant is taken for pod borer incidence score.

3.4.2 Protein content %

The protein content in dry seeds was determined by estimating the organic nitrogen by adopting the micro-Kjeldahl method. The seeds of the sample were grinded in the major grinder to maintain uniformity and easiness for digestion. The samples were oven dried at 600^0C for 8 hours were subjected for estimation of organic nitrogen by adapting standard procedure.

Estimation of protein

Total protein content of pigeonpea grains of all samples was estimated by modified micro-Kjeldahl method.

Digestion process

About 0.5 g of sample is transferred into the digestion tube and 5-7 gm of K2SO4 and CuSO4 mixture was added. Thereafter, 10 ml of concentrated Sulphuric acid was added in digestion tubes and were placed on the digestion block with temperature set at 360ºC and then increased to 410ºC. After 2 to 3 hours, when the samples turns colorless or of light green color, the digestion tubes were taken out from digestion block. The tubes were then allowed to cool at room temperature.

Distillation process

Digested samples were subjected to Pelican make distillation unit and distillation of sample was carried out using 4 per cent Boric acid and 40 per cent Sodium hydroxide. 10 ml of Boric acid was then taken in conical flask, to which 2-4 drops of mixed indicator dye was added. The flask was placed beneath the condenser with the delivery tip immersed in the solution. The digested samples were transferred to distillation apparatus and 8-10 ml of 40 per cent Sodium hydroxide was then added to it. Around 20 ml of distillate was collected in a conical flask. A blank was always run containing the same quantity of the entire reagent but without the sample for every set of nitrogen determination.

Titration process

The distilled samples were titrated against the 0.05 N Sulfamic acids until the first appearance of violet colour as the end point. The titer value was used to calculate per cent Nitrogen, which is then used to estimate total protein content by using conversion factor 6.25.

$$N\ (\%) = \frac{(\text{Vol. of Sulfamic acid} - \text{Vol. of blank}) \times \text{Normality} \times 14 \times 100}{\text{Sample weight (g)} \times 1000}$$

Protein % = N (%) x 6.25.

Statistical analysis

Analysis of variance

The data obtained from the individual plants were statistically analyzed as per the procedure given by Gomez and Gomez (1984).

The skeleton of analysis of variance for Randomized Block Design (RBD)

Table 3.2 Analysis of variance

Source of variation	Degrees of freedom	Mean sum of squares	'F' ratio
Replications	(r-1)	MSR	MSR/MSE
Treatments	(t-1)	MST	MST/MSE
Error	(r-1)(t-1)	MSE	-
Total	(rt-1)	-	-

Where, r= Replication, t= Treatment

Genotypic and phenotypic coefficients of variation were calculated as per the formula suggested by Burton and De Vane (1953).

Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{\sigma^2_g}}{\bar{X}} \times 100$$

Where, σ^2_g = Genotypic variance

$\vec{X}$ = Mean of character

Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{\sigma^2_p}}{\bar{X}} \times 100$$

Where, σ^2_p = Phenotypic variance

$\vec{X}$ = Mean of character

The estimates of genotypic and phenotypic coefficients of variation were classified as low, moderate and high as suggested by Sivasubramaniam and Madhavamenon (1973)

>20% = High

10-20% = Moderate

<10% = Low

Parameters of variation

Range

Range is the difference between the highest and the lowest value of a series of observations and thus provides the information about the extent of variability present in the genotypes.

Mean

The mean was calculated as:

$$\overline{X} = \frac{\sum_{i=1}^{n} Xi}{N}$$

Where, Σxi = Summation of all the observations

N = Total number of observations

Heritability

Heritability in broad sense (h^2_{BS}) is defined as the proportion of the genotypic variance to the total variance (phenotypic). This was estimated by using the formula suggested by Burton (1952).

$$h^2\ (BS) = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where, h^2 (BS) = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

The broad sense heritability estimates were categorized as low, moderate and high as follows:

< 50% = Low heritability

50 – 70% = Moderate heritability

>70% = High heritability

Genetic advance

Expected genetic advance (GA) was calculated as per method suggested by Grafius (1959)

$$GA = K.\sigma p.h^2$$

Where, K = Constant (Standard selection differential) having value of 2.06 at 5% selection intensity

σ_p = Phenotypic standard deviation

h^2 = Heritability estimate

Genetic advance as percentage of mean

$$\text{GA as percentage of mean} = \frac{GA}{\overline{X}} \times 100$$

Where, GA = Expected Genetic advance

$\overline{X}$ = Mean of the character

Estimates of correlation coefficient

Correlation coefficient (r) is the measurement of relationship between two variables. It was estimated by using the formula given by Dewy and Lu (1959).

$$r_{(xy)} = \frac{Cov(xy)}{\sqrt{Var(x).Var(y)}}$$

Where, $r_{(xy)}$ = Correlation coefficient between variable x and y Var (x) = Variance of x variable

Var (y) =Variance of y variable

Cov (xy) = Covariance between variable x and y

Genotypic, phenotypic and environmental correlation coefficients werecomputed by substituting corresponding variance and covariance in the above mentioned formula.

Significance of correlations

't' test was applied to test the significance of the correlation coefficients. 't' values were calculated by using the following formula

$$t = \frac{|r|}{\sqrt{1 - r^2}} \times \sqrt{n-2}$$

Comparing't' values at (n-2) degrees of freedom tested the significance of correlation coefficient (r). If calculated value of't' is greater than the tabular value of 't' at (n-2) degree of freedom at given probability level, the coefficient of correlation is considered as significant.

Path coefficient analysis

The genotypic correlation coefficients (r) were further partitioned into direct and indirect effects with the help of path coefficient analysis as suggested by Dewy and Lu (1959). Path coefficient analysis splits the genotypic correlation coefficient into the measure of direct and indirect effects. It measures the direct and indirect contribution of independent variables on dependent variable

The equation shows a basic relationship between correlation coefficient and path coefficient. These equations were saved by presenting them in matrix notations.

$$A=B.C$$

The solution for the vector "C" may be obtained by multiplying both sides by inverse of B matrix i.e. B-1 thus

$$B_{-1}\ A=C$$

After calculations of the values of path coefficient i.e. "C" vector, it is possible to obtain the path value for residual (R).

$$R = \sqrt{1- di \times rij}$$

Where, di = direct effect of i^{th} characters

rij = correlation coefficient of i^{th} characters with j^{th} character

Results and discussions:

Analysis of variance and mean performance

The average performances of the 20 pigeonpea genotypes were shown in the Table 4.1. Analysis of variance worked out for seed yield and its component characters indicated that the mean sum of squares due to genotypes were highly significant for all the characters. Significant mean squares due to seed yield and attributing characters revealed existence of considerable variability in the material studied for the improvement of various traits. Similar results were reported by Sidhu *et al*. (1985), Srinivas *et al*. (1999), Venkateshwarlu

(2001), Sinha and Singh (2005), Chetukuri *et al*. (2013), Visakho Shuny *et al*. (2013) and Kesha Ram *et al.* (2016).

Genetic parameters of variation

Genetic parameters of variation for seed yield and its components in total pigeonpea genotypes were presented in Table 4.2. The over all, mean and range for yield and its components revealed that there were substantial genetic variability for most of the characters among all the genotypes under study. Genetic parameters of variation were discussed character wise.

Character mean and range

Days to flower initiation

Days to flower initiation ranged from 65 to 76 days with a mean value of 71.06 days. The genotype RPS 2015-23 (76 days) and RPS 2015-22 (95 days) was recorded as late flowering type and RPS 2007-10 (65 days) as early flowering types.

Days to 50% flowering

Days to 50% flowering varied between 95 (RPS 2015-13) to 83 (ICPL-88039) days with a mean value of 87.01 days.

Days to maturity

Among the genotypes days to maturity varied between 128 to 138 days with a mean value of 134.17 days.

Plant height (cm)

The plant height ranged from 70.0 to 95.8 cm with an average plant height of 80.67 cm. Among all genotypes, RPS 2007-10 (95.8 cm) was recorded as tallest and RPS 2015-28 (70.0 cm) as the dwarf most genotype.

Number of primary branches plant-1

The number of primary branches per plant ranged between 2.6 to 7.6 branches with an average of 5.84 branches. The maximum number of primary branches per plant was recorded in Rajeevlochan (7.6). Whereas, the lowest number of branches per plant was recorded in RPS 2015-22 (2.6).

Number of secondary branches plant-1

The number of secondary branches per plant ranged between 1.4 to 7.6 branches with an average of 4.23 branches. The maximum number of branches per plant was recorded in TJT-501 (7.6). Whereas, the lowest number of branches per plant was recorded in RPS 2015-22 (1.4).

Number of pods plant-1

The mean value of number of pods per plant was 64.53 with a ranged from 24.0 to 98.8. The genotype TJT-501 (98.8 pods) recorded with the highest number of pods per plant and RPS 2015-22 (44.0 pods) was lowest number of pods per plant.

Pod length (cm)

The length of pod for genotypes ranged from 4.12 cm to 5.80 cm with mean pod length of 5.02 cm. The genotype RPS 2015-22 (4.12 cm) recorded with minimum pod length and JKM-189 (5.80 cm) with maximum pod length.

Number of seeds pod-1

The average number of seeds per pod was 2.65 ranging from 2.06 to 4.0 seeds per pod. The genotypes *viz.* RPS 2007-10 had maximum number of seeds per pod (4.0) and the genotype UPAS-120 was recording minimum number of seeds (2.06) per pod.

100 seed weight (g)

The mean value of 100 seed weight was 9.83 (g) ranging from 8.0 to 11.0 (g). The genotype UPAS-120 (8.0 g) recorded with minimum and RPS 2015-22 (11.0) with maximum 100 seed weight.

Seed yield plant-1 (g)

The seed yield per plant ranged from 7.6 to 23.2 (g) with an average of 14.40 (g). The genotype BDN-2 recorded the lowest (7.6 g) and RPS-2015-25 (23.2 g) gave the highest seed yield per plant.

Seed yield (Kg/ ha)

The seed yield Kg/ha ranged from 927.47 to 2094.93 Kg with an average of 1626.99 Kg. The genotype BDN-2 927.47 Kg recorded the lowest and RPS 2007-10 (2094.93 Kg) was obtained the highest seed yield Kg/ ha.

Protein content %

The protein content % ranges from 15.30 to 22.50 % with an average of 19.70

%. The genotype RPS 2015-13 (15.30 %) recorded the lowest and ICPL-87 (22.50 %) had the highest protein content %.

Pod borer (Helicoverpa armigera) incidence score

Among the tested genotypes, the lowest percent pod damage due to pod borer (*Helicoverpa armigera*) was recorded in RPS 2007-109 (2.6%) whereas maximum percent pod damage was observed in RPS 2007-105 (12.7%)

Genotypic and Phenotypic coefficients of variation

Genotypic and Phenotypic coefficients of variation were simple measures of variability; these measures were commonly used for the assessment of variability. The relative values of these types of coefficients gives an idea about the magnitude of variability present in a genetic population. Thus, the components of variation such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was computed. The phenotypic coefficients of variation were marginally higher than the corresponding genotypic coefficient of variation indicated the influence of environment in the expression of the character under study. Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were categorized as low (less than 10%), moderate (10-20%) and high (more than 20%) as suggested by Sivasubramanian and Madhavamenon (1973).

Among the different yield attributing traits, number of secondary branches per plant had the highest magnitude of GCV (34.51%) and PCV (36.67%) followed by number of pods per plant(28.37% and 28.68%) and seed yield per plant (26.67% and 26.69%). The moderate GCV and PCV were observed for number of

primary branches per plant (15.61% and 17.32) followed by number of seeds per pod (12.65% and 14.39%). The low GCV and PCV were observed for protein content % (7.65 and 7.95) followed by plant height (7.49 and 8.02), pod length (6.03 and 7.63), 100 seed weight (4.73 and 6.29), days to flower initiation (3.98% and 4.13%), days to 50 % flowering (6.75% and 6.85%) and days to maturity (1.73% and 1.91%).

Similar findings were reported by Malik *et al*. (1987), Patel and Patel (1998) Basavarajaiah *et al*. (2000), Rathore *et al.* (2013), Visakho Shuny *et al.* (2013) and Kesha Ram *et al.* (2016).

Heritability and genetic advance

Heritability estimates along with genetic advance are normally more useful in predicting the gain under selection than that of heritability alone. However, it is not necessary that a character showing high heritability will also exhibit high genetic advance (Johnson *et al*. 1955). An attempt has been made in the present investigation to estimate heritability in broad sense and categorized as low (<50%), moderate (70%) and high (>70%) as suggested by Robinson (1966).

In present investigation high magnitude of heritability was recorded for most of the characters. The highest heritability was recorded for the character seed yield Kg/ha (98.84%) followed by number of pods per plant (97.62%), days to 50% flowering (94.72%), days to flower initiation (92.80%), protein content (92.56%), number of secondary branches per plant (88.56%), plant height (87.11%), seed yield per plant (86.45%) and days to maturity (82.68%). The moderate heritability was observed for pod length (62.35%) and 100 seed weight (56.65%).

The magnitude of genetic advance as percentage of mean was categorized as high (> 30%), moderate (30% - 10%) and low (< 10%). Genetic advance as percentage of mean was observed high for number of secondary branches per plant (66.90%) followed by seed yield per plant (51.09%), seed yield Kg/ha (34.38%). Genetic advance as percentage of mean was recorded as moderate for number of primary branches per plant (28.97%) followed by number of seeds per pod (22.90%), protein content percent (15.16%) plant height (14.40%) and rest of the characters showed low genetic advance as percentage of mean.

Similar findings were reported by Yadavendra *et al*. (1981) , Bainiwal *et al*. (1983), Pansuriya *et al*. (1998), Singh (1999), Srinivas *et al*. (1999), Basavarajaiah *et al*. (2000), Chetukuri *et al***.** (2013) and Kothimbire *et al.* (2016).

Estimation of correlation coefficients

Correlation coefficient is a statistical measure which is used to find out the degree and direction of relationship between two or more variables. In plant breeding, correlation coefficient analysis measures the mutual relationship between various characters and determines the component characters on which selection can be based for genetic improvement. Knowledge about interrelationship between yield and yield contributing characters facilitates the choice of efficient breeding method to be adopted. To estimate the association between two characters, correlation coefficient at phenotypic, genotypic and environmental levels were worked out in all possible combinations among yield components Table 4.3.

Correlation of attributing characters with seed yield

Association studies revealed that seed yield Kg/ha showed the highest significant positive correlation with number of seed per pod (r=0.421) followed by number of secondary branches per plant (r=0.388), plant height (r=0.306) and 100 seed weight (r=0.280). Moreover, days to flower initiation was found to significant

positive correlation with days to 50 % flowering (r=0.659). Plant height showed significant positive correlation with number of pods per plant (r=0.576). Number of primary branches per plant showed significant positive correlation with number of pods per plant (r=0.725) followed by pod length (r=0.561) and number of secondary branches per plant (r=0.555). Number of secondary branches per plant showed significant positive correlation with number of pods per plant (r=0.576). Number of pods per plant showed significant positive correlation with number of seeds per pod (r=0.614) followed by pod length (r=0.517). Pod length showed significant positive correlation with number of seeds per pod (r=0.451). Number of seeds per pod showed significant positive correlation with 100 seed weight (r=0.500). Hence, direct selection for seed yield per plant, number of secondary branches per plant, number of primary branches per plant, number of pods per plant, days to 50% flowering and days to maturity may be advantageous for selecting the high yielding genotypes in *rabi* pigeonpea from the available genotypes.

The experimental findings on correlation coefficient analysis are in general agreement with the results reported earlier by Munoz and Abrams (1971), Joshi (1973), Mukewar and Muley (1975), Brar (1993), Sarma *et al*. (1994), Chandana *et al.* (2014) and Singh and Singh (2016).

Direct and indirect effect of attributes on seed yield

In present study number of secondary branches per plant (1.059) exhibited maximum positive direct effect on seed yield followed by 100 seed weight (0.746), number of primary branches per plant (0.541), plant height (0.428), pod length cm (0.318), days to 50% flowering (0.282) and days to flower initiation (0.101), whereas number of pods per plant (-1.391), protein content % (-0.261) and number of seeds per pod (-0.007) had negative but significant direct effect on seed yield.

Days to flower initiation had maximum positive indirect effect on seed yield via., number of pods per plant (0.785) followed by days to 50 % flowering (0.282), protein content % (0.083), 100 seed weight (0.053) and number of seeds per pod (0.004) whereas negative indirect effect on seed yield via., secondary branches per plant (-0.725), number of primary branches per plant (-0.389), plant heightn (-0.163) and days to maturity (-0.093).

Days to 50% flowering had maximum positive indirect effect on seed yield via., number of secondary branches per plant (1.062) followed by 100 seed weight (0.747), primary branches per plant (0.541), plant height (0.429) and pod length cm (0.318), whereas negative indirect effect on seed yield via., number of pods per plant (-1.392), protein content % (-0.261) and number of seeds per pod (-0.007).

Days to maturity had maximum positive indirect effect on seed yield via., number of pods per plant (0.232) followed by days to 50 % flowering (0.081), days to flower initiation (0.017) and protein content % (0.008), whereas negative indirect effect on seed yield via., number of primary branches per plant (-0.070) followed by 100 seed weight (-0.025) and pod length cm (-0.005).

Plant height showed positive indirect effect on seed yield via., days to flower initiation (0.727) followed by protein content % (0.589), days to maturity (0.187), number of pods per plant (0.039) and number of primary branches per plant (0.012) whereas negative indirect effect on seed yield via., days to 50% flowering (-1.167), 100 seed weight (-0.223) and secondary branches per plant (-0.070).

Number of primary branches per plant had maximum positive indirect effect on seed yield via., secondary branches per plant (0.588) followed by pod length cm (0.178), plant height cm (0.125), whereas negative indirect effect on seed yield via., pods per plant (-1.009), 100 seed weight (-0.168) and days to flower initiation (-0.073).

Number of secondary branches per plant had maximum positive indirect effect on seed yield via., number of primary branches per plant (0.300) followed by plant height cm (0.158) and pod length cm (0.052), whereas

negative indirect effect on seed yield via., number of pods per plant (-0.802), days to 50 % flowering (-0.154) and days to flower initiation (-0.056).

Number of pods per plant had maximum positive indirect effect on seed yield via., days to maturity (0.877) followed by number of secondary branches per plant (0.611), number of primary branches per plant (0.392 and plant height cm (0.247) whereas negative indirect effect on seed yield via., days to flower initiation (-0.056), number of seeds per pod (-0.004) and days to 50 % flowering (-0.003).

Pod length (cm) had maximum positive indirect effect on seed yield via., number of primary branches per plant (0.304) followed by 100 seed weight (0.177) number of secondary branches per plant (0.175), plant height cm (0.050) and days to 50

% flowering (0.019), whereas negative indirect effect on seed yield via., number of pods per plant (-0.718) and days to flower initiation (-0.015).

Number of seeds per pod had maximum positive indirect effect on seed yield via., 100 seed weight (0.373) followed by secondary branches per per plant (0.248),primary branches per plant (0.209) and plant height cm (0.209), whereas negative indirect effect on seed yield via., number of pods per plant (-0.854) and days to flower initiation (-0.056).100 seed weight (g) had maximum positive indirect effect on seed yield via., days to 50% flowering (0.125), pod length cm (0.075), protein content % (0.061), plant height cm (0.049) and days to flower initiation (0.007), whereas negative indirect effect on seed yield via., number of secondary branches per plant (-0.155), number of primary branches per plant (-0.121), days to maturity (-0.017) and number of seeds per pod (-0.003).

Protein content (%) had maximum positive indirect effect on seed yield via., number of pods per plant (0.410) followed by seed number of secondary branches per plant (0.133) and number of primary branches per plant (0.091). whereas negative indirect effect on seed yield via., days to 50% flowering (-0.261), plant height (-0.067), days to flower initiation (-0.032) and days to maturity (-0.017). Similar findings were reported by Veeraswamy *et al*. (1975), Brar (1993), Jahagirdar *et al*. (1994), Sarma *et al*. (1994), Gowda *et al*. (1996), Musaana and Nahdy (1998), Basavarajaiah *et al*. (1999), Sinha and Singh (2005), Chandana *et al*. (2014) and Kothimbire *et al.* (2016).

Table 4.1 Analysis of variance for seed yield and its components in *rabi* pigeonpea

Source of variation	DF	Days to flower initiation	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary Branches plant^{-1}	No. of secondary branches plant^{-1}	No. of Pods Plant^{-1}	Pod length (cm)	No. of Seeds pod^{-1}	100 seed weight (g)	Seed yield plant^{-1} (g)	Protein content %
Replication	2	4.51**	6.06**	5.06*	2.14	0.02	2.18**	16.26	0.005	0.16*	0.02	4.33	0.08
Treatment	19	24.68**	32.54**	17.42**	114.92**	2.68**	6.67**	1011.45**	0.33**	0.37**	0.81*	46.06**	38.37**
Error	38	0.62	0.59	1.14	5.40	0.19	0.28	8.14	0.06	0.03	0.17	2.31	1.00

*** Significant at 1% probability, * Significant at 5% probability*

Table 4.2 Genetic parameters of variation for seed yield and its components in 20 genotypes of *rabi* pigeonpea

Character	Mean	Range		GCV %	PCV %	H^2 (%)	Genetic Advance	Genetic Advance as % of mean
		Min	Max					
Days to flowering Initiation	71.07	65	75	3.985	4.137	92.81	5.62	7.91
Days to 50% flowering	87.02	94	98	3.750	3.853	94.73	6.45	7.52
Days to maturity	134.17	128	136	1.737	1.910	82.68	4.36	3.25
Plant height (cm)	80.67	73	91	7.490	8.025	87.11	11.62	14.40
Number of primary branches plant^{-1}	5.84	2.6	7.6	15.607	17.319	81.21	1.69	28.97
Number of secondary branches plant^{-1}	4.23	1.4	9.2	34.513	36.673	88.57	2.83	66.91
Number of pods plant^{-1}	64.54	23.4	98.8	28.337	28.680	97.62	37.22	57.68
Pod length (cm)	5.02	4.12	5.80	6.030	7.638	62.34	0.49	9.81
Number of seeds pod^{-1}	2.65	2.02	4.0	12.650	14.395	77.23	0.60	22.90
100 seed weight (g)	9.83	8.0	11.0	4.734	6.289	56.65	0.72	7.34
Seed yield plant^{-1} (g)	14.40	6.8	23.2	26.677	28.691	86.45	7.36	51.09
Seed yield (kg/ha)	1626.99	927.47	2094.93	16.788	16.885	98.85	559.41	34.38
Protein content %	19.70	15.30	22.50	7.653	7.954	92.57	2.99	15.17

Table 4.3 Genotypic (G), Phenotypic (P) and Environmental (E) correlation coefficients for seed yield and its components in *rabi* pigeonpea

S. No.	Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches plant^{-1}	Secondary branches plant^{-1}	Pods plant^{-1}	Pod length cm	Number of seeds pod^{-1}	100 seed weight (g)	Seed yield (Kg/ha)	Protein content %
1	Days to flower initiation	G	0.659**	0.178	-0.380**	-0.720**	-0.684**	-0.564**	-0.149	-0.552	0.072	-0.216	-0.318*
		P	0.622**	0.149	-0.362**	-0.612**	-0.621**	-0525**	-0.082	-0.467**	0.050	-0.206	-0.286*
		E	0.059	-0.069	-0.207	0.109	-0.010	0.289*	0.192	0.004	-0.011	0.048	0.121
2	Days to 50% flowering	G		0.190	-0.056	-0.349**	-0.359**	-0.007	0.046	0.087	0.293*	0.133	-0.609**
		P		0.186	-0.065	-0.314*	-0.345**	-0.013	0.019	0.052	0.210	0.126	-0.579**
		E		0.190	-0.170	-0.079	-0.202	-0.177	-0.116	-0.203	-0.031	-0.097	-0.140
3	Days to maturity	G			0.234	-0.131	0.005	-0.167	-0.018	-0.252	-0.034	-0.047	-0.033
		P			0.190	-0.094	-0.072	-0.152	0.021	-0.202	0.069	-0.044	-0.024
		E			-0.056	0.075	-0.539**	-0.025	0.132	-0.005	0.335**	-0.044	-0.040
4	Plant height (cm)	G				0.291*	0.369**	0.576**	0.118	0.476**	-0.115	0.306*	-0.158
		P				0.261*	0.324*	0.538**	0.088	0.435**	-0.080	0.281*	-0.166
		E				0.105	-0.002	0.126	0.005	0.262*	0.001	-0.063	-0.245
5	Primary branches plant^{-1}	G					0.555**	0.725**	0.561**	0.310*	-0.164	0.114	0.157
		P					0.504**	0.665**	0.391**	0.150	0.139	-0.096	-0.322*
		E					0.227	0.290*	-0.032	0.022	-0.040	-0.090	0.088
6	Secondary branches plant^{-1}	G						0.576**	0.166	0.234	-0.147	0.388**	0.126
		P						0.550**	0.084	0.231	-0.129	-0.159	-0.048
		E						0.273*	-0.187	0.230	-0.113	0.485**	0.485**
7	Pods plant^{-1}	G							0.517**	0.614**	0.041	0.182	-0.295*
		P							0.392**	0.548**	0.048	0.180	-0.273*
		E							-0.120	0.203	0.169	0.035	0.182
8	Pod length cm	G								0.451**	0.237	0.248	-0.017
		P								0.356**	0.097	0.205	-0.003
		E								0.146	-0.109	0.152	0.061
9	Number of seeds pod^{-1}	G									0.500**	0.421**	-0.327*
		P									0.288*	0.375**	-0.272*
		E									-0.136	0.140	0.039
10	100 seed weight (g)	G										0.280*	-0.234
		P										0.044	0.046
		E										0.213	-0.162
12	Seed yield (Kg/ha)	G											0.128
		P											0.124
		E											0.035

** Significant at 1% probability; * Significant at 5% probability

Table 4.4 Genotypic path coefficients of various characters for seed yield (Kg/ha) in *rabi* pigeonpea

Characters	Days to flower initiation	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches plant^{-1}	Secondary branches plant^{-1}	Pods plant^{-1}	Pod length (cm)	Seeds pod^{-1}	100 seed weight (g)	Protein content %	Genotype 'r' with seed yield (Kg/ha)
Days to flower initiatio	**0.101**	0.282	-0.093	-0.163	-0.389	-0.725	0.785	-0.047	0.004	0.053	0.083	-0.216
Days to 50% flowering	0.100	**0.282**	-0.524	0.429	0.541	1.062	-1.392	0.318	-0.007	0.747	-0.261	0.133
Days to maturity	0.017	0.081	**-0.523**	0.100	-0.070	0.004	0.232	-0.005	0.001	-0.025	0.008	-0.047
Plant height (cm)	-0.038	-0.023	-0.122	**0.428**	0.157	0.391	-0.801	0.037	-0.003	-0.085	0.041	0.306*
Primary branches plant^{-1}	-0.073	-0.149	0.068	0.125	**0.541**	0.588	-1.009	0.178	-0.002	-0.168	-0.044	0.132
Secondary branches plant^{-1}	-0.069	-0.154	-0.002	0.158	0.300	**1.059**	-0.802	0.052	-0.001	-0.109	-0.033	0.388**
Pods plant^{-1}	-0.056	-0.003	0.877	0.247	0.392	0.611	**-1.391**	0.164	-0.004	0.031	0.077	0.182
Pod length (cm)	-0.015	0.019	0.009	0.050	0.304	0.175	-0.718	**0.318**	-0.003	0.177	0.004	0.248
Seeds pod^{-1}	-0.056	0.037	0.131	0.203	0.209	0.248	-0.854	0.143	**-0.007**	0.373	0.085	0.421**
100 seed weight	0.007	0.125	-0.017	0.049	-0.121	-0.155	-0.057	0.075	-0.003	**0.746**	0.061	0.280*
Protein content %	-0.032	-0.261	-0.017	-0.067	0.091	0.133	0.410	-0.005	0.002	-0.175	**-0.261**	0.128

Diagonal values indicate direct effects, Residual effect= 0.05487

Conclusions

Overall observations on variability, correlation coefficient and path coefficients for seed yield and its attributes in *rabi* pigeonpea genotypes indicated presence of ample variability for most of the traits. Correlation studies revealed that seed yield showed the highest significant positive correlation with number of seed per pod followed by number of secondary branches per plant. Moreover, number of seed per plant was found to be

correlated positively with number of pods per plant and number of primary branches per plant. Hence, direct selection for number of pods per plant, number of primary and secondary branches per plant is advantageous for selecting the high yielding genotypes in *rabi* pigeonpea. The path coefficient analysis showed that the number of secondary branches per plant had the highest direct effect on seed yield. Hence, this character must be considered in selection for high seed yield. Moreover, other important characters having considerable direct effects were number of seeds per pod, 100 seed weight (g), number of primary branches per plant and days to 50% flowering may leads to the development of high yielding genotypes from *rabi* pigeonpea genotypes. Whereas, indirect selection of the traits like days to maturity, plant height, pod length which ultimately lead to be development of high yielding genotypes.

Appendix A

Table 5.1 Mean performance of different characters of 20 pigeonpea genotypes

Treatments	Days to flower initiation	Days to 50 % flowering	Days to maturity	Plant – (cm)	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}	No. of pods plant^{-1}	Pod – (cm)	No. of seeds pod^{-1}	100 seed weight (g)	Seed yield per plant (g)	Seed yield (Kg/ha)	Protein content %	Pod Borer incidence score
RPS 2007-10	65.667	85.667	130.667	91.933	5.933	6.067	92.667	5.120	3.613	10.000	18.167	2,071.240	18.500	14.35
Rajeevlochan	67.000	86.333	135.667	87.467	7.200	4.467	89.200	4.667	2.803	10.167	20.433	1,752.483	19.900	8.84
JKM 189	68.667	85.667	135.667	84.067	6.533	4.600	70.267	5.513	3.080	10.333	14.167	2,024.607	21.450	13.82
BDN-2	67.667	84.667	136.333	81.400	6.933	4.467	80.867	5.213	2.967	10.000	8.400	963.830	17.900	7.86
TJT-501	70.333	85.667	134.667	84.600	6.467	7.167	96.067	5.453	2.713	10.000	13.767	1,854.020	18.700	10.69
UPAS-120	69.667	84.667	134.667	75.133	6.267	4.000	65.067	5.140	2.310	8.667	18.600	1,339.000	21.900	9.18
ICPL-87	70.667	83.667	130.667	64.933	6.067	4.200	52.867	5.220	2.347	10.167	11.767	1,566.010	22.000	11.67
ICPL-85063	70.667	83.667	135.333	74.200	5.400	3.067	30.233	4.873	2.547	10.000	15.233	1,651.740	20.700	9.67
ICPL-88039	67.667	85.333	135.333	82.000	6.400	8.333	68.067	4.613	2.333	9.333	12.567	1,843.743	20.400	7.76
ICPL-87119	69.333	85.667	128.667	79.267	7.200	4.133	76.533	5.373	3.067	10.000	10.333	1,846.550	20.000	9.38
RPS 2007-5	72.667	86.333	134.667	86.133	5.333	3.000	62.867	5.140	2.360	9.333	19.300	1,482.273	19.500	6.34
RPS 2008-4	71.667	84.000	130.333	81.667	5.400	3.667	60.000	4.313	2.287	9.167	14.000	1,159.550	20.200	9.07
RPS 2007-109	71.333	87.333	133.333	82.933	5.800	3.933	52.667	4.893	2.780	9.167	16.500	1,634.537	20.000	5.07
RPS 2007-106	71.667	85.667	136.667	82.800	5.733	5.067	52.600	4.980	2.513	9.833	12.567	1,565.767	21.100	8.09
RPS 2007-105	74.333	86.333	136.667	86.267	5.733	3.200	59.333	5.247	2.307	9.500	15.100	1,557.843	19.000	13.95
RPS 2015-25	73.667	92.333	136.333	82.667	6.033	3.733	60.200	5.147	2.487	9.667	23.000	1,935.177	20.600	8.02
RPS 2015-22	74.333	87.333	135.333	75.800	2.933	2.267	24.567	4.387	2.353	10.667	13.200	1,632.270	20.200	9.36
RPS 2015-13	75.667	94.333	135.333	74.000	4.867	2.867	53.400	4.780	2.647	9.667	10.667	1,658.600	16.000	6.80
RPS 2015-28	75.333	92.333	131.667	73.267	5.333	3.133	65.800	5.093	2.533	10.333	11.667	1,470.377	17.500	6.03
RPS 2015-29	73.333	93.333	135.333	82.800	5.267	3.267	77.467	5.267	2.993	10.667	8.600	1,530.163	18.500	10.63

Appendix B

Table 5.2 Weekly meteorological data during crop period 2016-17

Station: **Labhandi, Raipur**

Month/Weekly	Temperature (°C)		RF (mm)	Relative humidity (%)		WV	EP	SS
	Max.	Min.	0	I	II	(km/hr)	(mm/day)	(hr/day)
01-Nov-07	30.33	19.21	0.00	84.71	43.57	2.41	3.43	8.19
08-Nov-14	29.61	13.94	0.00	91.29	31.43	1.26	3.19	8.41
15-Nov-21	29.41	12.79	0.00	87.29	28.71	1.47	3.19	8.06
22-Nov-28	30.61	12.00	0.00	88.29	23.29	0.97	3.11	8.74
29-Nov-5 Dec	29.94	14.31	0.00	87.43	36.43	1.50	3.13	8.00
06-Dec-12	28.33	12.30	0.00	88.29	33.57	1.34	2.79	7.34
13-Dec-19	28.31	10.67	0.00	85.14	27.00	2.10	3.67	8.67
20-Dec-26	28.00	9.20	0.00	86.14	24.71	1.11	2.83	7.84
27-Dec-02 Jan	28.81	10.79	0.00	85.71	27.86	1.17	2.61	7.23
3-Jan-09	28.49	12.03	0.00	89.14	32.00	1.71	3.06	6.91
10-Jan-16	26.23	10.70	0.80	85.29	74.29	1.89	2.96	7.01
17-Jan-23	30.01	13.34	0.00	82.29	82.29	1.34	3.21	8.00
24-Jan-30	29.31	13.57	0.00	83.57	83.57	1.90	3.46	7.99
31 Jan-06 Mar	31.37	12.29	0.00	81.29	33.86	1.36	3.97	9.40
07-Fab-13	31.26	15.33	0.80	80.00	32.29	2.77	4.27	7.57
14-Fab-20	32.00	15.00	0.00	80.00	23.00	2.00	5.00	9.00
21-Fab-27	33.89	15.40	0.00	66.86	16.14	2.60	6.17	10.21
28 Fab-06 March	35.00	17.00	0.00	67.00	21.00	3.00	6.00	9.00
07-Mar-13	31.94	18.59	0.79	70.71	31.29	3.64	5.17	6.90
14-Mar-20	34.17	18.13	0.00	59.00	19.43	3.41	6.89	8.99
21-Mar-27	37.89	20.40	0.00	62.57	13.57	2.27	7.06	9.11

Source : Department of Agricultural Meteorology, Indira Gandhi Agricultural University, Raipur (C.G.)

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