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Fitting of the distributions for CV value of the groundnut experiments

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Abstract
The coefficient of variation (CV) is a widely used statistical measure to assess variability in agricultural experiments due to its scale-invariant property and ease of interpretation compared to variance. It is commonly applied to compare variability across traits or populations and to evaluate experimental homogeneity; a CV within acceptable limits indicates uniformity within blocks. Determining an appropriate probability distribution for modelling CV data is a key concern in agricultural research. In this study, seven probability distributions *viz.*, Normal, Lognormal, Gamma, Weibull, Exponential, Beta and Erlang were evaluated for their suitability in representing CV values. The goodness of fit for each distribution was assessed using four statistical tests: Kolmogorov-Smirnov, Cramer-von Mises, Anderson-Darling and Chi-square tests. These tests were applied to each dataset to identify the most appropriate distribution. Additionally, different forms of the selected distributions were examined to better understand the shape and characteristics of CV data. The study provides insights into selecting suitable probability models for CV values, facilitating improved interpretation of variability and supporting more reliable conclusions in groundnut experiments.

Keywords: Coefficient of variation, distribution fitting, goodness-of-fit tests, groundnut experiments

Introduction

Agriculture is the most important sector in the Indian Economy. It accounts for 18% of India's GDP and employs more than half of the workforce. India was the world's greatest producer of milk, pulses, and jute, and ranked second in rice, wheat, sugarcane, groundnut, vegetables, fruit, and cotton. It was also a major producer of spices, seafood, poultry, livestock, and plantatison crops. The agricultural research system is critical in achieving increased agricultural production and productivity. India's agricultural research system is one of the world's largest and most complex. With the Indian Council of Agricultural Research (ICAR) at the helm, we have 65 institutes, including four deemed universities, six national bureaus, thirteen project directorates, fourteen national research centers, 158 regional stations, and sixty all-India coordinated research projects. In agriculture, numerous experiments are undertaken at various research stations to determine the impact of treatments on field crop growth and yield characteristics, as well as their effects on soil productivity. Several factors influence the outcomes of such trials, necessitating the use of an index to assess their dependability. Furthermore, the homogeneity requirement must be employed when constructing the blocks, and CV can be used as a tool for this.

Coefficient of variation (CV) was a measure commonly applied to present variation in agricultural traits. Its merits are well known, most important being one that CV deals with what we could call the scale-invariant variability in the traits. It was easier to understand than variance it was based upon. Coefficient of variation used to compare the variation of a trait in two (or more) populations or, more commonly, the variation of different traits in a population of the study. If the CV was within certain limits one can say that block has homogeneity in the character under study. To obtain such limits i.e., to obtain confidence limits for the necessary important parameter. The study of such a confidence interval carried out for the distribution, which was fitting to the given data through the CV. Thus, for the reliability of the results of the field experiments the analysis of CV was necessary. Depending on which distribution was to be use for modelling of the CV data of an experiment, which was a common problem in agricultural science.

Distribution of CV was also having a high peak and long tail. Patel *et al.* (2010) discuss the method of fitting lognormal distribution to CV data of mustard crop experiments. Given a need to allow for, skewness and all unimodal distribution it has become interesting to study frameworks that are flexible enough to accommodate distributions with a broad range of properties. In most cases, need to fit two or more distributions to compare the results and select the most valid model. In the present study data for 2015-16 to 2023-24 on groundnut crop received from experiments of different Research Stations of Saurashtra region have used and tried to fit distributions like Normal, Lognormal, Gamma, Weibull, Exponential, Beta and Erlang.

2. Materials and Methods

2.1 Database

The CV values for yield character (secondary data) of 525 field experiments on groundnut conducted at different research stations and farm of Junagadh *viz.*, Main Oilseeds Research Station (Groundnut), Junagadh (Oilseed); Centre of Experimental Research Station, Sagadividi Farm; Dry Farming Research Station, Jam Khambhalia (JamK); Main Pearl Millet Research Station, Jamnagar (Jmr); Main Sugarcane Research Station, Kodinar (Kdr); Oilseed Research Station, Manavadar (Mdr); Main Dry Farming Research Station, Targhadia (Trg); Grass land & Agricultural Research Station, Dhari, Amreli and Instructional Farm, Department of Agronomy, J.A.U., Junagadh (Agronomy) were collected from period 2015-16 to 2023-24.

2.2 Methodology

The following seven statistical distributions viz., Normal, Lognormal, Gamma, Weibull, Exponential, Beta and Erlang were fitted as per Gupta and Kapoor, 1994. Computer software R studio was used for the purpose of fitting distribution on CV data for the present study.

2.2.1 Normal Distribution (Gauss, 1809)

The Normal distribution was first discovered in 1733 by English mathematician De-Moivre.

A random variable X is said to have a Normal distribution with parameters μ (mean) and σ^2 (variance) if its p.d.f. was given by the probability law:

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} exp - \frac{1}{2\sigma^2}\,(x-\mu)^2 \qquad (1)$$

= 0, otherwise

The first row moment (μ_1) = mean (μ), second row moment (μ_2) = σ^2, third row moment (μ_3) = 0, fourth row moment (μ_4) = $3\mu_2^2$, measure of skewness, $\beta_1 = \frac{\mu_3^2}{\mu_2^3}$, measure of kurtosis, $\beta_2 = \frac{\mu_4}{\mu_2^2}$.

2.2.2 Gamma Distribution (Greenwood and Durand, 1960)

A random variable X is said to have a Gamma distribution with parameter

λ□> 0, if its p.d.f. was given by:

$$f(x) = \frac{e^{-x}x^{\lambda-1}}{\Gamma(\lambda)}\,; \lambda > 0, 0 < x < \infty \qquad (2)$$

= 0, otherwise

The first row moment (μ_1) = λ, mean (λ), second row moment (μ_2) = λ, third row moment (μ_3) = 2λ, fourth row moment (μ_4) = 3λ, measure of skewness, $\beta_1 = \frac{4}{\lambda}$, measure of kurtosis, $\beta_2 = 3 + \frac{6}{\lambda}$.

2.2.3 Beta Distribution (Beckman and Tietjen, 1978)

A random variable X is said to have a Beta distribution of first kind with parameters μ and v [(μ,v) > 0] if its p.d.f. was given by;

$$f(x) = \frac{1}{B\,(\mu,v)}\, x^{\mu-1}(1-x)^{v-1}; (\mu,v) > 0, 0 < x < 1 \qquad (3)$$

= 0, otherwise

The first row moment (μ_1) = $\frac{\mu}{\mu+v}$, second row moment (μ_2) = $\frac{\mu v}{(\mu+v)^2\,(\mu+v+1)}$, third row moment ($\mu_3$) = $\frac{2\mu v\,(v-\mu)}{(\mu+v)^3\,(\mu+v+1)(\mu+v+2)}$, fourth row moment ($\mu_4$) = $\frac{3\mu v\,\{\mu v\,(\mu+v-6)+2(\mu+v)^2\}}{(\mu+v)^4\,(\mu+v+1)(\mu+v+2)(\mu+v+3)}$, measure of skewness, $\beta_1 = \frac{4\,(v-\mu)^2(\mu+v+1)}{\mu v\,(\mu+v+2)^2}$, measure of kurtosis, $\beta_2 = \frac{3\,(\mu+v+1)\mu v(\mu+v-6)+2(\mu+v)^2}{\mu v\,(\mu+v+2)(\mu+v+3)}$.

2.2.4 Weibull Distribution (Weibull, 1951)

A continuous random variable X has a Weibull distribution with parameter

c (>0), α (>0) and μ if its p.d.f was given by:

$$f(x) = \frac{c}{\alpha}\,(\frac{x-\mu}{\alpha})^{c-1}\,\exp\{-\left(\frac{x-\mu}{\alpha}\right)^c\}\,; x > \mu, c > 0 \qquad (4)$$

Where, c and α are shape and scale parameter, respectively.

The first row moment (μ_1) = $\Gamma(\frac{1}{c}+1)$, mean (μ), second row moment (μ_2) = $\Gamma\left(\frac{2}{c}+1\right) - [\Gamma\left(\frac{2}{c}+1\right)]^2$.

2.2.5 Exponential Distribution (Elfessi and Reineke, 2001):

A random variable X is said to have an Exponential distribution with parameter θ>0, if its p.d.f. was given by:

$$f(x) = \theta\left(e^{-\theta x}\right);\ x \geq 0 \qquad (5)$$

= 0, otherwise

Where, e is Euler's number (2.71828) and θ is rate parameter.

The first row moment (μ_1) = $\frac{1}{\theta}$, mean (μ), second row moment (μ_2) = $\frac{1}{\theta^2}$.

2.2.6 Lognormal Distribution (Heyde, 1963)

The positive random variable X is said to have a lognormal distribution if $\log_e$X was normally distributed with

$$f(x) = \frac{1}{x\sigma\sqrt{2\pi}}\exp\left\{-\frac{(\log x-\mu)^2}{2\sigma^2}\right\}, x > 0 \qquad (6)$$

$= 0, x \leq 0$

The first row moment $(\mu_1) = e^{\mu+\frac{\sigma^2}{2}}$, mean (μ), second row moment $(\mu_2) = \left(e^{\sigma^2} - 1\right)e^{2\mu+\sigma^2}$.

2.2.7 Erlang Distribution (Erlang, 1909)

A random variable X is said to have an Erlang distribution with parameters
$b > 0$ and $c > 0$, if its p.d.f. was given by:

$$f(x) = \frac{(x/b)^{(c-1)} \exp(-x/b)}{b\{(c-1)!\}}, |x| \leq \infty, b > 0 \text{ and } c > 0 \ (c \text{ is a positive integer}) \quad (7)$$

Where, b and c are scale and shape parameter, respectively.
The first row moment $(\mu_1) = bc$, mean (μ), second row moment $(\mu_2) = b^2c$.

2.2.8 Statistical Test for Distribution Fitting:

Test of goodness of fit:

Establishing a best-fit probability distribution for different parameters has long been a topic of interest in the field of agriculture. The investigation of parametric distribution strongly depends upon their distribution pattern. The present study planned to identify the best-fit probability distribution based on the distribution pattern for groundnut data set. The seven-probability distribution are select out of large number of commonly used probability distribution for such type of study. The test statistics computed for all seven-probability distribution.

The best fit probability distribution was identified based on highest ranks computed through all the four tests. The best fit probability distribution so obtained were presented with their test statistic value. Finally, the best fit probability distribution for CV value of field experiments was identified with the help of chi-square, Kolmogorov-Sminrov, Anderson-Darling and Cramer-von Mises tests.

3. Results and Discussion

The four goodness of fit tests *viz.*, Kolmogorov-Smirnov test, Cramer-Von-Mises test, Anderson-Darling test and Chi-Square test were used to decide best fitted distribution to CV values. The test statistic was computed and tested at (α=0.05) level of significance for each distribution. The assessments of all the probability distribution were made on the bases of total test statistics obtained by combining the entire four tests. The tests statistic value of the entire four tests used to identify the best fit distribution. Finally, the best fit probability distributions for CV value on groundnut experiment were obtained and the best fit distribution was identified. Similar study was also reported by Patel (1994), Singh (1995) and Gupta and Kundu (2001) for best fitted distribution on CV values. The results of all the distributions fitted on groundnut experiment CV values are mentioned below:

Average CV value and standard deviation of CV were found 11.11 and 2.85 respectively. Minimum and maximum value were found 1.90 and 26.74, respectively. Skewness coefficient was recorded 0.72 were indicated the slightly positively skewed distribution with slightly platykurtik (2.34) nature of CV values, suggesting departure from normality and the presence of right-skewed variability (Fig.1, 2, 3, 4, 5, 6 and 7).

Goodness-of-fit assessment using Kolmogorov-Smirnov (KS), Cramer-von-Mises (CVM), Anderson-Darling (AD) and Chi-square tests revealed (Table 1, 2, 3, 4, 5, 6 and 7) that the normal, Weibull and exponential distributions did not adequately describe the data. Among the fitted models, the gamma distribution showed the best fit, as evidenced by non-significant KS, CVM and AD statistics, while the Erlang distribution provided a reasonably close fit. Overall, the results indicate that the gamma distribution provides an appropriate representation of the variability structure of the present data.

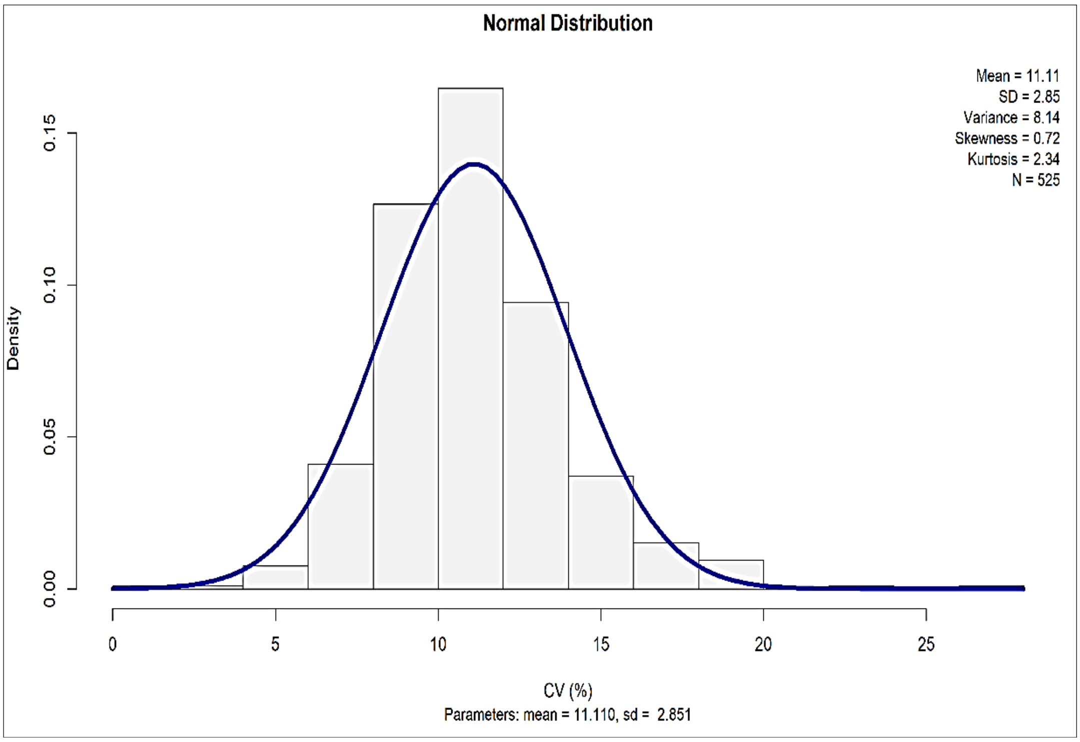

Fig 1: Fitting Normal Distribution to CV of Groundnut Yield

Table 1: Goodness-of-fit tests for Normal Distribution to CV of Groundnut Yield

Test	Statistic	Value	DF	p-value (Pr > Stat)	Decision
Kolmogorov-Smirnov	D	0.0636	-	0.0286	Reject
Cramer-von Mises	W^2	0.5024	-	0.0393	Reject
Anderson-Darling	A^2	3.2279	-	0.0210	Reject
Chi-square	χ^2	3445.20	3	< 0.001	Reject

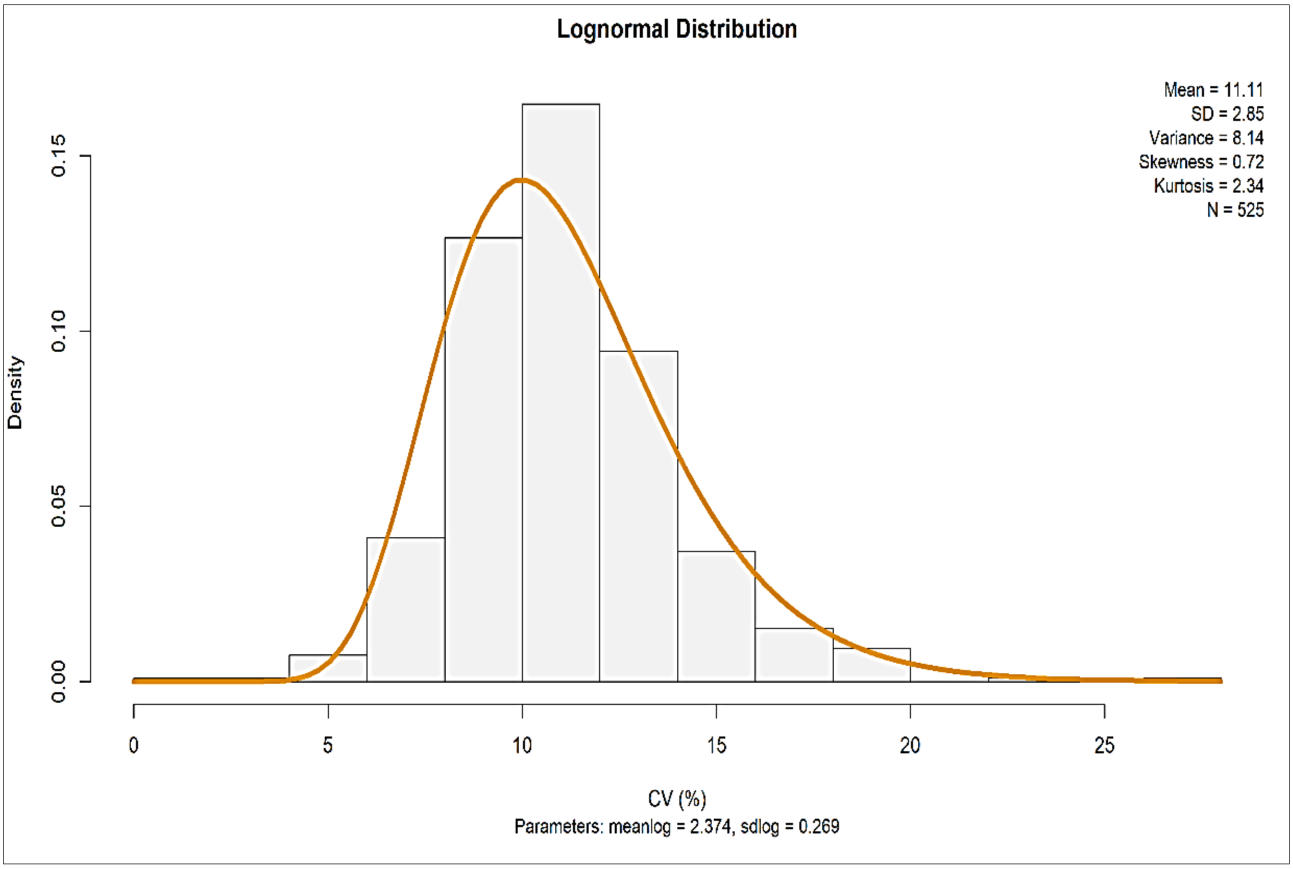

Fig 2: Fitting Lognormal Distribution to CV of Groundnut Yield

Table 2: Goodness-of-fit tests for Lognormal Distribution to CV of Groundnut Yield

Test	Statistic	Value	DF	p-value (Pr > Stat)	Decision
Kolmogorov-Smirnov	D	0.0471	-	0.1955	Accept
Cramer-von Mises	W^2	0.4249	-	0.0621	Accept
Anderson-Darling	A^2	2.8306	-	0.0334	Reject
Chi-square	χ^2	54.21	3	< 0.001	Reject

Table 3: Goodness-of-fit tests for Gamma Distribution to CV of Groundnut Yield

Test	Statistic	Value	DF	p-value (Pr > Stat)	Decision
Kolmogorov-Smirnov	D	0.0403	-	0.3608	Accept
Cramer-von Mises	W^2	0.2504	-	0.1879	Accept
Anderson-Darling	A^2	1.7508	-	0.1265	Accept
Chi-square	χ^2	34.89	3	< 0.001	Reject

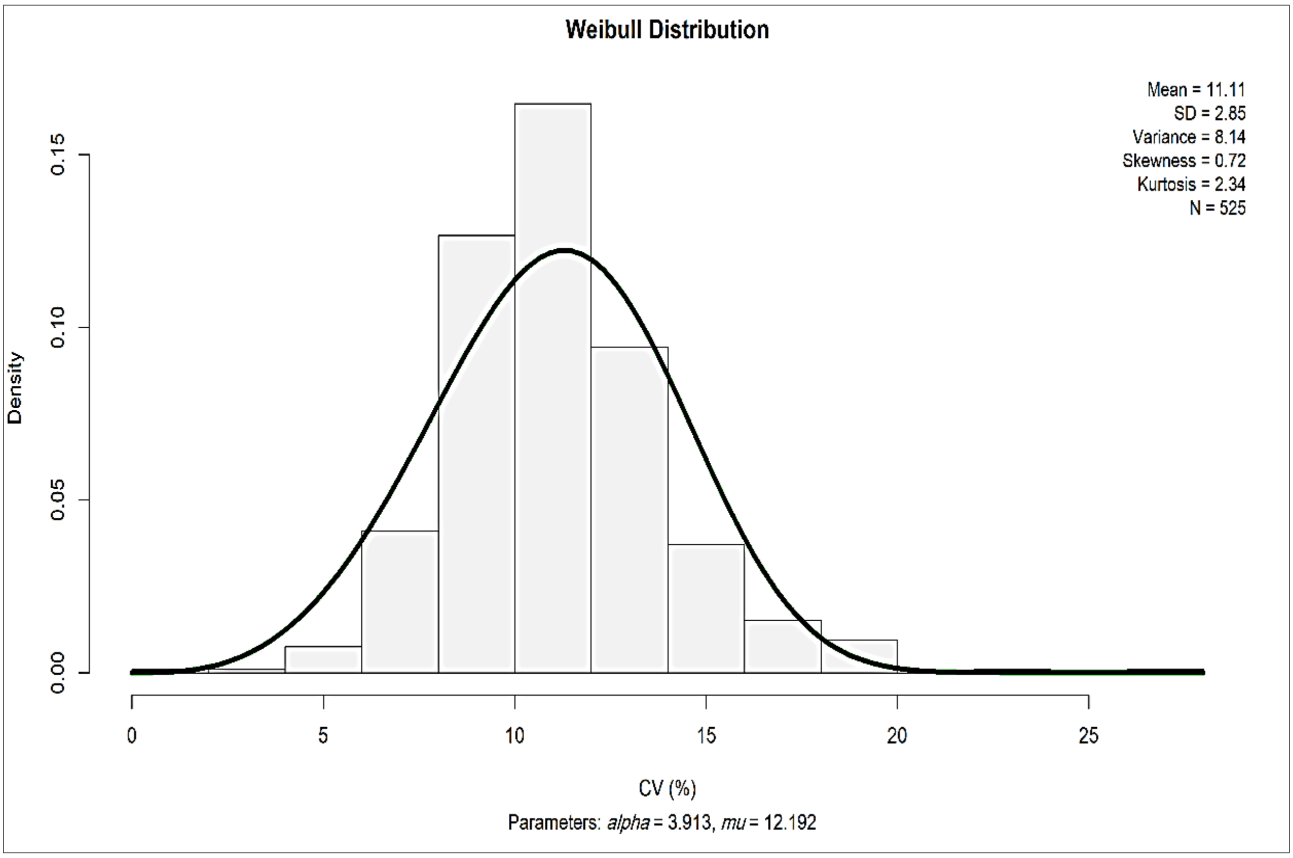

Fig 3: Fitting Gamma Distribution to CV of Groundnut Yield

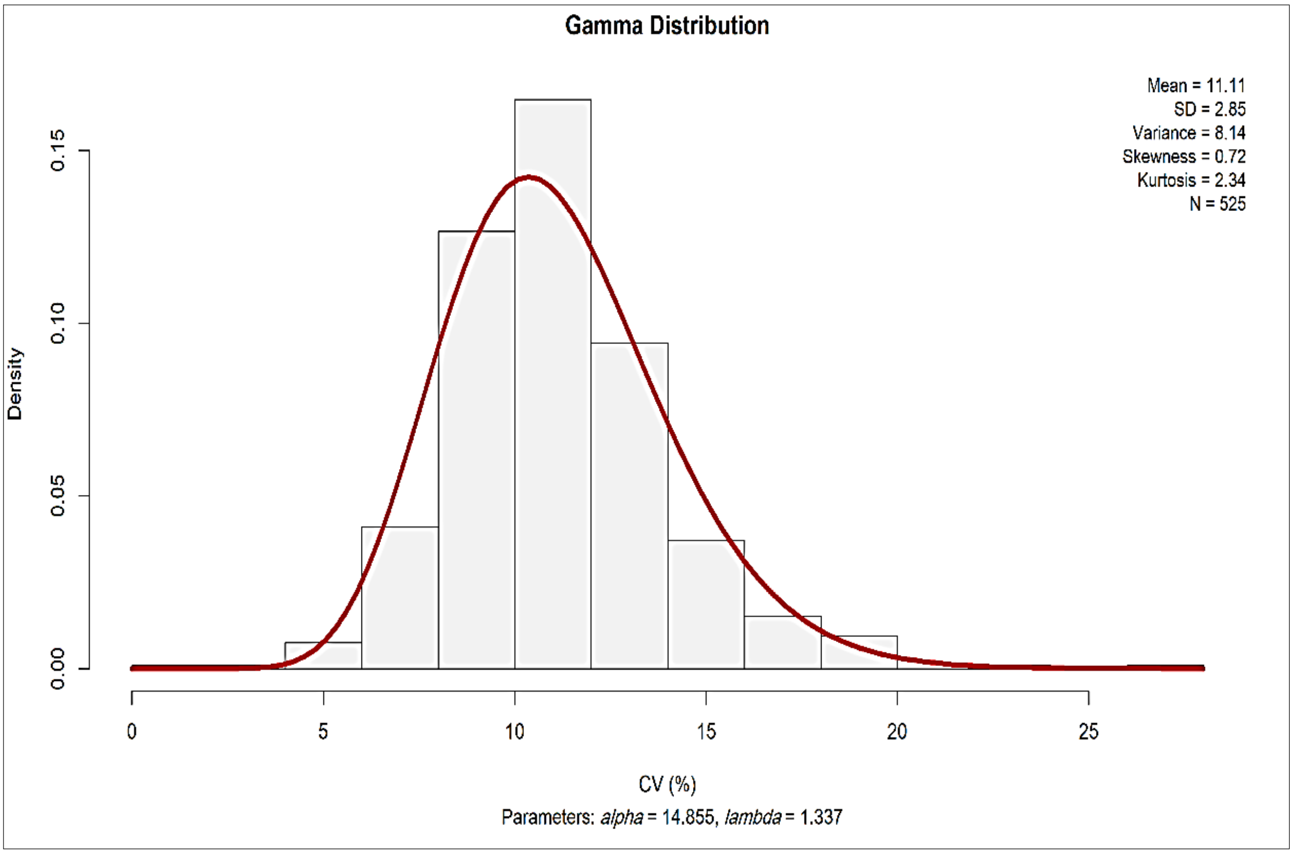

Fig 4: Fitting Weibull Distribution to CV of Groundnut Yield

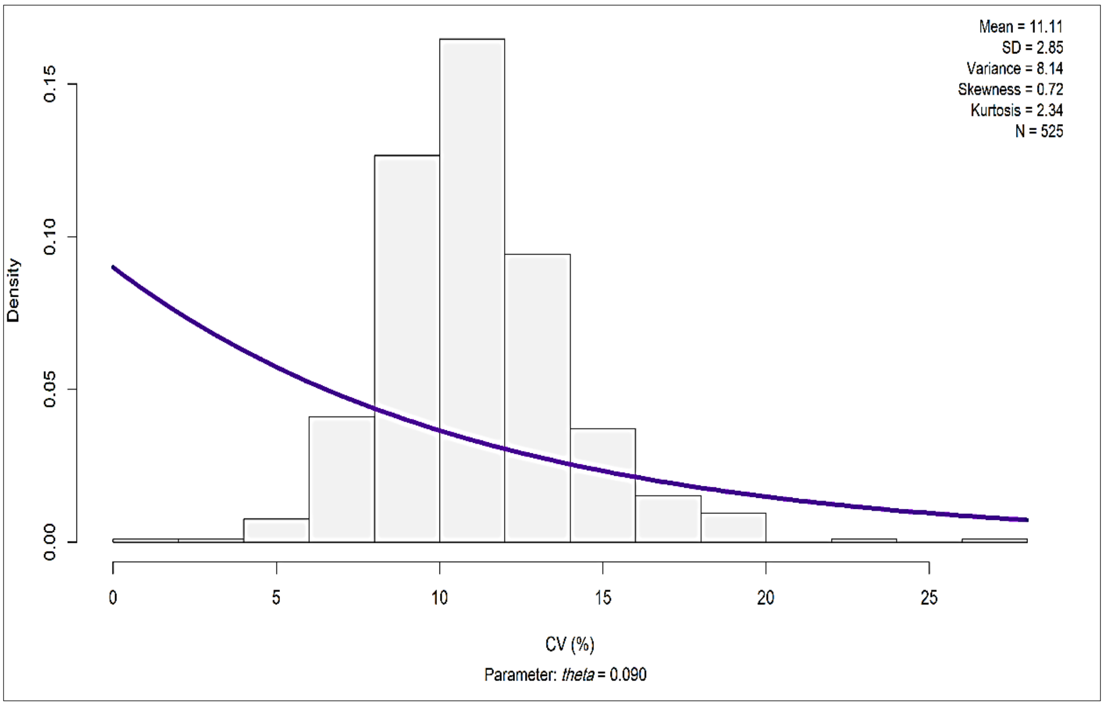

Fig 5: Fitting Exponential Distribution to CV of Groundnut Yield

Table 4: Goodness-of-fit tests for Weibull Distribution to CV of Groundnut Yield

Test	Statistic	Value	DF	p-value (Pr > Stat)	Decision
Kolmogorov-Smirnov	D	0.0765	-	0.0043	Reject
Cramér-von Mises	W^2	1.1732	-	0.0010	Reject
Anderson-Darling	A^2	7.6608	-	0.0002	Reject
Chi-square	χ^2	31082.24	3	< 0.001	Reject

Table 5: Goodness-of-fit tests for Exponential Distribution to CV of Groundnut Yield

Test	Statistic	Value	DF	p-value (Pr > Stat)	Decision
Kolmogorov-Smirnov	D	0.4265	-	< 0.001	Reject
Cramér-von Mises	W^2	29.2052	-	< 0.001	Reject
Anderson-Darling	A^2	139.225	-	< 0.001	Reject
Chi-square	χ^2	868.18	4	< 0.001	Reject

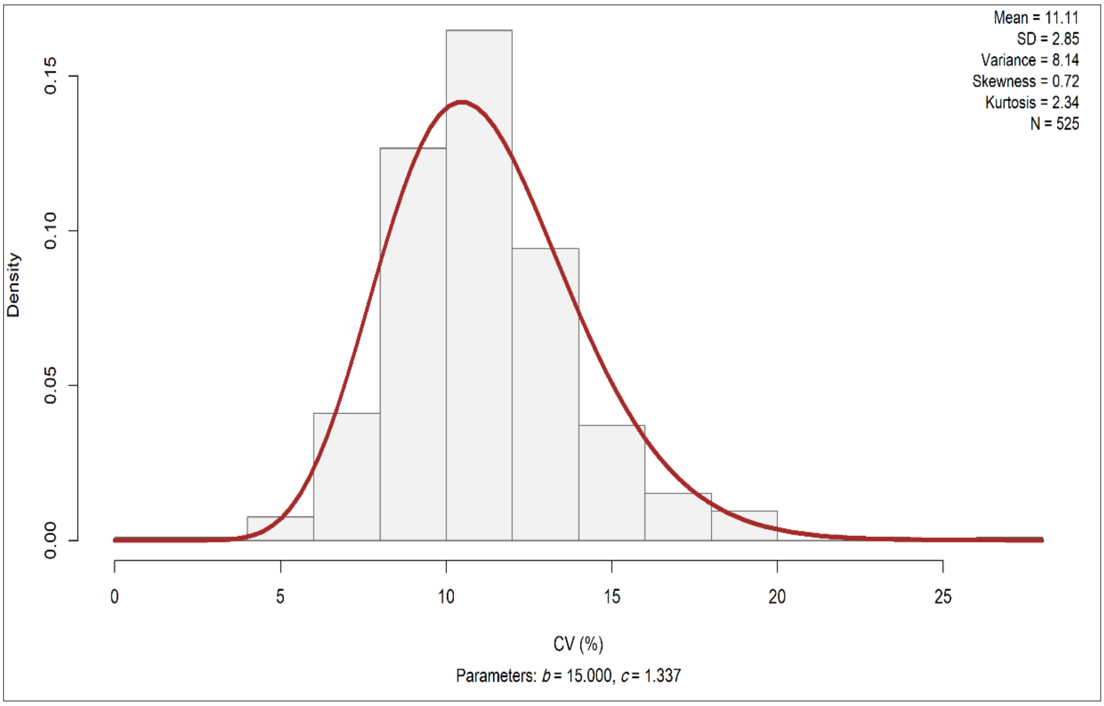

Fig 6: Fitting Beta Distribution to CV of Groundnut Yield

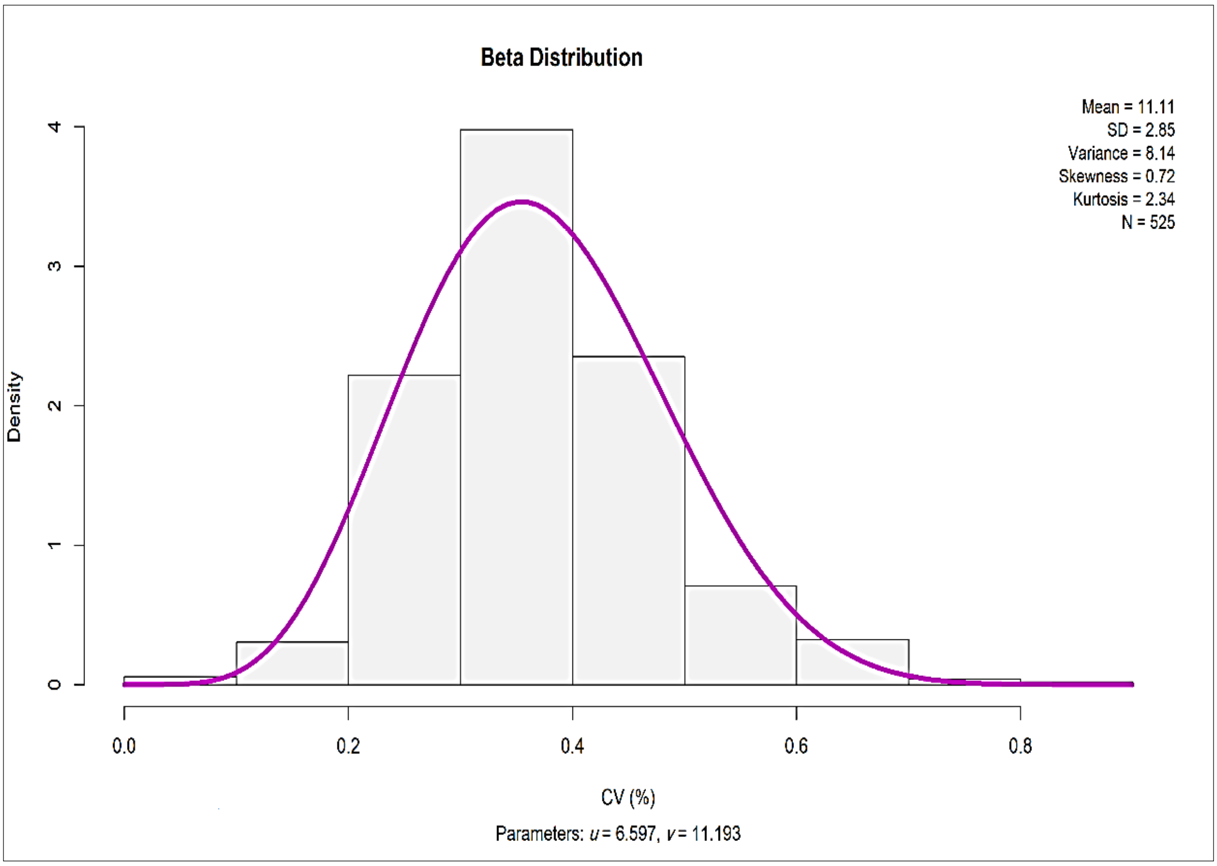

Fig 7: Fitting Erlang Distribution to CV of Groundnut Yield

Table 6: Goodness-of-fit tests for Beta Distribution to CV of Groundnut Yield

Test	Statistic	Value	DF	p-value (Pr > Stat)	Decision
Kolmogorov-Smirnov	D	0.0508	-	0.1348	Accept
Cramér-von Mises	W^2	0.3240	-	0.0001	Reject
Anderson-Darling	A^2	2.2265	-	< 0.001	Reject
Chi-square	χ^2	69.39	3	< 0.001	Reject

Table 7: Goodness-of-fit tests for Erlang Distribution to CV of Groundnut Yield

Test	Statistic	Value	DF	p-value (Pr > Stat)	Decision
Kolmogorov-Smirnov	D	0.0500	-	0.1447	Accept
Cramér-von Mises	W^2	0.3000	-	0.1352	Accept
Anderson-Darling	A^2	1.9535	-	0.0975	Accept
Chi-square	χ^2	35.90	4/3	< 0.001	Reject

4. Conclusion

All the seven distributions considered in the study were Normal, Lognormal, Gamma, Weibull, Exponential, Beta and Erlang, among them Normal, Weibull, Exponential and Beta found poor fit for groundnut experiments. Gamma distribution found to be the best fit for the groundnut experiments followed by Erlang distribution. While lognormal distribution found to be medium fit for the same. On general, the Gamma distribution fits well to CV of experimental data for groundnut crops.

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