

GENETIC DIVERGENCE IN FRENCH BEAN
(Phaseolus vulgaris, L.)

A Thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI, (Dist. Ahmednagar)
MAHARASHTRA STATE
INDIA

IN PARTIAL FULFILMENT OF REQUIREMENTS FOR DEGREE OF

MASTER OF SCIENCE (AGRICULTURE)

IN

CYTOGENETICS AND PLANT BREEDING

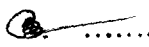
BY

EKNATH RANGNATH VAIDYA
B.Sc.(Agri) First Class

MAHATMA PHULE KRISHI VIDYAPEETH
COLLEGE OF AGRICULTURE
PUNE 411 005

1992



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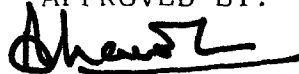
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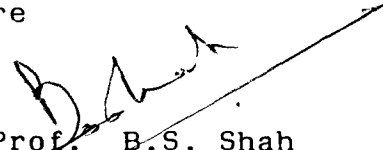
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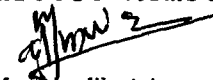
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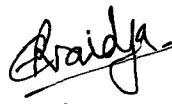
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Date : 20 March, 1992.


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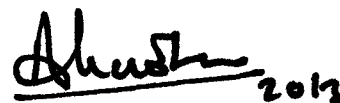
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The assistance and help received during the course of these investigations have been duly acknowledged.

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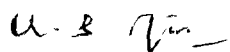
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CERTIFICATE

This is to certify that the thesis entitled, "Genetic divergence in french bean (Phaseolus vulgaris L.)" submitted in partial fulfillment of the requirement of the College of Agriculture, Pune, Mahatma Phule Krishi Vidyapeeth, Rahuri, for the award of degree of MASTER OF SCIENCE (Agriculture) in CYTOGENETICS AND PLANT BREEDING, embodies the results of a bonafide research carried out by SHRI. E.R Vaidya, under the guidance and supervision of Dr. A.N. Chaudhari, Assistant Professor of Botany, College of Horticulture, Pune and that no part of the thesis has been submitted for any other degree or publication.

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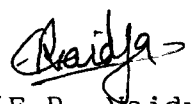
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Place : Pune-5

Date : 20 March, 1992


(E.R. Vaidya)

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ABSTRACT

ABSTRACT

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BY

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1992

Major Professor and Chairman : Dr. A.N. Chaudhari
Department : Agricultural Botany
Major field : Cytogenetics and Plant Breeding

Fifty french bean genotypes were evaluated for their genetic diversity. Significant differences were observed among the genotypes for all the eleven characters indicating the presence of variability. The estimates of PCV were higher as compared to GCV for all characters. Very high heritability was obtained for the character protein content followed by leaf area per plant. High heritability values with high genetic advance was observed for the characters plant height, number of pods per plant, leaf area per plant 100 seed weight and number of seeds per pod indicating a high additive genetic variance and hence, these characters can be improved by selection.

The seed yield per plant was significantly and positively correlated with number of pods per plant, number of seeds per pod, Harvest index and leaf area per plant at both genotypic and phenotypic levels. Its significant positive association was exhibited between days to 50 per cent flowering

and maturity at genotypic level only. It was significantly and negatively correlated with 100 seed weight at both genotypic and phenotypic levels.

The highest direct effect on seed yield was observed due to the days to 50 per cent flowering followed by days for maturity and harvest index. The highest positive indirect effect on the yield was observed due to days for maturity followed by number of pods per plant through days to 50 per cent flowering.

The D^2 values ranged from (between Royal red and Red cloud) 7.76 to 2330.56 (between Manus and EC 39439). On the basis of D^2 values, fifty genotypes were grouped into seven clusters. The cluster A was largest one possessing thirty genotypes. The maximum inter cluster divergence was observed between the clusters B and E ($D = 38.85$) followed by clusters D and E ($D = 31.77$), while it was minimum between the clusters A and C ($D = 12.54$). A tentative breeding programme is suggested.

Chapter Opener Page

INTRODUCTION

I. INTRODUCTION

French bean (Phaseolus vulgaris L.) commonly known as Rajmah bean is a short duration pulse crop. It belongs to family leguminosae. According to Janoria et al., (1984) it has been placed under the family fabaceae and is a native of middle and South America (Evans,1979). The chromosome number of french bean is $2n=22$. It is a polymorphic and self pollinated pulse crop. Domestication and subsequent breeding in Phaseolus has resulted in considerable modification in growth habit. Thus, the field evaluation of wild material and cultivars have revealed that plant type ranged from indeterminate climbers to determinate bush type (Evans,1973).

Phaseolus are valued grain legumes or pulse crops in many tropical countries and usually consumed as dry beans, whereas, in temperate countries, varieties have been developed for fresh pod consumption and for processing as frozen vegetables. They are important sources of protein in human diet in tropical Africa and America, it also supplements the carbohydrate staple foods, like maize and cassava.

4) Beans are also of considerable importance in North America and Europe. Spanish explorers were perhaps the first to introduce it into Europe, In Europe, the french bean spread rapidly in the sixteenth and seventeenth centuries and reached England by 1594 (Purseglove, 1968). From Europe, it spread to the U.S.A., East Indies, India and other parts of the world.

According to Evans (1979), wild populations of Phaseolus are still available, primitive cultivars are found in middle and South America, land races in African tropics and a range of more advanced cultivars in Europe and North America. In India french bean is most extensively grown in U.P., Himachal Pradesh, Jammu and Kashmir and part of Western Maharashtra. India stands first both for the area (9.56 Lakh ha.) and total production (3.65 Lakh tonnes) followed by Brazil and Mexico. The U.S.S.R. stands first for per hectare production (2121 kg/ha) followed by Poland (1910 kg/ha) and France (1667 kg/ha). Whereas, India is low in per hectare production (410 kg/ha) (Anonymous, 1991). In Maharashtra, Satara district is leading first both in area (19,852 ha) and production (75,427 qt) followed by Pune and Sangli.

French bean is one of the important economic legume crop as it provides direct economic returns in the form of grains and pods used as vegetable for humanbeings, fodder for animal and organic matter for soil. It is consumed both as a pulse and vegetable. Dry bean cooked either whole or split and number of dishes are prepared from it. The tender green pods^{are} used as a vegetable. The straw from the plant can be fed to cattle, sheep and horses. It is satisfactory as part of the roughage when fed with good hay and is comparable to corn or sorghum fodder in nutritive value. They are also a rich source of food for nitrogen fixing bacteria in the soil. The deep root system helps in bringing up the essential nutrients from the lower region to upper region.

According to Bebin and Sinkha (1971), dry seed contains many nutrients in large quantities. It contains approximately moisture 11.00%, protein 22%, fat 1.6%, fiber 4.0%, carbohydrate 57.8%, ash 03.6%, calcium 137 mg/100 g, iron 6.7 mg/100 g, vitamin-A 30 mg/100 g, thiamine 0.54 mg/100 g, riboflavin 0.18 mg/100 g, niacin 2.1 mg/100g and ascorbic acid 3.0 mg/100 g. Other micronutriens are also observed in a little quantity.

At present development of strict ideotype as identified by the physiologist and adaptability to a wide range of environments is a major criteria for selection in french bean, (Evans,1979). For increasing yield potential and quality of any crop, the primary aim is to evolve improved varieties. This may be achieved by selecting promising types from naturally existing variation followed by selection of the best varieties.

Peneva, (1973) reported that, there is a considerable variation in plant habit, flower colour, size of pod, number of pods per plant, number of seeds per pod and nutrient content. This variability is of immense importance to the plant breeder, since the number of cultivars that could be developed and tailored to suit the various requirements is almost endless. Precise information about the extent of genetic diversity is invi~~l~~table in expanding the genetic base in any breeding programme. While initiating such a programme a survey of the available variability within the species for the desired traits, enables the breeder in determining the most potential parent to be used.

The correlation coefficients indicate association between the two variables. The study of path coefficients specify the causes and measures relative importance of each causal factors (Dewey and Lu, 1959). Singh and Mehndiratta (1970) also concluded that correlation studies alone may not give complete information, but the study in conjunction with path effect relationship existing between different pairs of characters will be more useful. The direct and indirect path effects, if considered together, the selections are likely to be more effective. It was therefore, proposed to study the path analysis and correlation in diverse genotypes of french bean. The importance of this technique in plant breeding can be judged from the fact that this method ascertains direct and indirect influence of a variable on a given correlation coefficient and thereby helps a plant breeder to plan his breeding programme accordingly.

In breeding programme the selection of parents in hybridization is largely based upon wide adaptation, high yielding potential and genetic diversity. Eco-geographic distance was considered as the criteria for measuring genetic diversity, but recent studies for measuring genetic divergence through Mahalanobis D^2 statistics have indicated that genetic diversity need not necessarily be related to geographic diversity. The D statistics is a sum of squares of differences between corresponding mean value of two sets of suitable weighted

measurements (Burnaby,1966). The D^2 statistics provides a measure of the actual magnitude of divergence for both the groups under comparison

The genetic diversity which is the basis of plant breeding is produced due to inherent genetic differences in plant species and is of major interest to the plant breeder. Collection and study of wide and comprehensive germplasm is recognised as an essential method to develop new promising varieties of crop plants. Many of the quantitative characters of plants such as seed yield, protein content, number of pods per plant, number of seeds per pod and 100 seed weight are of economic importance.

Very little research work for improvement of this crop has been carried out. There is lot of scope for improvement of this crop for dry bean. The low yield of this crop is mainly attributed to the lack of stable high yielding strains, drought tolerant, diseases and insect pest resistance strains and lack of information on the management practices. Keeping these considerations in view, the present study was undertaken to estimate the magnitude of genetic variability, genetic divergence, correlations and path analysis in fifty french bean cultivars selected from the germplasm collection of Botany Department, College of Agriculture, Pune-5 for the present investigation.

The main objectives of the study :

- 1) To study the genetic diversity in different genotypes of french bean;
- 2) To study the inter and intra cluster divergence;
- 3) To estimate the degree and magnitude of genetic variability in different characters;
- 4) To work out the genotypic and phenotypic correlation coefficients among the characters studied; and
- 5) To work out path analysis for the characters under study.

Chapter Opener Page

REVIEW
OF
LITERATURE

II. REVIEW OF LITERATURE

The literature pertaining to the present investigation has been reviewed under the following headings.

- I Variability and genetic parameter
- II Correlation
- III Path analysis
- IV Genetic diversity

2.1 Variability and genetic parameter

2.1.1 Variability

Fisher (1930) first presented the method to separate out the genotypic effects based on phenotype and environmental factors. He expressed the genotypic variability in terms of genotypic coefficient of variation. The genotypic coefficient of variation which helps to measure the range of genetic variability in a character was suggested by Hutchinson (1940). This also provides a means to compare the genetic variability present in various quantitative characters. Frankel (1947), Burton (1951) and Panse (1957) emphasized the utility of genetic components of variance as a basis for predicting the response of quantitative characters, to selection in different breeding programmes.

Seth et al., (1972) while studying the genetic variability in nine cultivars of dwarf french beans reported significant differences for days to flowering, number of primary branches, pod weight, pod number per plant and green pod yield.

Genetic variability in french bean was also reported by Aggarwal and Singh (1973) for characters days to first flower, days for maturity, pod length, seeds per pod and 100 seed weight.

Shetty et al., (1973) reported significant differences for pod length, number of pods and yield of pod except in days to flower in fifty genotypes of french bean.

Woolfe and Hamblin (1973) studied protein content of 336 determinate varieties of Phaseolus vulgaris. The range of protein content amongst the varieties was from 20 to 33 per cent.

Pande et al., (1975) while analysing the genetic variability in french bean reported that the characters plant height, days to first flowering, primary branches and pod length accounted for about 74 per cent of variability in yield similar, findings were also reported by Sharma et al., (1977).

Siuper (1978) observed considerable variability in plant height, length, width and thickness of pod in 16 cultivars of Phaseolus.

Rosario and Montilla (1980) while studying the performance of black and pinto beans reported the superiority of black beans over pinto beans. The black beans viz., Jampa (2426), Venezulla 44 (2276), ICA-TVI (2125) kg/ha yielded significantly high over pinto beans (650 to 1050 kg/ha).

While examining the twenty diverse french bean varieties, Natarajan and Arumugam (1981) observed that the number of pods per plant, branches per plant, pod length, number and weight of seeds per pod, plant height and pod diameter together

accounted for 87% of total variation in green pod yield. The first five characters made the biggest contribution with the number of pods per plant exerting the maximum difference.

Ustimenko et al., (1981) analysing of data on twelve characters including yield component in seven french bean varieties revealed considerable phenotypic and genotypic variation for most of the characters. In general, phenotypic variation was greater than genotypic variation but plant height was a notable exception.

Navale and Patil (1982) observed significant difference for days to flowering (28-40 days) and maturity period; (71-85 days). They also reported wide variation for number of pods per plant (5-24), grains per pod (2.99-5.89) and 100 seed weight (16.2-37.79) in 16 locally collected accessions of french bean.

Quintero (1982) while studying the behaviour of four bean varieties (Cueto 25-9, ICA-Pijao, V-8 and Velasco Largo) reported significant differences between varieties for the characters viz., weight of grain per plant, number of grains per pod and per plant, pods per plant and seed yield. He also observed nonsignificant differences for branches and racemes per plant and plant height.

Joshi and Mehra (1983) in the studies with indigenous and exotic collections of french bean reported significant

differences for plant height, number of leaves, number of branches, number of pods and number of seed per plant, seed weight, days to flowering, days for maturity and seed yield per plant.

Hosfield et al., (1984) in their studies with french bean, observed highly significant differences for all the characters including seed shape, size and weight as well as seed colour.

Shah et al., (1986) observed a wide range of variation in the characters like plant height, days to flowering, pod per plant, days to harvest and pod yield per plant. Other characters length and width of pod shows comparatively a lower range of phenotypic variation.

Bollati (1987) while evaluating the performance of eleven varieties of french bean observed good amount of variability in which the variation for flowering ranged between 34-69 days, maturity 74-106 days and seed yield 341-1573 kg/ha.

Shete and Kale (1988) observed that high range of variability for days to flowering, pod length, number of leaves per plant, number of seeds per pod, 100 seed weight, seed yield and plant height in 36 cultivars of french bean. They also observed high genotypic and phenotypic coefficient of variation for plant height, number of leaves per plant and 100 seed weight.

Avila et al., (1990) collected french bean germplasm from Cochabamba valley in Bolivia and studied its protein content. They were observed protein content of collected germplasm varied from 19 to 27 per cent.

Scully et al., (1991) studied one hundred and twelve common bean genotypes and were observed high genetic and phenotypic variation for days of maturity harvest index and seed yield.

2.1.2 Heritability

The heritability estimates have been considered of obvious importance to plant breeder as they indicate the resemblance between parents and offspring for a given characters. Thus, the improvement in any trait depends upon heritability.

Burton (1952) suggested the use of heritability estimates with genotypic coefficient of variation to give precise estimate of genetic advance. Johnson et al., (1955) have pointed out that in a selection programme heritability values as well as estimates of genetic advance are more useful than heritability alone. According to Hanson et al., (1956) heritability and genetic advance are the two complementary concepts. The heritability values may be used to estimate the expected genetic advance through selection. The heritability enables the plant breeder to base his selection on phenotypic performance for improvement of characters.

Padda (1971) in the study variety and environment interaction affecting flowering and vegetative response in beans observed high heritability for number of days for first flower.

Seth et al., (1972) also observed high heritability in characters viz., plant height (43.75%), days to flowering (51.08%), pod length (35.26%) and green pod yield per plant (78.09%). They also observed moderate heritability for number of pods per plant (18.02%).

Aggarwal and Singh (1973) reported high estimates of heritability for 100 seed weight (93.52%), pod per plant (88.47%), days to maturity (87.29%), pod length (84.63%) and also more than 60% heritability for days to flowering, grains per pod and yield per plant.

Pande et al., (1975) reported high heritability estimates for plant height, primary branches and pod weight in french bean.

Sharma et al., (1977) reported high heritability for days taken to flowering (76.64%), plant height (74.17%) length of pod (80.00%), number of pods per plant (83.19) and yield per plant (62.77%).

Shah et al., (1986) reported very high heritability for the characters like plant height (99.73%), number of primary

branches (96.89%), days to flowering (96.24%), pod length (98.20%), pods per plant (92.03%) and pod yield per plant (96.98%).

Shete and Kale (1988) in their studies observed more than 90 per cent heritability in french bean for plant height, days to flowering, number of leaves per plant, 100 seed weight and seed yield per plant. They also observed more than 80% heritability for pod length and number of seeds per pod.

Scully et al., (1991) observed more than 90 per cent heritability for character viz., days to flowering days for maturity, harvest index and seed yield per plant.

2.1.3 Genetic advance

Genetic advance or genetic gain is a measure to predict the expected progress under selection scheme. Heritability gives information on the magnitude of inheritance of quantitative characters, but genetic advance enables to evaluate the selection procedures. Higher the value of genetic advance, better will be the progress in the succeeding generations under directional selection. Heritability serves as a component in the estimation of genetic advance.

Seth et al., (1972) in their studies with french bean observed that high genetic advance was present for the number of primary branches, pod weight, plant height, days to flowering and green pod yield per plant.

✓ Aggarwal and Singh (1973) also reported high genetic advance for seed yield per plant, 100 grain weight, pods per plant, pod length and grains per pod.

Sharma et al., (1977) reported high genetic advance for the characters number of branches per plant, plant height, number of pods per plant.

Joshi and Mehra (1983) observed high genetic advance for characters plant height, number of leaves, number of pods and number of seeds per plant, 100 seed weight, days to flowering and yield per plant.

◁ Shete and Kale (1988) also reported high genetic advance for characters number of leaves per plant, plant height and 100 seed weight, whereas, it was low for pod length and number of seeds per pod.

2.2 Correlation

The correlation measures the degree of association between two variables. Correlated characters are of interest to the plant breeder for three chief reasons, firstly, the genetic causes of correlation through the pleiotrophic action of gene, secondly, in connection with changes brought about by selection and thirdly, in connection with natural selection (Falconer, 1981). The pleiotrophy is a genetic cause of correlation and linkage is a cause of transient correlation. Pleiotrophy is the

property of a gene which affects two or more characters, so that if the gene is segregating it causes simultaneous variation in the character it affects. The degree of correlation, arising from pleiotropy expresses the extent to which two characters are influenced by the same genes. Correlation resulting from pleiotropy is overall effect of all the segregating genes that affect both characters, some genes may increase both characters, while others increase one and reduce the other. The former tend to cause a positive correlation, the later a negative one. So pleiotropy does not necessarily cause a detectable correlation.

In the improvement of any crop, yield is the most important character. The inheritance of yield is complex in nature and is usually a sum product of various physiological processes. More than one character generally contributes towards the yield. Knowledge of association between these characters is, therefore, useful in selecting the individuals with high potential. Such association between plant characters is statistically determined by correlation coefficient.

Leleji et al., (1972) selected five lines of french bean for differences in protein content and were used as parents in crosses. They observed yield and protein content were negatively and highly correlated in F₂ and F₃ plants.

Lal and Padda (1972) studied correlation in french bean and showed that number of days to flower was positively

correlated with protein content of dry seeds; pod per plant showed significant positive correlation with seed yield per plant and pod yield per plant. Positive correlation of pods per plant with pod length were not significant. Pods per plant had a negative correlation with protein content. Positive correlation was observed between pod length and pods per plant.

Aggarwal and Singh (1973) while studying the correlation in kidney bean reported close resemblance between genotypic and phenotypic correlations. Seed yield was positively and significantly associated with days for first flower, days to maturity and pods per plant. The number of pods per plant were negatively associated with 100 seed weight.

Sharma et al., (1977) observed strong correlation between the number of branches per plant, number of nodes bearing bud, plant height and length of internodes in french bean. However, the association between length of pods and days for first flower and number of pods per plant and length of pod was negative.

Waines (1978) observed significant negative correlation between 1000 seed weight and protein content, in 47 cultivars of Phaseolus vulgaris.

Romalho et al., (1980) in two cultivars of field bean observed highly positive phenotypic and genotypic correlation between seed yield and number of pods per plant, number of seeds

per pod and 100 seed weight. Mitronov (1981) also observed significant positive correlation between yield and number of pods per plant.

Prakash and Ram (1981) observed that seed yield was positively and significantly associated with plant height (0.416), plant spread (0.388) and seeds per pod (0.378).

Navale and Patil (1982) in their studies on the correlation of yield and yield contributing characters of french bean reported positive and significant association between days to flower with number of pods and number of seeds per pod, number of pods with number of seeds per pod and with seed yield per plant.

Rodriguez et al., (1983) while studying correlation among various characters in local and improved varieties of beans observed significant negative correlation between days for first flower and yield. They concluded that late maturing varieties were not necessarily high yielder.

Joshi and Mehra (1984) observed at phenotypic level the highest positive and significant correlation with number of pods per plant, number of leaves per plant, number of seeds per plant and plant height ($r=0.77$ to 0.82), moderate positive correlation was observed ($r=0.65$ to 0.68) with days to flowering and days for maturity and negative correlation with number of branches, 100

seed weight and pod length ($r=0.02$ to -0.15). Number of cluster, number of pods and number of seeds per plant had high genotypic correlation among themselves. Number of pods, number of seeds and number of leaves per plant, plant height and days to maturity showed high and significant positive correlation with seed yield at genotypic level only ($r=0.75$ to 0.89).

Vaid et al., (1986) analysed correlations of different characters in one hundred genetically diverse germplasm of french beans over three environments showed that, yield was significantly and positively correlated with days to flowering days for maturity, plant height, pods per plant, pods per cluster and seeds per pod at both genotypic and phenotypic level. They also observed close resemblance between genotypic and phenotypic correlation. The magnitude of genotypic correlation were greater than phenotypic correlation.

Nienhuis and Singh (1986) reported significant positive correlation of seed yield with seeds per pod; and seeds per pod with seed weight. In contrast, the correlation between seed yield and seed weight was negative.

Shah et al., (1986) while studying correlation in french bean observed positive correlation between yield and number of primary branches, pod length and number of pods per plant.

Shete and Kale (1988) reported that the strongest correlation were observed between the number of leaves per plant and height of plant, duration of harvest for green pod yield and height of plant which were positively correlated with pod yield.

Avila et al., (1990) while studying correlation in french bean, observed nonsignificant correlation among protein content, yield and seed size.

Scully et al., (1991) reported significant positive correlation between seed yield with days to flowering, days for maturity and harvest index at both genotypic and phenotypic levels.

2.3 Path coefficient analysis

Selection for an optimum advance could be based on judiciously computed index. Yield is a character of major interest influenced singly and complex character or jointly by many component characters (Whitehouse et al., 1958 and Graphious, 1959). It is therefore, necessary for a plant breeder to have information on the direct and indirect effects of the component characters on yield.

Wright (1921) developed a technique known as path coefficient analysis by which the extent and nature of direct and indirect effects of the component characters can be worked out. Further, Dewey and Lu (1959) gave the detailed procedure for path analysis with elimination of environmental variance.

Duarte and Adams (1972) in field bean reported that pod per plant, seeds per pod and maturity contributed maximum directly and indirectly to yield.

Aggarwal and Kang (1976) in horse gram (Dolichous biflorus L.) showed that pods per plant had a high positive direct and indirect effect on yield. The characters plant height, number of branches, pod length and 100 seed weight contributed indirectly to yield.

Prakash and Ram (1981) suggested the pod number per plant combined with pod length was the best selection criteria increasing green pod yield, whereas, pod number and pod length with seed number per pod was best for increasing dry seed yield.

Joshi and Mehra (1984) observed number of pods per plant, 100 seed weight and days to maturity as the components with high direct effects. Except 100 seed weight these characters also have high and significant correlation with seed yield. They also stated that as late maturity (beyond 80 days) is not desirable; greater emphasis should be placed on number of pods per plant in selection for seed yield.

Shah et al., (1985) while studied the path coefficient analysis in 25 french bean varieties reported that number of primary branches per plant and pod length had the greatest direct effect on pod yield.

Vaid et al., (1986) in the path coefficient analysis revealed that pod number per plant was the most important yield contributing component. Direct effect of hundred seed weight was also important at both genotypic and phenotypic levels. The other direct effects worth consideration were number of seeds per pod and plant height at genotypic level. The traits like days to flowering, days to maturity, pod length were found to be yield contributing characters of secondary importance, their effects via number of pod at both genotypic and phenotypic levels. These characters therefore could be used as useful criteria in developing high yielding varieties in french bean.

2.4 Genetic diversity

2.4.1 Concept of genetic diversity

The concept of D^2 statistics for measuring the divergence between the two population was first stated by Mahalanobis (1936). The main cause of divergence is ultimately the function of change in gene frequency between populations. The extent of change in gene frequency depends on the differential effect of evolutionary forces, which act on the population. In natural pollination, the frequency of given gene is determined by its relative contribution to the total adaption of individuals to their environment. The individuals which show more fitness contribute more than those which show less fitness to the population gene pool (Lush,1949). The D^2 statistics is a sum of square of differences between corresponding mean values of two sets of suitably weighted measurement (Burnaby,1966).

2.4.2 Genetic diversity in french bean and other crops

Allard (1961) studied the relationship between diversity and consistency of performance in different environments by using three distinct levels of genetic diversity. He concluded that genetic diversity and productivity were completely related and that many factors determined the productivity of mixed population. However, genetic diversity and stability appeared to be more simply related, irrespective of the components involved. Two techniques of multivariate analysis (component analysis and discriminant analysis) were examined by Cassie (1963).

Among the several statistical methods to quantify genetic divergence, multivariate analysis is a potent tool (Rao, 1960). In Brassica, Wheat, Sorghum and Soyabean, genetic diversity as measured by D^2 analysis was not found to be related with ecogeographic diversity (Murty and Arunachalam, 1966). They also stated that genetic drift and selection in different environments could cause greater diversity among genotypes their geographical distance in some crop plants.

Gupta and Singh (1970) in green gram (Phaseolus aureus) showed that the seed weight and pod length contributed towards the total divergence.

Singh et al., (1973) collected 2500 accessions of Asiatic Phaseolus spp. from different part of India. This

collection has been studied in detail and they observed genetic diversity for days to flower and maturity, pod length, seeds per pod, seed colour, plant height and disease resistance.

Choudhary et al., (1975) grouped fifty varieties of cluster bean into eleven clusters. Each cluster included the varieties of different ecogeographical region. The characters peduncle length, 100 seed weight, pods per plant, yield per plant and flowering time contributed 95 per cent of total diversity.

Bainiwal and Jatasara (1980) revealed maximum divergence in pigeon pea due to plant height, followed by pod length and days for first flowering. Aswa et al., (1981) also observed considerable amount of genotypic diversity in seed per pod and reported importance of this character in selection indices.

Adams et al., (1982) while studying the 97 seed type from Malwi reported that the genetic diversity in beans could be due to natural outcrossing.

Kumar et al., (1982) studied the seed yield along with nine qualitative characters in fifty genotypes of cowpea. The genotypes were grouped into seven clusters 21 lines in cluster I and one each in cluster VI and VII. Days to 50 per cent maturity, pod length, pod width and 100 seed weight contributed to genetic divergence. Genetic distance between cluster III and VI indicated that crossing between the genotypes of these two clusters may provide useful segregation with improved seed yield.

Hosfield et al., (1984) in their studies with french bean reported that there was considerable genetic diversity in seed colour, shape, size and weight of dry seed.

Shete and Kale (1988) while studying genetic diversity in french bean grouped 36 varieties into eleven clusters. They also showed varieties of different ecogeographical regions were found to cluster together and the characters viz., the number of leaves per plant, green pod yield, duration of harvesting, seed yield, height of plant, 100 seed weight and flowering time contributed 90 per cent of total diversity.

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MATERIALS
AND
METHODS

III MATERIALS AND METHODS

The present investigations were carried out at the College of Agriculture, Pune, during Kharif 1990. The details of materials used and statistical procedures followed during the course of investigation are presented below.

3.1 Materials

From the 150 accessions of french bean maintained at Department of Botany, College of Agriculture, Pune, 50 were used for the present investigation. A list of the accession, along with their source is given in Table 1.

3.2 Experimental Design

The experiment was laid out in a randomised block design with three replications, at Botany Farm, College of Agriculture, Pune, during Kharif 1990. Each entry represented a two rows of 4 m length, spaced 30 cm apart. The distance between the plants was 10 cm. Sowing was carried out by dibbling and only one healthy seedling was retained by thinning. The recommended dose of fertilizer i.e. 60 kg N/ha in the form of urea and 80 kg P_2O_5 /ha in the form of single super phosphate was applied. Nitrogen was applied in two split doses of 30 kg each. Cultural practices such as thinning, gap filling, weeding, interculturing and spraying of insecticides and pesticides were followed to ensure satisfactory crop growth.

3.3 Observations recorded

Observations were selected plants for the charac

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the five randomly below.

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Table 1: Genotypes and its source

Sr.No.	Genotype	Source
1	Yellow 4	I.A.R.I., New Delhi (India)
2	VL 64	Almora, U.P. (India)
3	VL 61	Almora, U.P. (India)
4	PDR 3	Pulse Project Co-ordinator, Kanpur, U.P.(India)
5	PDR 5	Pulse Project Co-ordinator, Kanpur, U.P.(India)
6	PDR 7	Pulse Project Co-ordinator, Kanpur, U.P.(India)
7	PDR 9	Pulse Project Co-ordinator, Kanpur, U.P.(India)
8	Jwala	Pulse Project Co-ordinator, Kanpur, U.P.(India)
9	Manus	Satara, M.S. (India)
10	HPR 35	Himachal Pradesh (India)
11	HPR 12	Himachal Pradesh (India)
12	HPR 33	Himachal Pradesh (India)
13	HPR 87	Himachal Pradesh (India)
14	HPR 137	Himachal Pradesh (India)
15	Refresh	Pulse Project Co-ordinator, Kanpur, U.P. (India)
16	Vaghya	Satara, M.S. (India)
17	K.B.7	Pulse Project Co-ordinator, Kanpur, U.P. (India)
18	Jampa improved	Satara, M.S. (India)
19	Almora	Almora, U.P. India
20	IC 47845	N.B.P.G.R. New Delhi (India)
21	Ajara black	Hattivade (Ajara), Kolhapur, M.S. (India)
22	Sabarmati	Pulse Project Co-ordinator, Kanpur, U.P.(India)
23	Poona white	Satara, M.S. (India)
24	Contender	I.A.R.I., New Delhi (India)
25	Tender green	I.A.R.I., New Delhi (India)
26	IC 47644	N.B.P.G.R. New Delhi (India)
27	Khaki	Satara, M.S. (India)
28	Royal red	Netherlands (Holland)
29	Montcalm	Netherlands (Holland)
30	Red could	Netherlands (Holland)
31	Red Mexican	Netherlands (Holland)
32	EC 94465	Calicolumbia, (South America)
33	EC 22367	Calicolumbia, (South America)
34	EC 43034	Calicolumbia, (South America)
35	IC 47429	N.B.P.G.R. New Delhi (India)
36	EC 108101	Calicolumbia (South America)
37	American red	Netherlands (Holland)
38	IC 49802	N.B.P.G.R. New Delhi (India)
39	IC 49844	N.B.P.G.R. New Delhi (India)
40	Red kote	Netherlands (Holland)
41	EC 26646	Calicolumbia (South America)
42	IC 49700	N.B.P.G.R., New Delhi (india)
43	EC 42960	Calicolumbia (South America)
44	EC 44747	Calicolumbia (South America)
45	EC 44744	Calicolumbia (South America)
46	EC 39439	Calicolumbia (South America)
47	EC 94469	Calicolumbia (South America)
48	IC 47842	N.B.P.G.R., New Delhi, (India)
49	IC 47653-1	N.B.p.G.R., new Delhi, (India)
50	IC 18618	N.B.P.G.R., New Delhi, (India)

3.3.1 Days to 50 per cent flowering

The number of days from sowing to the time when fifty per cent of the plants showed an emergence of flower were taken as the number of days for fifty per cent flowering. There were recorded on plot basis.

3.3.2 Days for maturity

The period between the date of sowing to the date of harvest of crop for seed was recorded as days for maturity. There were recorded on plot basis.

3.3.3 Plant height (cm)

Plant height was measured in cm from the base of the plant i.e. ground level to the tip of the main axis.

3.3.4 Number of pods per plant

The total number of pods per plant were counted on five randomly selected plants and average was worked out.

3.3.5 Pod length (cm)

The average length of pod was calculated by measuring length of five randomly selected pods from each of five selected plants.

3.3.6 Number of seeds per pod

The seed from the five randomly selected pods from observational plants were counted and the average number of seeds per pod was computed.

3.3.7 100 seed weight (g)

Hundred seeds were selected at random from each treatment and weighed in gm.

3.3.8 Harvest index (%)

It is calculated in percentage as per following formula:

$$\text{Harvest index} = \frac{\text{Seed yield}}{\text{Biological weight}} \times 100$$

3.3.9 Leaf area per plant (sq.cm)

Leaf area at 50 per cent flowering stage was measured with the help of LI-3000 portable leaf area meter on five randomly selected plants.

Working principle : LI-3000 Portable leaf area meter :

LI-3000 leaf area meter has two components viz., scanning head and readout console. When the leaf is passed through the scanning head, according to the width of leaf in each set of scan number of LEDs are blocked and sensed by lens photodiode system. According to number of scanning required, the length of the leaf is measured. From the average width and length of leaf, the leaf area is calculated and displayed on the console.

3.3.10 Crude protein content (%)

Crude protein content was analysed from seed samples by Microkjeldah's method (Anonymous, 1980).

$$\text{Crude protein (\%)} = \text{Microkjeldah's N} \times 6.25$$

3.3.11 Dry seed yield per plant (g)

The seed yield from five randomly selected plants was recorded and average seed yield per plant was calculated.

3.4 Statistical Methods

The mean values recorded for the various characters were used for the statistical analysis.

3.4.1 Analysis of variance

The first step in the statistical analysis is to test the null hypothesis, that there are no genotypic differences. This test involves the analysis of variance of randomized block design for metric traits. This was carried out as per the standard procedure given by Cochran and Cox (1957). Covariance analysis between all the pairs of the characters under study was carried out as per the procedure of the analysis of variance and covariance cited by Singh and Chaudhari (1985).

3.4.2 Variability and genetic parameters

A) Genotypic and phenotypic coefficients of variation

Genotypic and phenotypic coefficients of variation were estimated as per the following formulae suggested by Burton (1952).

i) Genotypic coefficient of variation (G.C.V.)

$$\text{G.C.V.} = \frac{\sqrt{6g}}{\bar{X}} \times 100$$

ii) Phenotypic coefficient of variation (P.C.V.)

$$\text{P.C.V.} = \frac{\sqrt{6p}}{\bar{X}} \times 100$$

Where,

\bar{x} = Mean of the character

σ^2_g = Genotypic variance of the character

σ^2_p = Phenotypic variance of the character

B) Heritability (h^2)

Heritability percentage in broad sense was calculated as per the formula cited by Allard (1960)

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

Where,

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

c) Genetic advance (G.A.):

Genetic advance was calculated according to the formula cited by Allard (1960).

$$G.A. = K \times \frac{\sigma^2_g}{\sigma^2_p} \times \sigma_p$$

where,

σ^2_g = Genotypic variance

σ^2_p = Phenotypic variance

k = Selection differential (At 5% selection intensity the value of k = 2.06).

3.4.3 Correlation

In order to study the interrelationships between the different characters, genotypic and phenotypic correlations were worked out by following the co variance analysis method. Genotypic and Phenotypic correlation coefficients, were worked out as per Al-Jibouri et al., (1958).

$$\text{Genotypic } r = \frac{\sigma_{p_{1.2}}}{\sqrt{(\sigma_{p_1}^2)(\sigma_{p_2}^2)}}$$

where,

$\sigma_{p_{1.2}}$ = is the genetic covariane between two traits

$\sigma_{p_1}^2$ = is the genetic variance of the first traits

$\sigma_{p_2}^2$ = is the genetic variance of the second trait

$$\text{Phenotypic } r = \frac{\sigma_{Ph_{1.2}}}{\sqrt{(\sigma_{Ph_1}^2)(\sigma_{Ph_2}^2)}}$$

where,

$\sigma_{Ph_{1.2}}$ = is the phenotypic covariance of the progeny means between the two traits

σ_{Ph_1} and σ_{Ph_2} = are the phenotypic variances of progeny means for each trait

Significance of the various correlation coefficients was tested from the statistical table of correlation coefficients at 1 and 5 per cent level of significance (Snedecor and Cochran, 1967).

3.4.4 Path-coefficient analysis

To establish a cause and effect relationship, the genotypic and phenotypic correlation coefficients were partitioned into direct and indirect effects by path analysis as suggested by Dewey and Lu (1959). The characters which exhibited a statistically significant correlation with yield were only considered for path analysis.

Path coefficients were obtained by solving a set of simultaneous equations as per Dewey and Lu (1959).

$$r_{ny} = p_{ny} + r_{n2}p_{2y} + r_{n3}p_{3y} + \dots$$

where,

r_{ny} = represented correlation between one component and yield

p_{ny} = represents path coefficient between that characters and yield

r_{n2} = represented correlation between that character and each of the other yield components

The indirect effect of a particular character through other character was obtained by multiplication of direct paths and particular correlation coefficients between these character separately.

$$\text{Indirect effect} = r_{ij} \times p_{ij}$$

where,

$$i = 1 \text{ to } 10 \text{ and } j = 1 \text{ to } 10$$

$$p_{ij} = P_{1y}, P_{2y}, \dots, P_{ny}$$

Path coefficient (P_{ij}), correlation coefficient (r_{ij}) and residual factors (x) were diagrammatically presented. The residual factors, i.e. variation in yield unaccounted for by these associations was calculated from the following formula.

$$\text{Residual factor (X)} = 1 - R^2$$

where,

$$R^2 = p_{1y} r_{1y} + p_{2y} r_{2y} + \dots + p_{ny} r_{ny}$$

3.4.5 Mahalanobis Generalized Distance (D^2)

The generalized distance between any two population is defined as

$$\Delta^2 = \sum \sum \lambda_{ij} \delta_i \delta_j$$

where,

λ_{ij} = reciprocal matrix to the common dispersion matrix

δ_i = difference between the mean values of the two population for the i th characters

This quantity was estimated by $D^2 =$ Statistics (Mujumdar and Rao, 1958) as

$$D^2 = \sum \sum s_{ij} \delta^i \delta^j$$

where,

$$s_{ij} = \text{Sample estimates of } \lambda_{ji}$$

$$\delta^i = \text{sample estimates of } \delta_i$$

This formula requires the inversion of the matrix of sum of squares and sum of products of characters of order eleven and then evaluation of 11 $((11+1)/2)$ terms whose sum is D^2 .

As the characters are usually correlated in a biological population, the original unstandardised correlated variables (X_1, X_2, \dots, X_p) were transformed to standardized uncorrelated variables (Y_1, Y_2, \dots, Y_p) by pivotal condensation of common error variance, co variance matrix as described by Rao (1952).

The actual values of D^2 between any two genetic stocks on the eleven characters were obtained by taking the sum of squares of the differences of the values of Y_1, Y_2, \dots, Y_{11} for the two genetic stocks. Thus, the total D^2 values for all possible pairs from the fifty genotypes were obtained.

3.4.5.1 Testing the significance of D^2 values

The D^2 value obtained for a pair of populations was taken as the calculated value of X and tested against the tabulated value of X^2 , with $(P-1)$ degrees of freedom, where p is the number of characters considered (Singh and Chaudhari, 1977).

3.4.5.2 Contribution of each character towards divergence

In all the combinations, each character was ranked on the basis of $d_i = y_{ij} - y_{ik}$ values. The first rank was given to the highest mean differences and the last rank to the lowest mean difference. The percentage of contribution was worked out on the basis of the number of times a character appeared first in the rank in all the combinations (Singh and Chaudhari, 1985).

3.4.5.3 Determination of population constellations

No fixed rules can be laid down for grouping the varieties into clusters. The only satisfactory criterion is that any two groups belonging to the same cluster should at least, on an average, show smaller D^2 than the D^2 of those belonging to different clusters. A method suggested by Tocher (Rao, 1952) was used for grouping the varieties into clusters. Accordingly, two closely associated groups were chosen and a third one having the smallest average D^2 among them was added to them. Similarly, the fourth having the smallest average D^2 from the first three was chosen and it was so continued till a stage when the average D^2 of a genetic stock from those already listed appeared to be high. Then, this stock was taken to be outside the cluster. The genetic stock of the first cluster were omitted and the rest were treated on the similar lines.

3.4.5.4 Average intra and inter cluster distance

The average intra cluster distance was obtained by using the following formula

$$D^2 = \frac{\sum D_i^2}{n}$$

where,

D^2 = sum distances between all possible combinations (n) of genotypes involved in a cluster.

The average inter cluster distance was calculated by using all possible D^2 values between genotypes included in any two cluster.

3.4.5.5 Cluster mean

Cluster means for individual characters were calculated on the basis of mean performance of the genotypes included in the cluster.

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RESULTS

IV. EXPERIMENTAL RESULTS

The results obtained in the present investigations on the, "Genetic Divergence In French Bean [Phaseolus vulgaris (L.)]" in respect of genotypic and phenotypic coefficient of variation, heritability, genetic advance, correlation, path analysis and genetic diversity are presented in this chapter.

4.1 Mean performance and range of variability

A wide range of variation was observed for all the characters studied. The mean performance of the genotypes for the eleven characters studied are presented in Table 2.

4.1.1 Days to 50 per cent flowering

Days to 50 per cent flowering ranged between 27.66 (EC 94465 and PDR 9) and 48.66 (Ajara black). The genotypes contender (28.33), Yellow 4 (29.00), HPR 87 (29.00), HPR 12 (29.33), HPR 35 (29.33) and Red cloud (29.66) were early to flower and the genotypes Sabarmati (48.00), EC 94465 (44.00), IC 47845, (43.00) and IC 49844 (41.33) were late which took more than 40 days to flowering.

4.1.2 Days for maturity

Days for maturity varied between 63.66 (Yellow 4) and 87.00 (K.B. 7). The genotypes HPR 35 (64.00), PDR 9 (66.66), EC 94465 (64.66), Contender (65.00) and EC 108101 (65.00) were early to mature and IC 47644 (86.00), Manus (82.33), Sabarmati (84.33), IC 49844 (85.66), IC 47842 (83.66) and Ajara black (85.00) were very late in maturity compared to other genotypes.

Table 2: Mean performance of fifty genotypes for eleven characters in french bean.

Sr.No.	Genotype	Days for 50 % flowering	Days for maturity	Height of plant (cm)	No. of pods/ plant	Length of Pod (cm)	No. of seeds/ pod	100 seed weight (g)	Harvest index (%)	Leaf area plant (sq.cm)	Protein content (%)	Seed yield/ plant(g)
1	Yellow 4	29.00	63.66	29.60	8.20	10.72	4.08	24.15	23.13	2258.81	22.06	7.50
2	VL 64	36.00	73.66	39.06	6.86	11.61	3.24	37.52	13.13	3059.71	24.16	5.44
3	VL 61	37.33	80.66	44.33	6.20	10.26	3.21	43.09	19.03	3266.10	23.00	8.00
4	PDR 3	34.33	76.66	46.46	8.26	10.29	3.33	36.50	21.41	2435.10	22.46	7.75
5	PDR 5	32.66	70.66	43.66	5.40	10.01	2.81	38.55	13.37	2169.42	23.52	4.67
6	PDR 7	34.33	75.66	43.33	6.13	11.06	3.62	41.74	20.04	2625.16	22.82	8.01
7	PDR 9	27.66	64.66	42.46	6.60	11.05	2.70	41.91	17.46	2459.57	24.27	5.19
8	Jwala	32.00	74.66	45.20	5.96	10.48	3.22	44.56	14.54	2679.18	26.03	6.30
9	Manus	36.33	82.33	39.50	4.98	10.37	3.00	41.91	24.31	2328.95	26.92	6.92
10	HPR 35	29.33	64.00	46.88	7.90	12.12	2.67	41.41	19.36	2960.27	22.48	13.10
11	HPR 12	29.33	66.00	45.86	6.60	12.86	4.53	30.68	16.47	3450.21	23.05	7.00
12	HPR 33	36.33	74.66	40.40	6.33	10.61	2.57	41.46	14.92	2126.04	22.83	7.00
13	HPR 87	29.00	66.00	47.33	6.46	11.69	3.85	33.36	19.06	3120.70	21.98	8.01
14	HPR 137	39.00	79.00	38.73	5.53	11.27	3.07	33.54	22.57	3214.87	21.98	8.77
15	Refresh	34.66	72.33	48.26	7.60	11.71	3.50	37.02	14.93	2980.73	22.90	8.00
16	Vaghya	33.00	74.33	36.13	7.00	10.66	3.74	33.23	20.21	2566.74	21.49	7.90
17	K.B. 7	39.00	87.00	46.63	6.63	10.47	3.46	36.10	16.52	3553.19	21.98	6.84
18	Jampa improved	39.00	77.66	43.13	16.26	9.46	6.75	17.86	24.49	4439.59	21.99	13.95
19	Almora	35.33	74.66	31.00	4.33	9.42	2.40	51.95	13.92	1863.52	23.03	5.61
20	IC 47845	43.00	80.33	73.43	6.20	11.29	3.76	43.15	18.75	2858.89	19.85	7.93
21	Ajara black	48.66	85.00	73.71	9.01	8.96	4.66	20.76	25.79	3045.05	21.93	7.45
22	Sabarmati	48.00	84.33	56.46	7.40	9.46	4.95	22.10	22.61	3729.89	22.40	8.08
23	Poona white	38.33	78.33	48.93	12.66	10.00	5.12	20.84	19.89	4420.96	24.46	10.02
24	Contender	28.33	65.00	34.26	6.00	12.84	3.75	38.05	13.98	3099.85	22.05	6.25
25	Tender green	32.66	68.66	56.23	6.05	10.33	4.10	28.13	16.15	2716.21	22.99	6.40
26	IC 47644	32.66	86.00	115.46	5.36	9.66	3.44	31.77	15.34	3069.75	22.99	5.78
27	Khaki	28.33	66.66	45.00	6.26	13.27	4.61	31.27	13.41	2450.59	24.11	7.15
28	Royal red	33.00	68.33	42.73	8.00	11.60	3.16	38.31	17.07	3415.51	23.09	8.23
29	Montcalm	35.66	76.00	42.80	5.73	10.89	2.75	49.46	14.19	2041.17	23.89	6.70
30	Red cloud	29.66	66.33	50.66	7.80	11.85	2.78	42.91	17.36	3535.98	23.17	8.00
31	Red mexican	35.33	67.33	63.55	8.20	9.20	4.22	33.06	14.47	3429.12	22.89	8.00
32	EC 94465	27.66	61.66	44.33	6.20	11.93	3.62	34.11	18.02	2773.64	22.48	6.24
33	EC 22367	33.61	77.66	47.00	6.05	11.82	3.97	38.56	15.24	3540.28	24.00	7.76
34	EC 43034	31.00	65.33	45.53	5.06	12.67	5.22	29.05	13.40	3085.55	19.99	5.23
35	IC 47429	38.66	77.00	44.75	6.83	10.77	4.61	26.20	22.03	2831.91	21.48	9.50
36	EC 108101	33.00	65.00	40.53	5.26	11.18	4.24	39.26	15.53	3053.40	23.03	5.42
37	American red	36.00	68.00	77.66	8.93	9.74	3.63	30.83	19.47	4171.03	23.03	7.74
38	IC 49802	35.33	71.33	44.35	5.25	10.73	4.55	30.27	14.37	3857.98	21.97	5.63
39	IC 49844	41.33	85.66	60.73	6.73	9.93	3.28	38.72	18.39	3311.11	23.40	7.24
40	Red kote	31.33	69.33	50.66	7.60	11.98	2.97	41.71	14.01	4040.76	22.89	4.83
41	EC 26646	36.33	77.33	84.60	10.46	11.23	2.89	36.52	21.19	2277.34	23.09	8.10
42	IC 49700	38.66	73.33	37.46	6.40	10.34	3.88	26.57	15.99	2872.52	23.36	5.89
43	EC 42960	34.33	75.33	43.60	7.00	11.97	4.40	28.72	19.36	3409.72	21.12	8.76
44	EC 44747	38.00	79.00	35.46	4.80	10.42	3.18	46.11	16.08	3198.38	19.90	5.78
45	EC 44744	38.00	73.00	43.33	5.50	11.35	4.24	30.11	20.86	2195.18	21.64	7.26
46	EC 39439	30.66	66.33	43.93	6.33	12.34	5.20	25.23	14.76	2985.85	19.56	7.60
47	EC 94469	32.00	66.33	57.30	6.93	11.33	3.88	30.43	20.03	3224.54	21.54	8.49
48	IC 47842	44.00	83.66	81.80	5.33	10.07	3.43	42.63	17.81	2715.40	20.80	7.08
49	IC 47853-1	39.66	75.66	56.36	4.00	9.98	3.52	28.06	14.95	2997.37	22.77	4.53
50	IC 18618	40.00	79.66	54.03	8.00	8.81	5.19	29.02	21.08	2354.88	23.14	11.97
	Mean	35.42	73.66	49.88	6.82	10.81	3.77	34.77	17.81	3005.29	22.57	7.52
	S.E. (Mean)	1.94	2.04	5.20	1.19	0.66	0.44	11.91	3.33	126.19	0.14	1.54
	CD at 5% level of significant	3.85	4.05	10.38	2.36	1.32	0.88	23.58	6.60	249.85	0.28	3.05

4.1.3 Plant height (cm)

Plant height ranged from 29.6 cm (Yellow 4) to 115.46 cm (IC 47644). The other genotypes Almora (31.00), Contender (34.26), Vaghya (36.13), IC 49700 (37.46) and HPR 137 (38.73) were dwarf and the genotypes EC 26646 (84.6), IC 47842 (81.8) and American red (77.66) were comparatively taller.

4.1.4 Number of pods per plant

Number of pods per plant ranged between 4.00 (IC 47653-1) and 16.26 (Jampa improved). The genotypes Poona white (12.66), EC 26646 (10.46), Ajara black (9.01), American red (8.93) and PDR 3 (8.26) produced more number of pods per plant, whereas, Almora (4.33), EC 44747 (4.80) and Manus (4.90) were with less pods per plant.

4.1.5 Pod length (cm)

Pod length ranged between 8.81 cm (EC 18618) and 13.27 cm (Khaki) (Plate 1A and 1B). The genotypes HPR 12 (12.86 cm), Contender (12.84 cm), EC 43034 (12.67cm), EC 39439 (12.34 cm) and HPR 35 (12.12 cm), produced longer pods, whereas, Ajara black (8.96), Red Mexican (9.20 cm), Sabarmati (9.46 cm), Jampa improved (9.46 cm), Almora (9.42 cm) and Red Mexican (9.27 cm) had shorter pods.

4.1.6 Number of seeds per pod

Jampa improved produced maximum number of seeds per pod (6.75) and it was minimum in Almora (2.40). The other genotypes

viz., EC 43034 (5.22), EC 39439 (5.20), IC 18618 (5.19) and Poona white (5.12) also recorded fairly high seeds per pod. HPR 33 (2.57), HPR 35 (2.67), PDR 9 (2.70) and Montcalm (2.75) had minimum number of seeds per pod.

4.1.7 100 Seed weight (g)

The genotype Almora recorded the highest 100 seed weight of 51.92 g and was followed by Montcalm (49.46g), EC 44747 (46.11 g), IC 47845 (43.15 g) and Red cloud (42.91 g). The high yielding genotype Jampa improved had the lowest 100 seed weight (17.86 g) followed by Ajara black (20.76 g) and Poona White (20.84 g).

4.1.8 Harvest index (%)

The genotype Ajara black recorded the highest harvest index (25.79%) followed by Jampa improved (24.49%) and Manus (24.31%) whereas, it was lowest in VL 64 (13.13%).

4.1.9 Leaf area per plant (sq.cm)

Leaf area per plant ranged between 1863.52 sq.cm (Almora) and 4439.59 sq.cm (Jampa improved). The genotypes Poona white (4420.96 sq.cm), American red (4171.03 sq.cm) and Red kote (4040.76 sq.cm) also had very high leaf area. The leaf area variation presented in Plate 2A and 2B.

4.1.10 Protein content (%)

Protein content of the different genotypes studied ranged between 19.85 % (IC 47845) and 26.92% (Manus). The

PLATE 1: POD LENGTH VARIATION IN FRENCH BEAN

PLATE 1 (A):

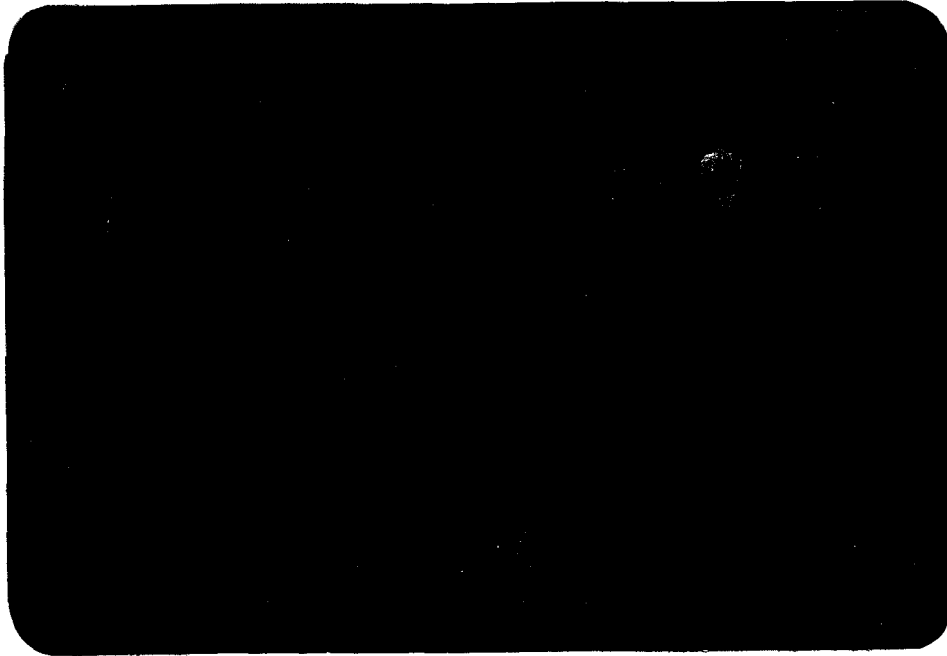
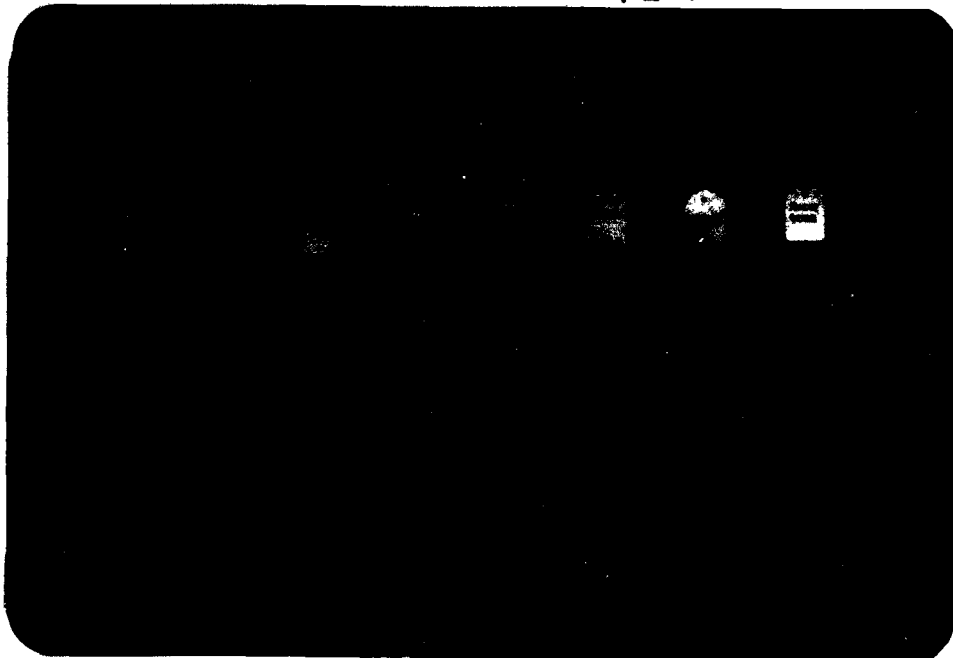


PLATE 1 (B):



**PLATE 2: LEAF AREA VARIATION
IN FRENCH BEAN**

PLATE 2(A)-

PLATE 2(B)

genotypes Jwala (26.03 %), Poona white (24.46 %), PDR 9 (24.27 %) and VL 64 (24.16%) have recorded high protein content when compared with other genotypes.

4.1.11 Seed yield per plant (g)

Seed yield per plant ranged between 4.53 g (IC 47653-1) and 13.95 g (Jampa improved). The genotypes HPR 35 (13.1 g), IC 18618 (11.97g) and Poona white (10.02 g) gave high seed yield. The genotypes EC 108101 (9.50 g), HPR 137 (8.77 g) and EC 42960 (8.76g) gave medium seed yield. The genotypes PDR 3 (4.67g), PDR 9 (5.19 g), IC 47429 (5.23 g) and VL 64 (5.44 g), gave low yield as compared with other genotypes.

4.2 Analysis of variance

The analysis of variance revealed that the mean sum of square (MSS) due to the treatments were highly significant for all the eleven characters studied (Table 3).

4.3 Genotypic and Phenotypic coefficient of variation

The magnitude of genotypic coefficient of variation was low as compared to the magnitude of phenotypic coefficient of variation for all characters (Table 4). The genotypic and phenotypic coefficient of variation was low for number of seeds per pod (0.63 GCV and 0.93 PCV) followed by pod length (0.67 GCV and 1.56 PCV) and it was high for the leaf area per plant (352209.90 GCV and 376096.20 PCV) followed by plant height (224.29 GCV and 265.53 PCV). Other characters such as days to

Table 3: Analysis of variance for 11 characters in french bean

Sr. No.	Source	DF	Days to 50% flowering	Days to maturity	Height of plant (cm)	No. of pods/plant	Length of pod (cm)	No. of seeds/pod	100 seed weight(g)	Harvest index(%)	Leaf area plant(q cm)	Protein content (%)	Seed yield/plant
1	Repli- cation	2	16.00 **	28.46 **	66.14 **	3.68 **	2.83 **	0.16 **	123.78 **	55.97 **	37248.00 **	0.007 **	18.63 **
2	Treatment	49	50.28	137.89	714.12	10.70	3.36	2.20	177.58	34.72	1080516.00	5.972	8.52
3	Error	98	5.70	6.30	41.23	2.14	0.67	0.30	14.67	16.71	23886.37	0.031	3.57

* : Significant at 5% level

** : Significant at 1% level

Table 4 : Parameters of genetic variability in french bean

Sr. No.	Character	Mean	Range	Genotypic Coeff. of Variation (GCV)	Phenotypic coeff. of variation (PCV)	Herita- bilit h (broad sense)	Genetic advance (GA)	Expected genetic advance in % of mean
1	Days to 50% flowering	35.42	27.66-48.66	24.86	30.56	81.3	6.75	19.05
2	Days to maturity	73.68	63.66-87.00	43.86	50.17	87.4	12.75	17.30
3	Plant height (cm)	49.89	29.60-115.46	224.29	265.53	84.5	28.35	56.82
4	No. of pods/plant	6.82	4.00-16.26	2.85	5.00	57.0	2.62	38.41
5	Pod length (cm)	10.91	8.81-13.27	0.89	1.56	57.3	2.21	20.25
6	No. of seeds/pod	3.77	2.40- 6.75	0.63	0.93	67.8	1.34	35.54
7	100 Seed wt (g)	34.77	17.86-51.92	54.30	68.97	78.7	13.47	38.74
8	Harvest index (%)	17.81	13.13-25.79	6.00	22.71	26.4	2.60	14.59
9	Leaf Area/plant	3005.29	1863.52-4439.59	352209.90	376096.20	93.6	1183.09	39.36
10	Protein content (%)	22.57	19.56-26.92	1.98	2.01	98.4	2.87	12.71
11	Seed yield/plant (g)	7.32	4.53-13.95	1.65	5.22	31.6	1.48	20.21

50 per cent flowering, days for maturity, number of pods per plant, 100 seed weight, harvest index and seed yield showed a moderate phenotypic and genotypic coefficient of variation.

4.4 Heritability (h^2 - b.s.)

All the characters showed high broad sense heritability except harvest index (Table 4). The estimates of broad sense heritability ranged between 26.40 per cent (harvest index) and 98.4 per cent (Protein content). The characters leaf area, days to 50 per cent flowering, days for maturity and plant height had more than 80 per cent heritability. The other characters 100 seed weight (78.7%), number of seeds per pod (67.8%), pod length (57.3%), number of pods per plant (57.0%) and seed yield per plant (31.6%) also had high broad sense heritability.

4.5 Genetic advance

The highest genetic advance was observed for the character leaf area per plant (1183.09%) and it was lowest for number of seeds per pod (1.34%) (Table 4). Plant height (28.35%), 100 seed weight (13.47%) and days for maturity (12.75%) showed medium genetic advance. The characters viz., days to 50% flowering (6.75%), protein content (2.87%), number of pods per plant (2.62%), harvest index (2.60%), pod length (2.21%) and seed yield per plant (1.48%) showed low genetic advance when compared with other characters.

4.5.1 Expected genetic advance

The highest expected genetic advance was observed for the character plant height (56.82%). The character leaf area per plant (39.36%), 100 seed weight (38.74%), number of seeds per pod (35.54%) showed fairly high expected genetic advance. The expected genetic advance was of medium magnitude for pod length (20.25%), seed yield per plant (20.21%), days to 50% flowering (19.05%) and days for maturity (17.30%). Harvest index (14.59%) and protein content (12.71%) recorded low expected genetic advance as compared to other characters (Table 4).

4.6 Genotypic and phenotypic coefficients of correlation

The genotypic and phenotypic coefficients of correlation between the various characters are presented in Table 5. The only significant correlations, either in positive or negative directions are described.

4.6.1 Days to 50 % flowering

Days to 50 per cent flowering showed highly significant positive genotypic and phenotypic correlations with days for maturity, plant height and harvest index and significantly negative with pod length. It had significant positive and negative genotypic association with seed yield per plant and 100 seed weight respectively.

4.6.2 Days for maturity

Days for maturity showed a significant positive genotypic and phenotypic correlation with plant height, days to

Table 5: Genotypic (G) and Phenotypic (P) correlation coefficients among different characters in french bean

Character	Days for maturity	Height of plant	No. of pods/plant	Length of pod	No. of seeds/pod	100 seed weight	Harvest index	Leaf area/plant	Protein content	Seed yield/plant	
Days for 50% flowering	G	0.929	0.582	0.084	-0.845	0.188	-0.216	0.485	0.127	-0.145	0.257
	P	0.811	0.498	0.034	-0.594	0.132	-0.193	0.288	0.113	-0.122	0.147
Days for maturity	G	0.391	-0.003	-0.709	0.040	-0.029	0.508	0.015	-0.019	0.293	
	P	0.339	0.019	-0.521	0.002	-0.005	0.240	0.009	-0.018	0.162	
Height of plant	G	0.142	-0.437	0.004	-0.144	0.154	0.156	-0.037	0.023		
	P	0.101	-0.281	0.002	-0.093	0.059	0.140	-0.041	0.043		
No of Pods/plant	G	-0.283	0.489	-0.518	0.725	0.494	0.017	0.896			
	P	-0.080	0.417	-0.359	0.322	0.346	0.024	0.629			
Length of pod	G	-0.148	0.218	-0.565	-0.030	-0.143	-0.394				
	P	0.053	0.080	-0.190	-0.042	0.091	0.073				
No. of seeds/pod	G	-0.901	0.427	0.450	0.368	0.682					
	P	-0.710	0.256	0.355	-0.278	0.507					
100 seed weight(g)	G	-0.613	-0.416	0.291	-0.573						
	P	-0.253	-0.344	0.248	-0.282						
Harvest index	G	0.091	-0.072	0.826							
	P	0.055	-0.026	0.477							
Leaf area/plant	G	-0.109	0.465								
	P	-0.101	0.247								
Protein content	G	0.050									
	P	-0.025									

* : Significant at 5% level

** : Significant at 1% level.

50 per cent flowering and harvest index and significant negative association with pod length. Its genotypic association with seed yield per plant was significantly positive.

4.6.3 Plant height

The genotypic and phenotypic association between plant height and days to 50% flowering and days for maturity was significant and positive, however, its association with pod length was significantly negative.

4.6.4 Number of pods per plant

The trait number of pods per plant showed highly significant positive genotypic and phenotypic correlation with seed yield per plant, leaf area per plant, harvest index and number of seeds per pod, while they were significantly negative with 100 seed weight. The number of pods per plant and pod length negatively and significantly correlated at genotypic level only.

4.6.5 Pod length

Highly significant and negative genotypic and phenotypic association were observed between the character pod length and days to 50 per cent flowering, days for maturity and plant height. The significant and negative genotypic association were also observed between pod length and number of pods per plant, harvest index and seed yield per plant, whereas, its genotypic association with 100 seed weight was positive and significant.

4.6.6 Number of seeds per pod

Number of seeds per pod showed highly significant positive genotypic and phenotypic association with seed yield, leaf area and number of pods per plant, whereas, its association with 100 seed weight and protein content was highly significant and negative at both genotypic and phenotypic levels.

4.6.7 100 Seed weight

100 Seed weight showed a significant negative genotypic and phenotypic association with seed yield and leaf area per plant, harvest index, number of seeds per pod and number of pods per plant, whereas, its genotypic and phenotypic association with protein content was significantly positive. The genotypic association between 100 seed weight and days to 50% flowering and pod length was significantly negative and positive respectively.

4.6.8 Harvest index

Harvest index showed a highly significant positive genotypic and phenotypic association with seed yield per plant, number of seeds per pod, number of pods per plant, days for maturity and days to 50 per cent flowering, whereas, its genotypic and phenotypic association with 100 seed weight and pod length was negative and significant.

4.6.9 Leaf area per plant

The trait leaf area per plant showed significant positive genotypic and phenotypic association with seed yield per plant, number of seeds per pod and pod length was negative and significant.

4.6.10 Protein content

Protein content exhibited a significant positive genotypic and phenotypic correlation with 100 seed weight. Its genotypic and phenotypic association with number of seeds per pod was negative and significant.

4.6.11 Seed yield per plant

The trait seed yield per plant recorded highly significant positive genotypic and phenotypic association with leaf area per plant, harvest index, number of seeds per pod and number of pods per plant, however, its genotypic and phenotypic association with 100 seed weight and pod length was negative and significant. Seed yield per plant also showed significant positive association with days to 50 per cent flowering and days for maturity at genotypic level only.

4.7 Path coefficient analysis

Path coefficient analysis was carried out to find out the direct and indirect contribution from each of the characters. The genotypic correlation coefficient were further partitioned into direct and indirect effects (Fig.1) and presented in Table 6.

Days to 50 per cent flowering produced the highest positive direct effect on seed yield (Table 6) followed by days for maturity. The other characters harvest index (0.255), 100 seed weight (0.172) and protein content (0.083) have also produced positive effect on seed yield. The highest negative

Table 6: Direct (diagonal) and indirect (above and below diagonal) effects of ten components on yield in french bean.

Cluster	Days for 50% flowering	Days for maturity	Height of plant (cm)	No.of pods/plant	Length of pod (cm)	No.of seeds/pod	100 seed weight (g)	Harvest index %	Leaf area plant (sq cm)	Protein content (%)	Seed yield plant
Days for 50% flowering	<u>3.97</u>	-1.149	-0.622	0.174	-1.598	-0.036	0.090	-0.387	-0.097	-0.095	** 0.257
Days for maturity	-1.237	<u>3.694</u>	-0.418	-0.007	-1.340	-0.008	0.012	-0.405	-0.011	0.012	** 0.293
Height of plant	-1.069	2.314	<u>-0.483</u>	0.294	-0.826	-0.001	0.060	-0.123	-0.119	-0.024	0.023
No.of pods/plant	2.066	0.336	0.004	<u>-0.152</u>	-0.535	-0.094	0.216	-0.578	-0.378	0.011	** 0.896
Length of pod	1.891	-3.362	0.877	0.467	<u>-0.585</u>	0.028	-0.091	0.450	0.023	-0.094	** -0.394
No.of seeds/pod	-0.191	0.748	-0.049	-0.005	1.011	<u>-0.279</u>	0.375	-0.341	-0.344	-0.242	** 0.682
100 seed weight	-0.416	-0.858	0.036	0.154	-1.071	0.412	<u>0.172</u>	0.489	0.318	0.191	** -0.573
Harvest index	-0.797	1.930	-0.628	-0.164	1.497	-1.068	-0.082	<u>0.255</u>	-0.069	-0.047	** 0.826
Leaf area/plant	-0.764	0.507	-0.019	-0.167	1.020	-0.056	-0.086	0.173	<u>-0.072</u>	-0.071	** 0.465
Protein content	0.657	-0.578	-0.023	0.039	0.036	-0.270	0.070	-0.121	0.057	<u>0.083</u>	-0.050

*, ** significant at 5% and 1% level, respectively.

Residual Value = 0.198

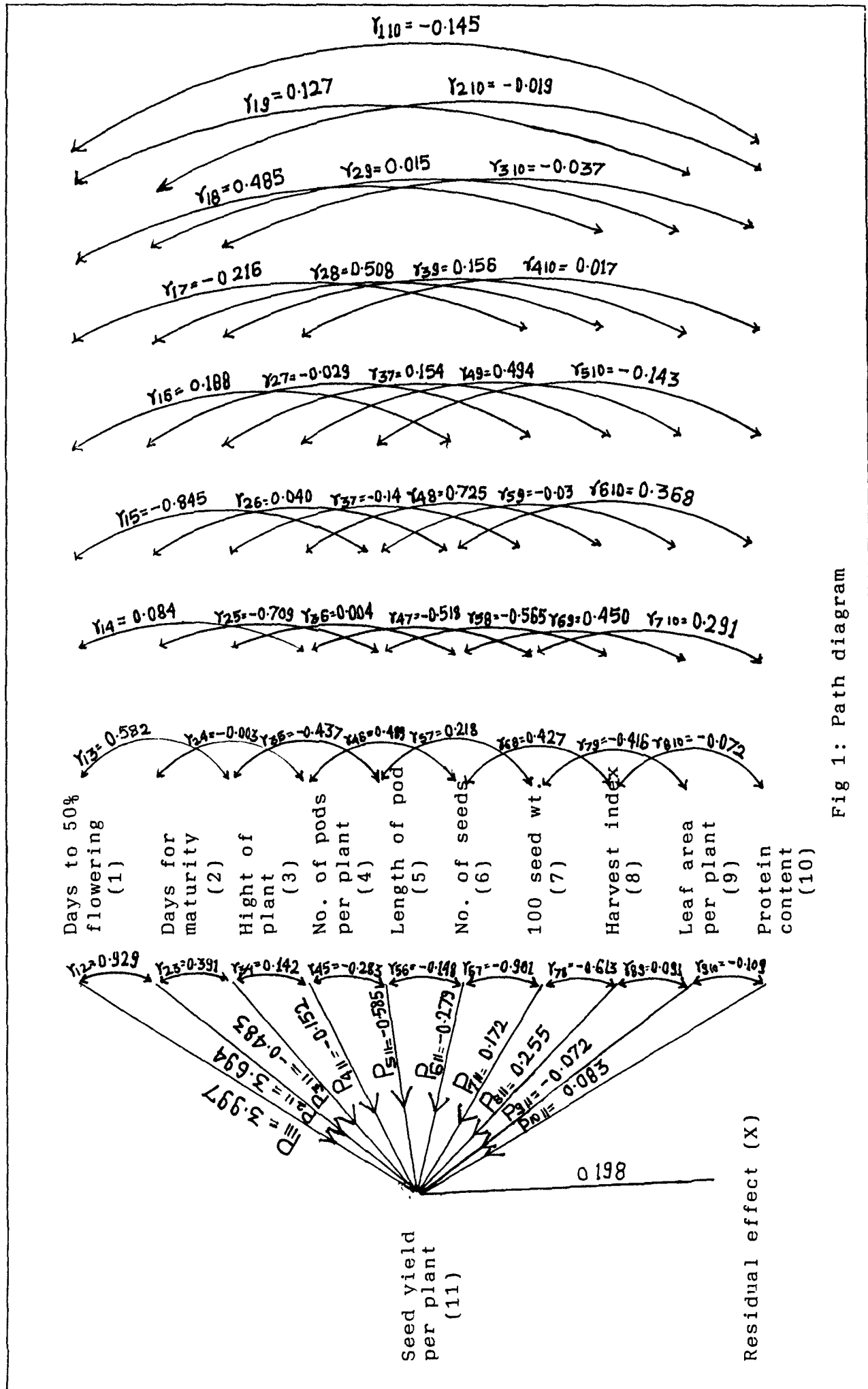


Fig 1: Path diagram

direct effect on seed yield had recorded by length of pod(-0.585) followed by height of the plant (-0.483). Other characters number of seeds per pod (-0.152) and leaf area per plant (-0.072) also produced negative direct effect on seed yield.

The highest indirect positive effect on seed yield had recorded by height of the plant (2.314) through days for maturity followed by number of pods per plant (2.066) through days to 50 per cent flowering. Harvest index through days to maturity (1.30) and length of pod (1.497), leaf area per plant (1.020) and number of seeds per pod (1.011) through pod length also produced positive indirect effect on seed yield.

The highest indirect negative influence on seed yield had recorded by length of pod (-3.362) via days to maturity followed by days to 50 per cent flowering (-1.598) via length of pod. Other characters days for maturity (-1.340) and 100 seed weight (-1.071) via length of pod; days for maturity (-1.237) and height of plant (-1.069) via days to 50% flowering and harvest index (-1.068) via number of seeds per pod produced negative indirect influence on seed yield.

4.8 Divergence

The data obtained for each of the eleven characters studied was subjected to D^2 analysis. The genotypes differed significantly from each other their mean for all the characters performance indicating the presence of a good amount of variability.

Table 7: Distribution of fifty french bean genotypes in seven clusters.

Cluster	Total No. of Genotypes	Genotype numbers included in cluster
A	30	28,30,15,11,40,36,10,3,31,33,32,6,2,25,13,24, 49,4,39,37,12,5,38,14,27,47,41,1,7,17
B	10	34,46,42,44,43,20,35,16,48,45
C	3	29,19,50
D	3	21,22,18
E	2	8,9
F	1	23
G	1	26

N.B : Sr. Nos. of genotypes are as per Table 2.

4.8.1 D^2 analysis

The D^2 values ranged between 7.76 and 2330.56. The D^2 value was maximum (2330.56) between the genotypes Manus and EC 39439, while it was the lowest (7.76) between Royal red and Red cloud (Appendix 1).

4.8.2 Cluster formation and their inter and intra cluster divergence

On the basis of D^2 values, fifty genotypes from different sources were grouped into seven distinct clusters. The distribution of these fifty genotypes in different clusters is given in Table 7.

Among the seven clusters, cluster A was the largest, possessing thirty genotypes, followed by the cluster B with ten genotypes, the clusters C and D with three genotypes each, the cluster E with two genotypes and the clusters F and G had a only one genotype each.

The clusters A, B and C included both exotic as well as indigenous genotypes, whereas, cluster D, E, F and G included only indigenous genotypes.

The inter and intra cluster D^2 values and D values are given in Table 8 and graphically presented in Fig.2. The maximum inter cluster divergence was observed between the cluster B and E ($D = 38.85$) followed by D and E ($D = 31.77$). Minimum inter

Table 8: Intra (diagonal) and inter cluster D^2 and D values

Cluster	A	B	C	D	E	F	G
A	103.99 (10.19)	318.96 (17.85)	157.46 (12.54)	264.68 (16.26)	629.02 (25.08)	242.46 (15.57)	242.37 (15.56)
B		99.40 (9.97)	463.66 (21.53)	230.79 (15.19)	1509.48 (38.85)	669.48 (25.87)	463.05 (21.51)
C			97.92 (9.89)	424.62 (25.60)	432.77 (20.80)	356.83 (18.88)	272.29 (16.50)
D				103.79 (10.18)	1009.89 (31.77)	294.50 (17.16)	246.79 (15.70)
E					49.72 (7.05)	496.45 (22.28)	690.83 (26.28)
F						00.00 (00.00)	260.56 (16.14)
G							00.00 (00.00)

(Figures in parantheses indicate D values)

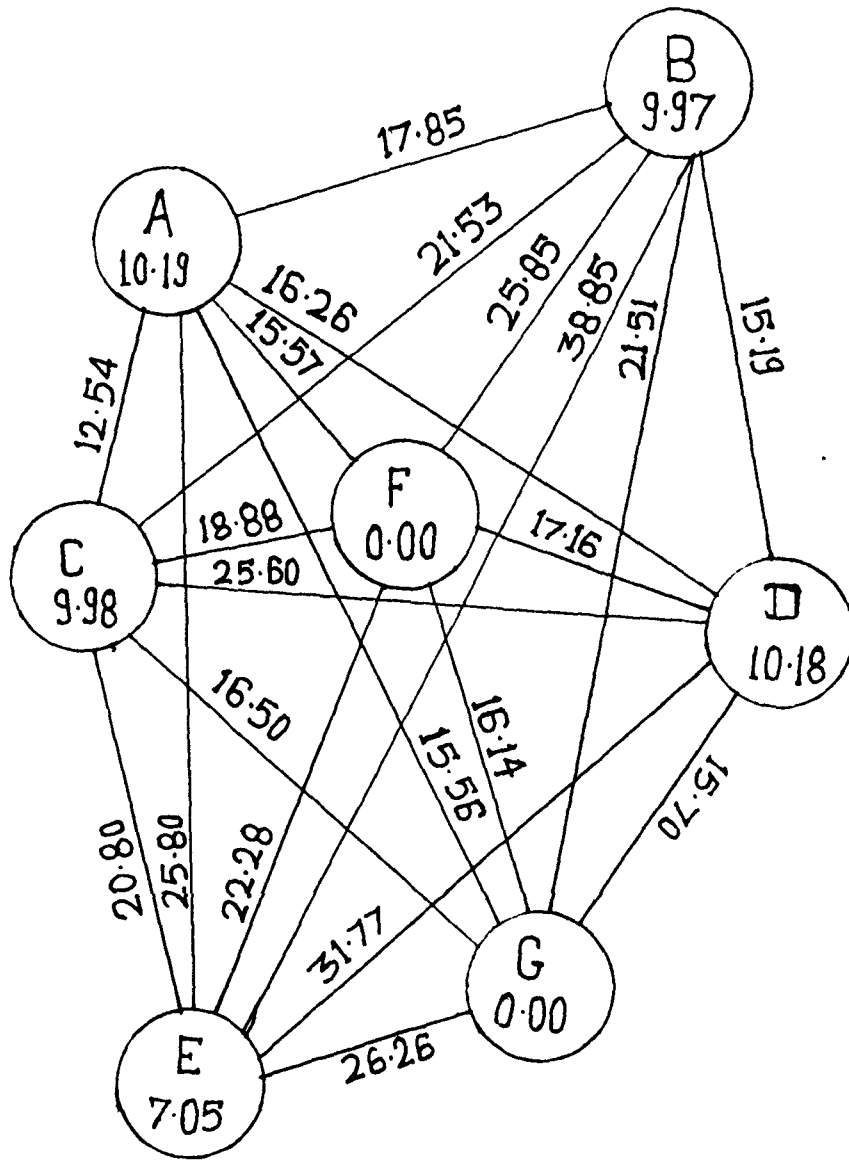


Fig 2: Mutual relationship among seven clusters

cluster divergence was observed between the cluster A and C (D = 12.54). Total 21 intercluster combinations were made up from seven clusters (Table 8) . Out of 21 inter cluster combinations three combinations viz., A with E, B with F and E with G were within the range of 25.08 to 26.28. Five combinations viz., B with C and G; C with D and E and E with F were within the inter cluster divergence of 20.60 to 22.28. Ten combination viz., A with B, D, F and G ; B with D; C with F and G; D with F and G and F with G were within the inter cluster divergence of 15.19 to 18.88.

The intra cluster divergence of clusters A (10.19), B (9.9), C (9.8), D (10.18) and E (7.05) suggested a substantial diversity within themselves, while the remaining clusters F and G consisted of a single genotype and hence, had no intra cluster divergence.

4.8.3 Cluster mean

The mean values of all the clusters for eleven characters are presented in Table 9. The genotypes in cluster D took maximum days (45.22) to 50 per cent flowering, whereas, the genotypes in cluster A and G flowered very early. The cluster mean for the days for maturity was lowest in the cluster A(71.16) whereas, it was highest in cluster G (86.00). The cluster G had long flowering span as compared to other clusters. The cluster A possess genotypes with early flowering and short flowering span.

Table 9: Cluster mean for eleven characters in french bean

Cluster	Days for 50% flower- ing	Days for maturity	Height of plant (cm)	No.of pods/ plant	Length of pod (cm)	No.of seeds/ pod	100 seed weight (g)	Harvest index (%)	Leaf area plant (sq.cm)	Protein content (%)	Seed yield plant
A	33.39	71.16	48.63	6.61	11.15	3.52	35.90	17.16	3033.68	22.86	7.48
B	36.93	74.76	48.54	6.04	11.15	4.16	33.10	17.92	2871.31	20.90	7.29
C	36.99	76.77	42.61	6.02	9.70	3.44	43.47	16.39	2086.52	23.35	8.09
D	45.22	82.33	57.76	10.89	9.29	5.45	20.24	24.33	3738.17	22.12	9.82
E	35.16	78.49	42.35	5.47	10.42	3.11	43.23	19.43	2504.06	26.47	6.61
F	38.33	78.33	48.93	12.66	10.00	5.12	20.84	19.89	4420.96	24.46	10.02
G	32.66	86.00	115.46	5.36	9.66	3.44	31.77	15.34	3069.75	22.99	5.78

The cluster mean for the height of plant ranged between 42.616 (cluster C) and 115.46 (Cluster G). The cluster A,B,C,E, and F were dwarf as compared to cluster G and D.

The cluster mean for number of pods per plant ranged between 5.36 (cluster G) and 12.66 (cluster F). The cluster D, A, B and C also gave more number of pods when compared with clusters G and E. The pod length for cluster A and B was same and highest (11.15cm). Whereas, it was lowest for cluster D (9.29cm). The pod length for clusters E and F was more than clusters C, D and G. The highest number of seeds per pod in cluster D (5.45) followed by cluster F (5.12) whereas, it was the lowest in cluster E (3.11). Cluster B possess also more number of seeds per pod as compare to clusters A, C and G.

The cluster mean for the 100 seed weight was maximum in cluster C (43.47 g) followed by cluster E (43.23 g) whereas, it was minimum in cluster D (20.24). The cluster A, B and G possess genotypes with more than 30.00 g 100 seed weight.

The cluster mean for harvest index was maximum in cluster D (24.33%) whereas, it was minimum in cluster G (15.34%). The clusters E and F also had high harvest index as compared to clusters A, B, C and D. The leaf area was highest in cluster F (4420.96 cm) whereas, it was lowest in cluster C (2086.52 cm). The clusters A, D and G recorded high leaf area as compared to clusters B, C and E.

The cluster mean for protein content ranged between cluster B (20.90%) and cluster E (26.47%). The clusters F and C have also recorded high protein content as compared to clusters A,B,D and G. The highest seed yield was observed in clusters F (10.02 g) of followed by the clusters D (9.82 g) whereas, it was the lowest in cluster G (5.78). The clusters A, B and C have high seed yield as compared to cluster E and G.

The clusters F and D had high seed yield as compared to the other clusters A, B, C, E and G due to the more number of pods per plant, number of seeds per pod and leaf area per plant.

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DISCUSSION

V. DISCUSSION

In the present investigation fifty genotypes of french bean were evaluated to assess the amount of variability present and to study the genetic divergence and establish the relationship between them. Correlation and path analysis were also worked out to study the association between different characters and direct and indirect effects of the component characters on yield.

The result obtained in the present investigation are discussed as below.

5.1 Range of variability

Assessment of the available germplasm for its range of genetic variability offers great scope for breeding high yielding genotypes. Yield is a polygenic character, the expression of which is greatly influenced by environmental factors. This is also true with other quantitative characters, which are directly or indirectly associated with the yield.

The analysis of variance revealed that the mean sum of square due to treatment were highly significant for all characters studied.

In the present investigations, a wide range of variability was observed for yield and different yield contributing characters (Table 2). Significant differences were observed for days to 50 per cent flowering. The variation for 50 per cent flowering ranged between 27.66 (EC 94465 and PDR 9) and

48.66 (Ajara black). The genotypes Contender, Khaki, HPR 87, Yellow 4, HPR 35, HPR 12 and Red cloud were very early and flowered in less than 30 days. Navale and Patil (1982) also reported similar results in sixteen locally collected accessions. Aggarwal and Singh (1973), Pande et al., (1975), Sharma et al., (1977), Joshi and Mehra (1983), Shah et al., (1986) and Shete and Kale (1988) also reported presence of good amount of variability for days to flowering. However, Shetty (1973) did not find significant differences for this trait.

The differences for days for maturity were also significant and varied between 63.66 (Yellow 4) and 87.00 (K.B.7). The genotypes PDR 9, HPR 35, contender and EC 108101 were early maturing with 65 days. Aggarwal and Singh (1973), Navale and Patil (1982), Joshi and Mehra (1983), Bollati (1987), Shete and Kale (1988) also reported significant differences for maturity period.

Plant height varied between 29.6 cm (Yellow 4) and 115.46 cm (IC 47644). The genotypes VL 64, Manus, Vaghya, Almora, HPR 137, Contender and IC 49700 were dwarf (< 40 cm). These results were well comparable with the findings of Pande et al., (1975), Sharma et al., (1977), Siuper (1978), Joshi and Mehra (1983).

Significant differences were observed for number of pods per plant. It ranged between 4.0 (IC 47653-1) and 16.26

(Jampa improved). The genotypes Poona white, EC 26646 and Ajra black also had more than nine pods per plant. Seth et al., (1972), Shetty (1973), Aggarwal and Singh (1973), Sharma et al., (1977), Navale and Patil (1982), Joshi and Mehra (1983), Shah et al., (1986) and Shete and Kale (1988) also observed good amount of variability for pods per plant.

The number of seeds per pod ranged between 2.40 (Almora) and 6.75 (Jampa improved). The other genotypes, Poona white, EC 43034, EC 39439 and IC 18618 also produced more seeds per pod (> 5). These results were well comparable with the results of Aggarwal and Singh (1973), Navale and Patil (1982), Joshi and Mehra (1983) and Shete and Kale (1988).

Pod length varied between 8.81cm (IC18618) and 13.27 cm (Khaki). The genotypes HPR 12, HPR 35, EC 39439 and EC 43034 also produced longer pods (> 12 cm). These results were well comparable with the findings of Seth et al., (1972), Aggarwal and Singh (1973), Shetty (1973), Sharma et al., (1977), Navale and Patil (1982), Joshi and Mehra (1983), Shah et al., (1986) and Shete and Kale (1988).

Significant differences were observed for 100 seed weight and it ranged between 17.86 g (Jampa improved) and 51.95 g (Almora). Other genotypes viz. Montcalm (49.46 g) and EC 42960 (46.11 g) produced high 100 seed weight. Aggarwal and Singh (1973), Joshi and Mehra (1983) and Shete and Kale (1988) have

also reported genotypes with high seed weight along with seed weight variation.

The genotype VL 64 recorded lowest harvest index (13.13%) and it was highest for Ajra black (25.79%). Jampa improved and Manus had high harvest index (24%). Similar results were also reported by Scully et al., (1991).

Good amount of variation was observed for leaf area per plant. It ranged between 1863.52 sq.cm (Almora) and 4439.59 sq.cm (Jampa improved). The genotypes Poona white, American red and Red kote have also recorded more than 4000 sq.cm leaf area. Joshi and Mehra (1983 and 1984) and Shete and Kale (1988) observed significant differences for number of leaves per plant.

Significant differences were observed for protein content. In the present studies the protein content varied between 19.56 per cent (IC 47845) and 26.92 per cent (Manus). The genotypes Jwala, Poona white, PDR 9, VL 64, Khaki and EC 22367 recorded more than 24 per cent protein. These results were well compared with those of Woolfe and Hamblin (1974) and Avila et al., (1991). Nonsignificant differences were observed in exotic and indigenous genotypes for protein content in the present study.

The significant differences were also observed for seed yield per plant and it was varied between 4.33 g (IC 47653-1) and 13.95 g (Jampa improved). The genotypes HPR 35, IC 18618 and

Poona white recorded more than 10 g seed yield per plant. Aggarwal and Singh (1973), Rosario and Montilla (1980), Joshi and Mehra (1983), Sheta and Kale (1988) and Scully et al., (1991) also reported good amount of variability for seed yield per plant.

Nonsignificant differences were observed between exotic and indigenous genotypes for all the characters under study. Among the fifty cultivars Jampa improved, HPR 35, Poona white, VL 61, EDR 7, IC 47429, IC 18618, Royal red, Red cloud and EC 22367 were observed good for over all performance for the characters under study and these are useful in further french bean breeding programme.

5.2 Genotypic and Phenotypic coefficient of variation

It is essential to assess the genetic components of variability in the further genetic improvement. The additive genetic variance will be the constant heritable portion of the total variation.

The results indicated that phenotypic coefficient of variation were greater than genotypic coefficient of variation for all characters (Table 4). The genotypic and phenotypic coefficients of variations were high for the characters leaf area per plant, plant height, 100 seed weight and days for maturity. The genetic coefficient of variation helps to measure genetic variability in a characters and provides a measure to compare the genetic variability present in various quantitative characters

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(Mujumdar et al., 1969). In present investigation high genetic coefficient of variation were observed for leaf area per plant, plant height and days for maturity, it indicated a good scope for their improvement through selection. Similar results reported by Seth et al. (1972), Aggarwal and Singh (1973), Joshi and Mehra (1983) and Scully et al. (1991). Moderate values of genotypic and phenotypic coefficients of variation were observed for days to 50 per cent flowering, number of pods per plant, harvest index and seed yield, whereas, it was low magnitude for number of seeds per pod and pod length. These findings showed conformity with findings reported by Joshi and Mehra (1983) and Shete and Kale (1988).

5.3 Heritability (b.s.) and genetic advance (percentage of mean)

Genetic variability is the heritable portion of the total variation. Heritability percentage in broad sense is the ratio of genetic variation to the phenotypic variation. Hence, the characters with high heritability values are of important to plant breeder. In the present studies high estimates of heritability were recorded for all the traits under study except harvest index, which showed moderate heritability. These findings are in agreement with the reports of earlier workers, Padda (1971), Seth et al., (1972) Pande (1975), Joshi and Mehra (1983), Shah et al., (1986) and Shete and Kale (1988). Scully et al., (1991) reported similar results for seed yield, days to flowering and maturity, except harvest index.

Although high heritability was recorded for most of traits under study, but its genetic gain was not high in all the cases (Table 4). Burton (1952) suggested that genetic coefficient of variation and heritability estimates together, gave better ideas about the amount of genetic advance expected through selection. The high heritability estimates with low genetic advance being the indication of non-additive gene effects such as epistasis, dominance and other gene interactions (Panse, 1957). Johnson et al., (1955) pointed out that in a selection programme heritability values as well as estimates of genetic advance are more useful than heritability alone. In the present study pods per plant, seeds per pod, plant height, 100 seed weight and seed yield per plant had high heritability associated with high genetic advance, which shows presence of additive gene effects and hence they are more useful traits for breeding. Similar results were recorded by Seth et al., (1972), Aggarwal and Singh (1973), Sharma et al., (1977), Navale and Patil (1982), Joshi and Mehra (1983) and Shete and Kale (1988).

5.4 Correlations

The knowledge of association among the characters is useful to the breeder for improving the efficiency of the selection. The genotypic correlation provides an estimate of inherent association between genes controlling any two characters, whereas, phenotypic correlation indicates the extent of the observed relationship between the two characters under

consideration. Hence, it is of greater significance and can be effectively utilized in formulating an effective selection scheme.

In the present investigations the results indicated that, at the genotypic level seed yield showed (i) the highest positive and significant correlation with number of pods per plant followed by harvest index and number of seeds per pod (ii) moderate positive and significant correlation with days to 50 per cent flowering, days for maturity and leaf area per plant, whereas, nonsignificant positive correlation with plant height (iii) Low negative nonsignificant correlation with protein content, whereas, significant and negative with pod length and 100 seed weight (Table 5). Aggarwal and Singh (1973), Navale and Patil (1982), Joshi and Mehra (1984), Vaid et al., (1986) and Shete and Kale (1988) also reported significant positive correlation of seed yield with number of pods per plant, seeds per pod, days for maturity and 50 per cent flowering. Aggarwal and Singh (1973), Joshi and Mehra (1984) and Vaid et al., (1986) reported significantly negative correlation between seed yield and pod length. Nienhuis and Singh (1986) also observed significant negative association between seed yield and 100 seed weight, whereas, Aggarwal and Singh (1973) reported significant positive correlation between them. Scully et al., (1991) also observed significant positive correlation of seed yield with days for maturity and harvest index. Avila et al., (1990) observed

nonsignificant correlation among protein content and yield whereas, Leleji et al. (1971) reported significant negative association.

At the phenotypic level seed yield showed (i) the highest positive and significant correlation with number of pods per plant, followed by harvest index and number of seeds per pod, whereas, nonsignificant positive correlations with days to 50 per cent flowering, days for maturity and plant height, (ii) moderate significant positive correlations with leaf area per plant, (iii) significant negative correlation with 100 seed weight and nonsignificant and negative with protein content. These findings confirmed the results of Aggarwal and Singh (1973), Joshi and Mehra (1984), Vaid et al., (1986) and Shete and Kale (1988).

Significant positive association was observed among the days to 50 per cent flowering, days for maturity and plant height both at genotypic and phenotypic levels. These finding well confirmed with those of Vaid et al., (1986); Shah et al., (1986); Scully et al., (1991). The association of number of pods per plant with number of seeds per pod, harvest index and leaf area, was significantly positive, whereas, its association with 100 seed weight was significantly negative both at genotypic and phenotypic levels. Vaid et al., (1986) and Joshi and Mehra (1984) also reported significant positive associations between pods per

plant and seeds per pod, they also reported significant negative association of pods per plant with 100 seed weight. Significant negative association of pod length with days to flowering, days for maturity and plant height both at genotypic and phenotypic levels were observed ; however, it showed significant negative association with pods per plant and harvest index at genotypic level only. These findings are in agreement with the results of Vaid et al., (1986). Shete and Kale (1988) also observed significantly negative association between pod length and days to flowering.

100 seed weight was significantly and negatively correlated with seeds per pod, harvest index and leaf area. It had positive and significant association with protein content, both at genotypic and phenotypic levels. Shete and Kale (1988) reported significantly negative association between 100 seed weight and seeds per pod. Harvest index had significantly positive association with days to flowering and maturity and seeds per pod. It had negative and significant association with 100 seed weight both at genotypic and phenotypic levels, and with pod length at genotypic level only. Contrasting results were reported by Scully et al., (1991) for this traits, it may be due to the differences in genotypes used and genotype x environmental interactions.

significant and positive association of leaf area per plant with pod per plant and seeds per pod were observed in the

present study. Joshi and Mehra (1984) and Shete and Kale (1988) also reported significant positive association of number of leaf with pods per plant and seeds per pod.

Based on the results obtained in the present investigation the characters number of pods per plant, number of seeds per pod, leaf area, harvest index and days for maturity, could be used for simultaneous selection for improvement in french bean.

5.5 Path coefficient analysis

In order to achieve a clear picture of the interrelationship of seed yield with its various components, direct and indirect effects- were worked out by using path analysis at genotypic level (Table 6) and (Fig. 1).

The highest direct positive effect on seed yield recorded by days to 50 per cent flowering followed by days for maturity and harvest index. The genotypic correlation between days to 50 per cent flowering, days for maturity and harvest index with seed yield was significant and positive indicating the true and perfect association between these characters. Moderate and positive direct effect of harvest index and 100 seed weight were also observed. Duarte and Adams (1972) and Joshi and Mehra (1984) reported similar findings for days for maturity and seed weight.

Pod length recorded the highest negative direct effect with seed yield (Table 6) and it was followed by plant height and number of seeds per pod. These findings well confirmed with those of Durate and Adams (1972) and Joshi and Mehra (1984).

It is interesting to note that, plant height via days for maturity recorded the highest indirect effect with seed yield (Table 6) followed by pods per plant via days to 50 per cent flowering and via harvest index. The positive indirect effect on seed yield were also high due to length of pod via days to 50 per cent flowering and seeds per pod, harvest index and leaf area via pod length. Prakash and Ram (1981) also reported highly positive indirect effect of days for maturity on seed yield. Joshi and Mehra (1984) also reported that days for maturity and pod per plant exerted high positive indirect effect on seed yield.

Pod length via days for maturity recorded the highest negative indirect effect on seed yield, and likewise days to 50 per cent flowering and maturity via pod length; plant height via days to 50 per cent flowering; 100 seed weight via pod length and harvest index via number of seeds per pod. Prakash and Ram (1981) also reported negative indirect effect on seed yield due to 100 seed weight via pod length. Joshi and Mehra (1984) also recorded high negative indirect effect of pod length via seeds per pod on seed yield.

5.6 Genetic diversity

The concept of genetic distance has been of vital utility, particularly in differentiating well defined populations several measures of distance have been proposed over the past two decade to suit various objectives (Jacquard, 1974), of which Mahalanobis (1930) generalized distance occupied a unique place in plant breeding. The utility of multivariate analysis by means of Mahalanobis D^2 statistic is a powerful tool in quantifying the degree of divergence between biological populations at genotypic levels and to asses the relative contribution of the different components to the total divergence is well established (Mahalanobis, 1936). However, in Biology, under the influence of random, unpredictable changes due to environments, there appear certain limitations in the application of this concept.

The results obtained in the present investigation on genetic diversity in french bean are discussed under the following head :

- i) Relative importance of characters towards genetic diversity;
- ii) Cluster formation.

5.6.1 Relative importance of characters towards genetic diversity

The relative importance of the individual characters towards genetic diversity can be known on the basis of the size of the coefficient of the canonical vectors (Rao, 1952). Based on

the present investigations days to 50 per cent flowering, days for maturity, number of pods per plant, seeds per pod, leaf area per plant, harvest index and seed yield were revealed as an important characters. These findings well confirmed with those of Shete and Kale (1988). Singh et al., (1973) reported similar results in Asiatic Phaseolus spp. Similar results also reported by Bains and Jatasara (1980) and Aswa et al., (1981) in pigeon pea.

Relative importance of the characters and per cent contribution of individual character towards genetic divergence have been used by several workers in different crops. However, Singh (1981) stated that this method of determining the influence of characters on genetic divergence is incorrect. Because, according to him, the transformed uncorrelated character (Y_i) does not have any biological meaning. He further pointed out that the workers who did use this method have wrongly taken character (Y_i) to be uncorrelated character (X_i) implying one to one correspondence between two variables. In fact, Y_i is a linear function of several X_i values. Therefore, Bains and Sood (1984) used cluster means (based on correlated data) to know the relative importance of the characters causing genetic divergence of cluster means were calculated for all the characters (Table 9). The results indicated the relative importance of days to 50 per cent flowering, days to maturity, number of pods per plant, number of seeds per pod, leaf area per plant, harvest index and

seed yield towards genetic divergence which confirm the results obtained on the basis of canonical method. Thus, it could be concluded that if the parents are selected on the basis of the traits viz. days to 50 per cent flowering, days for maturity, number of pods per plant, number of seeds per pod, leaf area per plant, harvest index and seed yield would be genetically diverse and could be used in the hybridization programme for genetic improvement in desirable direction. These findings confirmed with findings of Shete and Kale (1988) in french bean and Singh et al., (1973) in Asiatic Phaseolus spp. for the characters days to 50 per cent flowering and maturity, number of pods per plant and number of seeds per pod. Gupta and Sing (1970) reported similar results in green gram.

5.6.2 Cluster formation

The aim of forming clusters and finding out the intra and inter cluster divergence is to provide a basis for selecting genetically diverse parents. The selected parents should belong to different clusters. It appears logical to effective crosses between strains belonging to the clusters widely separated by high intercluster diversity. It is assumed that the statistical distance (D) is the index of genetic diversity.

In the present investigations, fifty genotypes were grouped into seven clusters, indicating high degree of divergence among the genotypes. The cluster A was the largest one and

comprised of 30 strains. While, the cluster B had 10 strains and cluster C and D had 3 strains each. The cluster E had two strains and the clusters F and G had a single strain each. The critical examination of Table 7 and indicating that the strains originating in different geographical areas could form one cluster while, different strains coming from the same region formed different clusters. This indicated that the geographic diversity is not resulted in genetic diversity. The clusters A, B and C possess both exotic as well as indigenous genotypes and it indicating the fact that though the genotypes are coming from different geographic regions genetically they are more or less similar. Cluster D,E,F and G possessing only indigenous genotypes, indicating the presence of genetic diversity for various characters in the indigenous material. These findings in agreement with results of Shete and Kale (1988). Choudhary et al., (1975) also reported similar results in cluster bean.

The maximum intercluster distance was observed between cluster B and E (38.85), followed by the clusters D and E (31.77). The mean for different characters of cluster E varied considerably from those of the other cluster B and D (Table 8). This indicated that the genotype in the cluster E probably possess genetic difference from the genotypic in the cluster B and D.

5.6.3 Tentative crossing programme

Based on the information from D^2 analysis, it could be suggested that the genotypes from diverse clusters possessing high yield potential for seed yield with the early maturity, high protein content, high number of pods per plant and seeds per pod, harvest index and leaf area per plant, might be very useful in forming suitable breeding programme. Such crosses are expected to give superior recombinants in the subsequent fillial generations.

The following breeding programme can be suggested on the basis of intercluster divergence (Table 8), cluster mean (Table 9) and mean performance of genotypes (Table 2).

Cluster A with cluster E, B, D and G.

Cluster B with cluster E, F, C and G.

Cluster C with cluster D, E, F and G.

Cluster D with cluster E, and F.

Cluster E with cluster F and G.

Cluster F with cluster F and G.

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SUMMARY
AND
CONCLUSIONS

VI. SUMMARY AND CONCLUSION

For the present investigations fifty french bean (Phaseolus vulgaris L.) genotypes were selected from the germplasm collection maintained at Department of Botany, College of Agriculture Pune, and were evaluated during Kharif 1990. The major objectives of the investigation were to study the nature and extent of variability for different characters, association between different characters, path analysis and genetic divergence between the different genotypes, with the understanding to identify desirable and potential parents for breeding programmes in improvement of the yield.

The results obtained are summarized below.

6.1 Extent of variability

Treatments differences were significant for all the characters studied, indicating the presence of good amount of variation for different characters among the genotypes studied. However, the differences between exotic and indigenous genotypes were not significant in the expression of different characters.

Jampa improved recorded the highest seed yield (13.15g) per plant followed by HPR 35 (13.1 g). Amongst the other genotypes, Poona white and IC 18618 also produced more than 10 g seed yield per plant.

The variation for leaf area ranged between 1863.52 sq.cm (Almora) and 4439.59 sq.cm (Jampa improved). The genotypes Poona white, American red and Red kote have also recorded high

leaf area (> 4000 sq.cm). Good amount of variation was observed for number of pods per plant. It ranged between 4.00 (IC 47653-1) and 16.26 (Jampa improved). The genotypes Poona white, EC 26646 and Ajara black recorded more than nine pods per plant. Number of seeds per plant ranged between 2.40 (Almora) and 6.75 (Jampa improved). The genotypes EC 43034, EC 39439, IC 18618 and Poona white recorded more than five seeds per pod. The genotypes Khaki recorded the maximum pod length (13.2 cm) and was followed by HPR 12, contender, EC 43034, EC 39439, and HPR 35. Seed weight is another important component of yield, the 100 seed weight ranged between 17.84 g (Jampa improved) and 51.92 g (Almora). Montcalm, EC 44747, IC 47845 and Red cloud recorded higher than 42 g 100 seed weight. A part from the significant differences range of variation for protein content was limited (19.85 to 26.92%). The genotypes Jwala, Manus, Poona white, PDR 9 and VL 64 recorded more than 24 per cent protein content indicating the suitability protein content. Days to 50 per cent flowering and maturity are the major yard sticks in selecting genotypes for earliness. In the present investigations EC 94465, PDR 9, Yellow 4 Contender and HPR 35 flowered early i.e. before 30 days and matured before 65 days, suggesting the exploitation of such early genotypes in the scarcity areas of Maharashtra.

Considering the days to 50 per cent flowering and maturity, plant height, number of pods per plant, number of seeds per pod, protein content and seed yield it may be concluded that

Jampa improved, HPR 35, Poona white, Royal red, Red cloud, IC 47429, IC 18618, PDR 7, VL 61 and EC 22367 were observed good among fifty french bean genotypes.

6.2 Genetic parameters

The estimates of phenotypic coefficient were high when compared to the genotypic coefficient of variation for all the characters. Both the genotypic and phenotypic coefficient of variation were of high magnitude for leaf area per plant and plant height. The other characters days to 50 per cent flowering, days to maturity, number of pods per plant, 100 seed weight, harvest index and seed yield recorded a good amount of genotypic and phenotypic coefficient of variation. This indicate the presence of variability for the different characters in the material used for study.

The broad sense heritability estimates were of high magnitude for all the character studied except harvest index (26.4%). The heritability for protein content, leaf area, days to 50 per cent flowering, days for maturity and plant height were more than 80 per cent. 100 seed weight, pod length, number of pods per plant and seeds per pod recorded more than 50 per cent heritability, whereas, seed yield had 31.6 per cent heritability.

The plant height recorded highest expected genetic advance (56.82%). The leaf area, 100 seed weight, number of pods per plant and seeds per pod also recorded more than 35 per cent

expected genetic advance, whereas, seed yield and pod length more than 20 per cent expected genetic advance.

High heritability associated with high genetic advance were observed for the characters plant height, leaf area, 100 seed weight, number of pods per plant, number of seeds per pod and seed yield.

6.3 Correlation coefficient

The correlation between seed yield and number of pods per plant, number of seeds per pod, harvest index and leaf area were significantly positive at both genotypic and phenotypic levels, whereas, it was significantly positive with days to 50 per cent flowering and maturity at only genotypic level. The association between seed yield and 100 seed weight was negatively significant at both genotypic and phenotypic levels whereas, association of pod length with seed yield was negatively significant only at genotypic level. Seed yield was negatively correlated with protein content.

The number of pods per plant and seeds per pod, harvest index, leaf area, days to 50 per cent flowering and days for maturity would be considered for simultaneous selection to improving the seed yield in french bean.

6.4 Path analysis

The path coefficient analysis revealed that, the days to 50 per cent flowering had the highest positive direct effect

on seed yield followed by days for maturity and harvest index, the genotypic association of these characters was significantly positive, indicating the true and perfect association of these characters, suggesting its role in simultaneous selection while selecting genotypes with high yield. The character pod length recorded highest negative direct effect on seed yield. The highest positive indirect effect on seed yield was through plant height via days for maturity and was followed by pods per plant via days to 50 per cent flowering and harvest index via days for maturity.

The results obtained in the present investigations revealed that days to 50 per cent flowering, days for maturity, harvest index and number of pods per plant were the major yield contributing characters followed by leaf area and number of seeds per pod. The breeder may consider these characters while selecting the genotypes for high yield in french bean.

6.5 Genetic divergence

The D^2 values ranged from 7.76 (between Royal red and Red cloud) to 2330.56 (between Manus and EC 39439). On the basis of D values all the fifty genotypes studied were grouped in seven clusters. Cluster A was the largest having thirty genotypes followed by cluster B with ten genotypes. The cluster C and D with three genotypes each and cluster E with two genotypes. Cluster F and G had a single genotype each. The

cluster A,B and C included both exotic and indigenous genotypes, indicating the fact that though the genotypes are coming from different geographic regions, genetically they are more or less similar.

The intra cluster divergence of cluster A,B,C,D, and E suggested a substantial diversity within themselves. The maximum inter cluster distance was recorded between clusters B and E (D = 38.85) followed by clusters D and E (D = 31.77) whereas, it was minimum between cluster A and C (D = 12.54).

Based on the cluster means it is observed that the genotypes in cluster G were early in flowering and genotypes in cluster A were early to mature. Like wise cluster F for pods and leaf area per plant, cluster A, B for pod length, cluster C for 100 seed weight, cluster D for harvest index and seed yield and cluster E for protein content were the good sources for selecting the genotypes for respective characters.

Considering relative importance of the characters early flowering and maturity, number of pods per plant and seeds per pod, harvest index, leaf area and seed yield per plant, the genotypes Jampa improved, HPR 35, Poona white, Royal red, Red cloud, IC 47429, IC 18618, PDR 7, VL 61 and EC 22367 are desirable for further breeding programme to improve seed yield in french bean.

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* Original not seen.

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APPENDIX

VIII APPENDIX

Appendix I : Values of D-square arranged in ascending order

Sr.No.	Combination with Yellow 4	Combination with VL 64	Combination with VL 61	Combination with PDR 3	Combination with PDR 5
1	000.00(01)	000.00(02)	000.00(03)	000.00(04)	000.00(05)
2	036.69(32)	015.13(33)	018.41(15)	015.06.06.	021.68(29)
3	039.86(04)	035.40(27)	022.89(06)	025.61(12)	025.95(12)
4	042.81(16)	044.06(05)	023.34(39)	026.75(32)	029.54(27)
5	048.35(13)	047.84(28)	031.67(28)	027.04(15)	036.78(19)
6	064.14(24)	051.38(15)	034.71(49)	030.88(25)	041.30(07)
7	070.58(10)	051.64(07)	043.08(36)	039.86(01)	044.06(02)
8	072.95(47)	052.52(30)	049.05(33)	041.52(49)	046.96(06)
9	073.43(45)	057.71(03)	051.05(31)	044.16(10)	055.34(25)
10	075.34(25)	062.04(36)	051.09(04)	046.41(36)	060.92(15)
11	079.77(06)	064.46(29)	052.49(11)	049.57(13)	065.45(36)
12	088.63(36)	066.81(39)	054.10(30)	051.09(03)	067.98(04)
13	089.79(15)	067.70(06)	057.39(25)	051.39(16)	073.73(41)
14	090.82(12)	073.09(11)	057.71(02)	059.11(50)	081.63(32)
15	091.50(35)	073.94(25)	058.41(14)	063.95(45)	091.47(28)
16	101.35(14)	084.88(12)	060.56(40)	065.54(28)	092.45(33)
17	106.59(49)	092.94(31)	064.93(12)	066.74(31)	093.28(03)
18	110.78(11)	096.54(49)	068.01(32)	066.74(14)	095.68(10)
19	125.74(28)	103.17(40)	072.38(17)	067.98(05)	098.06(50)
20	127.53(31)	106.21(32)	073.22(10)	068.07(24)	098.87(49)
21	135.98(50)	106.38(10)	081.51(13)	068.38(41)	103.37(30)
22	141.85(38)	111.38(41)	081.64(50)	077.51(11)	117.57(11)
23	143.00(05)	112.41(04)	090.42(24)	079.74(19)	119.57(39)
24	146.17(03)	118.56(19)	093.28(05)	082.64(47)	124.68(31)
25	148.06(43)	130.93(50)	093.69(38)	090.44(35)	143.00(01)
26	158.23(19)	147.86(23)	107.41(41)	095.27(39)	164.25(24)
27	165.37(30)	159.96(37)	111.32(37)	095.85(30)	167.08(13)
28	173.92(41)	170.79(24)	119.13(16)	112.41(02)	190.32(40)
29	184.76(42)	175.99(13)	119.40(19)	117.89(17)	212.63(16)
30	185.95(17)	202.33(14)	123.61(22)	123.17(38)	213.22(14)
31	195.66(27)	204.02(08)	126.58(47)	127.80(29)	214.13(45)
32	205.24(40)	213.83(01)	127.35(27)	127.97(27)	251.16(37)
33	213.83(02)	228.65(38)	127.52(29)	135.02(40)	253.32(47)
34	219.65(21)	235.68(17)	137.14(35)	137.62(33)	259.80(08)
35	227.72(48)	254.86(26)	138.37(45)	160.65(21)	267.81(26)
36	229.38(39)	265.50(16)	146.17(01)	163.78(43)	279.05(38)
37	239.22(22)	266.14(47)	164.54(23)	170.83(22)	281.11(17)
38	246.67(33)	285.63(22)	174.13(07)	171.40(37)	287.20(35)
39	246.77(29)	288.73(45)	179.72(26)	174.23(07)	311.73(23)
40	251.98(37)	317.50(35)	185.70(21)	175.96(48)	347.53(22)
41	261.90(34)	368.08(21)	186.35(43)	212.94(26)	365.01(21)
42	262.50(07)	391.81(43)	228.36(48)	236.98(42)	398.25(43)
43	316.31(44)	395.35(09)	303.60(18)	310.40(23)	403.00(48)
44	325.48(46)	465.19(48)	326.68(42)	337.64(20)	451.34(09)
45	337.78(20)	506.02(18)	393.22(44)	342.04(44)	520.03(42)
46	354.32(18)	578.25(42)	418.90(20)	344.70(18)	619.94(18)
47	371.93(26)	697.02(44)	432.57(08)	349.88(34)	653.19(44)
48	431.10(23)	713.28(34)	449.38(34)	434.56(46)	654.94(34)
49	726.79(08)	729.28(20)	557.04(46)	535.02(08)	656.41(20)
50	1021.67(09)	856.36(46)	666.31(09)	788.60(09)	784.21(46)

Appendix I Contd

Combination with PDR 7	Combination with PDR 9	Combination with Jwala	Combination with Manus	Combination with HPR 35
000.00(06)	000.00(07)	000.00(08)	000.00(09)	000.00(10)
014.48(15)	031.82(27)	049.72(09)	049.72(08)	014.75(32)
015.06(04)	041.30(05)	137.12(07)	309.32(07)	029.10(28)
019.20(12)	050.63(29)	199.47(29)	350.32(29)	029.53(15)
022.89(03)	051.64(02)	200.57(27)	385.67(27)	030.26(24)
029.05(36)	098.93(33)	204.02(02)	395.35(02)	033.09(36)
032.43(32)	117.28(19)	249.17(33)	451.34(05)	033.31(13)
034.09(25)	118.85(30)	259.80(05)	457.88(33)	034.54(30)
038.80(49)	119.09(12)	379.26(19)	572.41(19)	042.50(11)
046.65(28)	127.11(36)	380.99(39)	578.24(39)	044.16(04)
046.96(05)	127.22(25)	386.11(41)	589.46(41)	048.88(06)
048.88(10)	132.82(28)	392.94(30)	595.37(23)	064.33(40)
058.09(19)	137.03(15)	397.54(23)	632.94(12)	064.95(25)
059.18(50)	137.12(08)	415.96(12)	642.35(50)	065.22(31)
059.63(11)	137.47(06)	421.38(28)	666.31(03)	070.58(01)
063.43(13)	139.00(41)	422.17(25)	666.56(25)	070.91(12)
063.88(39)	157.63(10)	432.57(03)	669.96(30)	073.22(03)
067.31(31)	160.38(32)	438.00(15)	671.99(06)	077.53(47)
067.70(02)	169.67(11)	439.06(06)	691.77(28)	089.09(49)
068.48(24)	174.13(03)	440.18(36)	695.13(15)	095.68(05)
068.74(14)	174.23(04)	452.83(50)	708.14(36)	097.12(16)
071.18(30)	188.31(31)	483.95(11)	750.87(49)	099.52(14)
077.65(41)	195.00(39)	492.05(31)	768.44(11)	106.38(02)
079.77(01)	206.52(50)	508.59(49)	776.48(31)	107.90(38)
081.16(16)	208.60(49)	535.02(04)	788.60(04)	118.28(33)
083.12(33)	231.40(40)	535.30(40)	793.41(26)	120.42(41)
084.62(29)	262.50(01)	542.80(10)	834.23(32)	130.61(27)
089.27(27)	272.03(24)	544.49(32)	844.23(40)	134.47(19)
089.59(45)	277.58(13)	571.00(37)	844.49(10)	137.13(37)
108.12(40)	288.20(37)	588.26(26)	869.62(37)	144.46(39)
114.02(17)	307.65(23)	717.43(24)	1021.67(01)	154.38(45)
114.04(47)	309.32(09)	721.92(13)	1051.50(13)	157.63(07)
121.82(35)	369.14(14)	726.79(01)	1052.03(24)	160.86(35)
128.15(38)	381.97(26)	780.76(14)	1069.30(14)	160.96(17)
137.47(07)	387.12(16)	828.34(17)	1120.75(17)	168.54(29)
171.36(37)	396.02(47)	842.62(38)	1131.79(22)	173.81(50)
180.03(22)	412.00(38)	862.83(22)	1153.04(45)	179.78(43)
192.37(43)	415.41(45)	878.92(45)	1185.23(38)	246.00(22)
204.37(21)	446.88(17)	880.39(16)	1194.79(16)	255.19(48)
212.17(26)	487.26(35)	894.52(47)	1240.11(21)	275.55(21)
212.88(48)	513.07(22)	971.49(21)	1250.29(47)	287.53(42)
263.19(23)	563.14(21)	974.24(35)	1284.45(35)	305.61(26)
300.15(42)	597.33(43)	1141.81(43)	1505.29(48)	315.26(23)
382.80(18)	647.13(48)	1172.41(48)	1510.71(43)	352.24(34)
384.24(44)	776.38(18)	1230.89(18)	1593.77(18)	370.22(44)
396.59(20)	779.99(42)	1430.99(42)	1825.43(42)	377.42(18)
410.11(34)	916.35(34)	1612.30(44)	2033.46(44)	394.28(20)
439.06(08)	932.57(44)	1627.41(20)	2034.69(20)	452.77(46)
511.98(46)	952.01(20)	1643.55(34)	2099.77(34)	542.80(08)
671.99(09)	1073.99(46)	1855.46(46)	2330.56(46)	844.49(09)

Appendix I Contd

Combination with HPR 12	Combination with HPR 33	Combination with HPR 87	Combination with HPR 137	Combination with Refresh
000.00(11)	000.00(12)	000.00(13)	000.00(14)	000.00(15)
018.70(28)	019.20(06)	013.79(24)	022.20(17)	014.22(28)
025.62(36)	021.81(19)	014.40(47)	027.42(35)	014.28(06)
026.34(15)	025.61(04)	019.19(32)	033.61(16)	018.06(36)
028.72(30)	025.95(05)	033.31(10)	035.20(38)	018.41(03)
031.72(32)	041.09(15)	039.39(16)	043.62(13)	025.98(32)
032.78(31)	052.37(29)	041.79(38)	045.37(43)	026.34(11)
033.56(40)	057.48(25)	041.88(11)	046.73(47)	027.04(04)
041.88(13)	059.53(36)	043.62(14)	052.87(45)	028.66(25)
042.50(10)	060.12(32)	046.82(15)	058.36(24)	029.53(10)
046.45(25)	064.93(03)	048.35(01)	058.41(03)	031.21(49)
048.94(24)	070.91(10)	049.57(04)	058.79(49)	032.07(31)
052.49(03)	073.78(49)	052.56(36)	066.18(15)	032.77(30)
054.27(33)	076.36(50)	059.88(28)	066.74(04)	041.09(12)
057.91(49)	076.86(41)	061.81(31)	068.74(06)	046.82(13)
059.63(06)	084.11(28)	063.43(06)	072.12(22)	051.38(02)
070.56(38)	084.88(02)	067.21(35)	080.01(32)	052.39(24)
073.09(02)	090.82(01)	067.67(25)	090.82(11)	054.28(40)
076.82(37)	091.83(27)	069.40(49)	095.54(28)	054.58(39)
077.51(04)	109.34(39)	071.76(43)	096.27(36)	054.96(33)
086.15(47)	110.55(24)	078.65(40)	099.52(10)	060.92(05)
090.82(14)	111.69(30)	081.51(03)	100.94(31)	066.18(14)
095.91(39)	113.24(13)	082.05(30)	101.35(01)	079.22(41)
101.41(27)	114.15(16)	088.51(45)	106.69(48)	082.74(50)
110.78(01)	114.60(45)	092.35(17)	108.92(21)	086.61(27)
117.57(05)	115.78(31)	113.24(12)	110.71(25)	089.79(01)
117.84(12)	117.84(11)	130.18(37)	111.64(40)	090.92(38)
127.46(17)	119.09(07)	155.44(22)	112.86(39)	091.88(47)
132.67(16)	124.95(14)	155.72(39)	123.46(42)	096.12(16)
143.64(50)	129.78(33)	156.56(50)	124.95(12)	103.11(19)
145.90(41)	174.44(47)	159.35(42)	136.46(50)	103.32(17)
159.00(35)	175.98(40)	163.30(48)	141.31(30)	105.60(37)
163.10(23)	176.04(35)	164.70(33)	168.37(37)	113.79(29)
168.36(22)	189.31(17)	167.08(05)	176.30(44)	122.76(45)
169.67(07)	208.69(38)	169.49(41)	184.73(33)	129.36(35)
172.36(43)	251.52(37)	175.99(02)	198.12(18)	137.03(07)
180.02(45)	257.00(26)	182.50(21)	201.43(41)	156.88(22)
198.79(19)	261.30(48)	200.33(27)	202.33(02)	176.16(43)
199.27(29)	267.37(22)	200.99(19)	203.80(20)	197.22(26)
243.06(21)	267.96(21)	202.86(34)	213.22(05)	199.87(21)
252.31(26)	274.17(43)	239.26(44)	213.37(34)	201.74(23)
283.21(18)	354.26(42)	247.00(18)	215.62(19)	228.16(48)
296.88(48)	357.10(23)	262.04(20)	252.34(26)	300.96(42)
328.00(42)	415.96(08)	268.70(29)	272.61(26)	323.44(18)
385.50(34)	454.59(44)	277.51(46)	279.92(46)	394.48(44)
431.69(44)	460.54(20)	277.58(07)	292.34(29)	400.93(34)
462.15(20)	490.40(34)	287.73(26)	297.13(23)	406.57(20)
483.95(08)	513.79(18)	315.68(23)	369.14(07)	438.00(08)
494.66(46)	593.53(46)	721.92(08)	780.76(08)	505.43(46)
768.44(09)	632.94(09)	1051.59(09)	1069.30(09)	695.13(09)

Appendix I Contd

Combina- tion with Vaghya	Combination with K.B.7	Combination with Jampa improved	Combination with Almora	Combination with IC47845
000.00(16)	000.00(17)	000.00(18)	000.00(19)	000.00(20)
020.08(45)	022.20(14)	104.14(22)	021.81(12)	046.15(44)
020.81(35)	042.97(38)	135.86(38)	034.21(29)	049.49(48)
033.61(14)	045.83(22)	149.07(43)	036.78(05)	059.79(42)
039.39(13)	053.95(35)	157.51(17)	058.09(06)	081.11(34)
039.75(47)	059.52(43)	169.00(21)	079.74(04)	091.83(46)
042.81(01)	072.38(03)	185.73(35)	102.74(36)	109.73(43)
051.39(04)	080.09(49)	192.74(47)	103.11(15)	131.94(35)
051.40(43)	080.71(16)	198.12(14)	114.52(27)	166.75(16)
052.82(24)	085.92(47)	216.94(37)	117.28(07)	170.85(45)
067.20(32)	092.26(21)	242.41(31)	117.79(25)	179.62(47)
078.83(42)	092.35(13)	247.00(13)	118.56(02)	203.80(14)
080.71(17)	096.27(45)	248.04(42)	119.40(03)	212.10(17)
081.16(06)	101.20(39)	266.47(16)	122.76(32)	214.47(21)
082.79(38)	103.32(15)	273.57(40)	123.18(50)	240.57(38)
095.90(48)	108.94(48)	283.21(11)	134.47(10)	262.04(13)
096.12(15)	114.02(06)	285.03(49)	138.97(41)	280.15(22)
097.12(10)	114.07(24)	303.60(03)	147.84(49)	290.84(24)
097.38(49)	117.89(04)	304.77(24)	151.22(28)	337.64(04)
114.15(12)	123.11(40)	312.07(48)	158.23(01)	337.78(01)
116.65(36)	123.46(31)	320.52(28)	174.91(39)	359.00(18)
118.07(25)	127.46(11)	320.72(23)	176.47(30)	364.52(49)
119.13(03)	134.11(28)	320.87(34)	179.40(33)	376.98(32)
132.67(11)	142.74(32)	323.44(15)	182.24(24)	394.28(10)
140.81(21)	150.58(36)	326.84(45)	186.87(45)	396.59(06)
142.49(31)	155.90(42)	330.72(39)	192.77(16)	406.57(15)
145.00(28)	156.31(25)	333.91(44)	198.10(31)	418.90(03)
146.25(44)	157.51(18)	344.70(04)	198.79(11)	426.97(31)
150.22(50)	160.96(10)	353.41(32)	200.99(13)	448.94(36)
151.12(34)	162.74(37)	353.78(25)	215.62(14)	460.54(12)
153.32(22)	169.91(50)	354.32(01)	265.76(40)	461.86(25)
166.75(20)	179.74(30)	357.62(46)	279.83(35)	462.15(11)
189.58(40)	185.95(01)	359.00(20)	284.86(47)	474.92(40)
192.77(19)	189.31(12)	359.15(36)	292.90(17)	481.08(50)
194.19(30)	191.04(44)	373.35(50)	321.24(38)	488.07(28)
199.78(39)	203.54(33)	377.42(10)	355.41(26)	504.71(39)
201.46(46)	212.10(20)	380.07(30)	364.61(48)	509.62(26)
208.88(41)	220.78(26)	382.80(06)	370.52(37)	515.70(37)
212.63(05)	232.86(41)	429.16(33)	379.26(08)	530.28(41)
255.09(37)	235.68(02)	433.38(26)	393.89(22)	553.64(30)
265.50(02)	253.29(34)	504.19(41)	397.01(21)	587.51(19)
266.47(18)	267.88(23)	506.02(02)	401.80(43)	656.41(05)
275.35(33)	281.11(05)	513.79(12)	459.90(23)	700.86(33)
292.91(27)	292.90(19)	619.94(05)	476.46(42)	729.28(02)
307.19(29)	321.22(46)	635.24(27)	562.30(44)	779.26(29)
329.75(26)	340.92(27)	685.21(19)	572.41(09)	801.14(27)
387.12(07)	357.67(29)	759.71(29)	587.51(20)	879.72(23)
450.12(23)	446.88(07)	776.38(07)	623.16(34)	952.01(07)
880.39(08)	828.34(08)	1230.89(08)	685.21(18)	1627.41(08)
1194.79(09)	1120.75(09)	1593.77(09)	740.67(46)	2034.69(09)

Appendix I Contd...

Combination with Ajara black	Combination with Sabarmati	Combination with Poona white	Combination with Contender	Combination with Tender green
000.00(21)	000.00(22)	000.00(23)	000.00(24)	000.00(25)
038.23(22)	038.23(21)	093.00(33)	013.79(13)	023.57(49)
072.66(35)	045.83(17)	107.85(37)	026.44(32)	028.66(15)
092.26(17)	072.12(14)	118.02(39)	030.26(10)	030.88(04)
095.49(48)	074.85(38)	147.86(02)	043.12(47)	030.97(31)
108.92(14)	082.50(35)	148.32(31)	048.10(36)	033.26(32)
109.21(49)	085.93(49)	159.58(40)	048.94(11)	033.73(36)
113.71(45)	104.14(18)	163.10(11)	052.39(15)	034.09(06)
135.30(47)	113.97(43)	164.54(03)	052.82(16)	046.45(11)
135.63(43)	115.26(39)	166.79(28)	058.36(14)	047.23(50)
140.81(16)	123.61(03)	179.36(30)	058.47(38)	055.34(05)
140.93(38)	123.64(31)	188.52(49)	060.23(28)	055.75(28)
141.15(26)	127.27(47)	201.74(15)	064.14(01)	057.39(03)
149.95(50)	137.99(37)	208.27(25)	068.07(04)	057.48(12)
160.65(04)	149.75(45)	211.01(22)	068.48(06)	061.97(41)
167.12(31)	153.32(16)	228.30(36)	079.02(40)	064.95(10)
168.52(39)	153.66(48)	244.06(50)	082.22(03)	067.67(13)
169.00(18)	155.44(13)	248.07(27)	090.42(30)	073.10(27)
177.12(42)	156.88(15)	252.92(38)	092.84(43)	073.94(02)
182.50(13)	157.06(50)	260.56(26)	093.13(31)	075.34(01)
182.79(25)	165.86(26)	263.19(06)	098.73(25)	076.08(39)
185.70(03)	168.36(11)	267.88(17)	099.47(35)	076.20(30)
199.87(15)	170.19(25)	294.81(41)	100.15(49)	083.84(33)
204.37(06)	170.83(04)	297.13(14)	109.02(45)	098.73(24)
205.55(37)	180.03(06)	299.40(32)	110.55(12)	107.65(47)
214.47(20)	185.40(40)	307.65(07)	114.07(17)	110.71(14)
219.65(01)	189.44(28)	310.40(04)	164.25(05)	111.99(37)
221.31(41)	197.45(36)	311.73(05)	167.35(33)	117.79(40)
233.00(32)	207.75(42)	315.26(10)	170.79(02)	117.79(19)
243.06(11)	208.00(24)	315.68(13)	179.61(42)	118.07(16)
252.10(36)	211.01(23)	320.72(18)	180.30(37)	126.48(29)
255.71(24)	211.51(32)	351.78(21)	182.24(19)	127.22(07)
264.98(28)	238.86(33)	357.10(12)	184.96(39)	129.25(45)
267.96(12)	239.22(01)	359.06(24)	198.50(27)	129.95(38)
275.55(10)	246.00(10)	366.53(29)	201.36(50)	143.89(35)
289.46(40)	247.95(30)	367.29(47)	203.08(48)	156.31(17)
290.71(44)	258.88(41)	397.54(08)	208.00(22)	160.69(26)
305.58(34)	267.37(12)	413.98(35)	213.40(34)	170.19(22)
329.13(30)	280.15(20)	431.10(01)	213.42(41)	182.79(21)
345.01(33)	285.63(02)	450.12(16)	237.40(44)	208.27(23)
351.78(23)	298.82(44)	455.18(43)	254.80(29)	222.32(43)
356.04(46)	327.34(34)	459.90(19)	255.71(21)	256.29(48)
365.01(05)	347.53(05)	485.46(45)	272.03(07)	333.95(42)
368.08(02)	389.60(27)	595.37(09)	290.84(20)	353.78(18)
397.01(19)	393.89(19)	606.18(48)	297.04(46)	422.17(08)
441.80(27)	394.75(46)	707.74(42)	304.77(18)	437.35(34)
465.73(29)	439.81(29)	854.17(34)	359.06(23)	461.86(20)
563.14(07)	513.07(07)	854.20(44)	369.10(26)	478.05(44)
971.49(08)	862.83(08)	879.72(20)	717.43(08)	539.95(46)
1240.11(09)	1131.79(09)	988.08(46)	1052.03(09)	666.56(09)

Appendix I Contd...

Combination with IC 47644	Combination with Khaki	Combination with Royal red	Combination with Montcalm	Combination with Red cloud
000.00(26)	000.00(27)	000.00(28)	000.00(29)	0.0000(30)
099.18(39)	029.54(05)	007.76(30)	021.68(05)	07.76(28)
113.67(41)	031.82(07)	014.22(15)	034.21(19)	021.44(40)
115.24(49)	035.40(02)	018.70(11)	050.63(07)	028.72(11)
141.15(21)	058.13(29)	022.74(40)	052.37(12)	032.77(15)
144.24(50)	065.26(33)	024.23(36)	058.13(27)	034.54(10)
152.45(31)	073.10(25)	029.10(10)	064.46(02)	040.76(36)
160.69(25)	082.26(36)	030.67(03)	084.62(06)	041.40(33)
164.37(37)	086.61(15)	034.14(31)	110.56(41)	048.44(31)
165.86(22)	089.27(06)	040.64(33)	113.79(15)	052.52(02)
179.72(03)	091.83(12)	041.26(32)	119.07(33)	054.10(03)
197.22(15)	100.97(28)	046.65(06)	123.44(36)	056.39(32)
212.17(06)	101.41(11)	047.84(02)	126.48(25)	071.18(06)
212.94(04)	102.06(30)	055.75(25)	127.52(03)	076.20(25)
220.78(17)	107.40(32)	059.88(13)	127.80(04)	080.72(37)
229.87(33)	113.24(41)	060.23(24)	136.37(50)	082.05(13)
252.31(11)	114.52(19)	064.23(49)	145.74(39)	082.22(24)
252.34(14)	127.35(03)	065.54(04)	148.64(28)	095.50(04)
254.67(28)	127.97(04)	076.18(39)	157.67(30)	097.31(49)
254.80(48)	130.61(10)	080.28(37)	164.14(32)	098.00(39)
254.86(02)	135.52(31)	084.11(12)	168.54(10)	102.06(27)
256.29(36)	135.60(50)	091.47(05)	168.60(49)	103.37(05)
257.00(12)	136.20(49)	092.78(38)	199.27(11)	111.69(12)
260.56(23)	144.71(39)	095.54(14)	199.47(08)	118.85(07)
267.81(05)	188.26(40)	100.57(27)	201.59(31)	126.78(38)
274.96(30)	195.66(01)	112.58(47)	246.77(01)	132.34(41)
277.92(32)	198.50(24)	124.43(41)	254.80(24)	141.31(14)
277.95(38)	200.33(13)	125.74(01)	260.09(40)	142.76(47)
279.21(35)	200.57(08)	132.82(07)	268.70(13)	157.67(29)
280.54(40)	241.37(37)	134.11(17)	292.34(14)	165.37(01)
282.60(47)	248.07(23)	141.07(50)	295.55(45)	176.47(19)
283.25(45)	272.61(14)	145.00(16)	307.19(16)	179.36(23)
287.73(13)	292.91(16)	148.64(29)	317.23(26)	179.74(17)
305.61(10)	300.11(47)	151.22(19)	344.10(37)	185.07(50)
307.37(27)	301.34(45)	166.79(23)	350.32(09)	194.19(16)
317.23(29)	307.37(26)	184.92(35)	357.67(17)	245.96(35)
329.75(16)	312.49(38)	189.44(22)	366.53(23)	247.95(22)
355.41(19)	340.92(17)	199.65(45)	374.11(47)	259.83(43)
369.10(24)	361.26(35)	208.21(43)	390.77(38)	260.34(45)
371.93(01)	385.67(09)	254.67(26)	391.57(35)	274.96(26)
380.64(43)	389.60(22)	264.98(21)	439.81(22)	329.30(21)
381.97(07)	441.80(21)	309.63(48)	465.73(21)	363.31(48)
433.38(18)	460.65(43)	320.52(18)	491.83(48)	380.07(18)
509.62(20)	524.73(48)	360.58(42)	525.20(43)	392.94(08)
513.97(42)	635.24(18)	421.38(08)	664.53(42)	435.18(42)
588.26(08)	637.49(42)	449.82(44)	759.71(18)	515.04(34)
646.66(44)	745.96(34)	453.20(34)	775.30(44)	518.89(44)
662.16(34)	794.53(44)	488.07(20)	779.26(20)	553.64(20)
770.50(46)	801.14(20)	566.11(46)	826.25(34)	637.72(46)
793.41(09)	888.83(46)	691.77(09)	970.49(46)	669.96(09)

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Combination with Red Mexican	Combination with EC94465	Combination with EC22367	Combination with EC43034	Combination with IC47429
000.00(31)	000.00(32)	000.00(33)	000.00(34)	000.00(35)
030.97(25)	014.75(10)	015.13(02)	011.07(46)	020.81(16)
032.07(15)	019.19(13)	040.64(28)	039.85(42)	024.94(45)
032.78(11)	025.09(36)	041.40(30)	060.44(44)	027.42(14)
034.14(28)	025.98(15)	049.05(03)	078.52(43)	030.02(43)
036.08(49)	026.44(24)	053.49(39)	081.11(20)	044.03(47)
036.09(37)	026.75(04)	054.27(11)	136.60(47)	053.95(17)
037.83(36)	031.72(11)	054.96(15)	138.05(35)	059.17(42)
048.44(30)	032.43(06)	064.49(36)	151.12(16)	065.66(48)
051.05(03)	033.26(25)	065.26(27)	160.95(48)	067.21(13)
054.48(40)	036.69(01)	066.97(40)	193.67(38)	068.62(38)
057.67(32)	041.26(28)	072.56(31)	196.00(45)	072.66(21)
061.81(13)	056.39(30)	083.12(06)	202.86(13)	082.50(22)
065.22(10)	057.67(31)	083.84(25)	213.37(14)	090.44(04)
066.74(04)	059.56(49)	092.45(05)	213.29(24)	091.50(01)
067.31(06)	060.12(12)	093.00(23)	253.29(17)	094.94(49)
068.86(39)	060.41(47)	093.30(49)	261.90(01)	099.47(24)
072.56(33)	067.20(16)	098.93(07)	305.58(21)	118.61(32)
077.38(38)	068.01(03)	109.86(37)	316.43(32)	121.82(06)
084.87(47)	080.01(14)	117.47(32)	320.87(18)	129.36(15)
092.94(02)	081.63(05)	118.28(10)	327.34(22)	131.94(20)
093.13(24)	088.27(40)	119.07(29)	349.88(04)	134.03(44)
096.07(50)	095.93(38)	129.78(12)	352.24(10)	137.14(03)
100.94(14)	106.21(02)	137.62(04)	380.29(49)	138.05(34)
103.70(41)	106.52(45)	139.87(41)	385.50(11)	143.89(25)
115.78(12)	107.40(27)	144.62(50)	399.25(36)	149.44(50)
123.46(17)	112.70(41)	164.70(13)	400.93(15)	149.83(31)
123.64(22)	117.47(33)	167.35(24)	408.19(31)	159.00(11)
124.68(05)	118.61(35)	179.40(19)	410.11(06)	160.10(36)
127.53(01)	121.96(50)	184.73(14)	434.98(40)	160.86(10)
135.52(27)	122.76(19)	187.43(38)	437.35(25)	176.04(12)
142.49(16)	133.47(39)	203.54(17)	449.38(03)	179.65(46)
148.32(23)	142.74(17)	229.87(26)	453.20(28)	184.92(28)
149.83(35)	145.67(37)	238.86(22)	490.40(12)	185.73(18)
152.45(26)	153.99(43)	242.94(47)	504.34(37)	193.84(39)
167.12(21)	160.38(07)	246.67(01)	515.04(30)	214.64(40)
180.50(45)	164.14(29)	249.17(08)	528.07(50)	238.97(37)
188.31(07)	211.51(22)	275.35(16)	580.40(39)	242.53(41)
188.46(43)	231.61(48)	305.14(35)	614.70(41)	245.96(30)
198.10(19)	233.00(21)	306.02(45)	623.16(19)	279.21(26)
201.59(29)	254.06(42)	345.01(21)	654.94(05)	279.83(19)
242.41(18)	277.92(26)	355.90(43)	662.16(26)	287.20(05)
245.26(48)	299.40(23)	429.16(18)	681.42(33)	305.14(33)
319.30(42)	316.43(34)	447.12(48)	713.28(02)	317.50(02)
408.19(34)	353.49(18)	457.88(09)	745.96(27)	361.26(27)
426.97(20)	357.03(44)	566.97(42)	826.25(29)	391.57(29)
437.14(44)	376.98(20)	670.00(44)	854.17(23)	413.92(23)
492.05(08)	409.78(46)	681.42(34)	916.35(07)	487.26(07)
511.79(46)	544.49(08)	700.86(20)	1643.55(08)	974.24(08)
776.48(09)	834.23(09)	823.83(46)	2099.77(09)	1284.45(09)

Appendix I Contd...

Combination with EC 108101	Combination with American red	Combination with IC 49802	Combination with IC 49844	Combination with Red kote
000.00(36)	000.00(37)	000.00(38)	000.00(39)	000.00(40)
018.06(15)	036.09(31)	034.64(47)	023.34(03)	021.44(30)
024.23(28)	058.52(40)	035.20(14)	042.31(49)	022.74(28)
025.08(32)	076.82(11)	041.79(13)	053.49(33)	033.56(11)
025.62(11)	080.28(28)	042.97(17)	054.58(15)	054.28(15)
029.05(06)	080.72(30)	045.23(43)	063.88(06)	054.48(31)
033.09(10)	100.81(49)	058.47(24)	066.81(02)	058.52(37)
033.73(25)	103.58(38)	068.62(35)	068.86(31)	060.56(03)
037.83(31)	105.18(39)	070.56(11)	076.08(25)	064.33(10)
040.76(30)	105.60(15)	071.29(40)	076.18(28)	066.97(33)
043.08(03)	107.85(23)	074.85(22)	076.26(50)	068.84(36)
046.41(04)	109.86(33)	077.38(31)	087.92(41)	071.29(38)
048.10(24)	111.32(03)	081.19(49)	095.27(04)	078.65(13)
050.14(49)	111.99(25)	082.79(16)	095.91(11)	079.02(24)
052.56(13)	124.57(36)	090.92(15)	096.91(36)	088.27(32)
059.53(12)	130.18(13)	092.78(28)	098.00(30)	103.17(02)
062.04(02)	137.13(10)	093.69(03)	099.18(26)	104.51(39)
064.49(33)	137.99(22)	095.93(32)	101.20(17)	105.76(49)
065.45(05)	140.12(47)	102.02(36)	104.51(40)	108.12(06)
068.84(40)	145.67(32)	103.58(37)	105.18(37)	111.64(14)
082.26(27)	159.96(02)	107.90(10)	109.34(12)	117.79(25)
088.63(01)	162.74(17)	123.17(04)	112.86(14)	118.51(47)
096.27(14)	164.37(26)	126.78(30)	115.26(22)	123.11(17)
096.91(39)	168.37(14)	128.15(06)	118.02(23)	135.02(04)
102.02(38)	171.36(06)	129.95(25)	119.72(05)	159.58(23)
102.74(19)	171.40(04)	134.17(45)	133.47(32)	175.98(12)
103.86(47)	175.53(41)	135.86(18)	144.46(10)	185.40(22)
107.79(50)	180.30(24)	140.93(21)	144.71(27)	188.26(27)
116.65(16)	205.55(21)	141.82(42)	145.74(29)	189.58(16)
123.44(29)	206.28(50)	141.85(01)	150.11(38)	190.32(05)
124.57(37)	216.94(18)	150.11(39)	155.72(13)	192.99(43)
126.82(41)	238.97(35)	159.17(48)	168.52(21)	199.76(41)
127.11(07)	241.37(27)	187.43(33)	174.91(19)	205.24(01)
150.58(17)	244.26(43)	193.67(34)	184.96(24)	214.64(35)
150.94(45)	251.16(05)	201.07(44)	193.84(35)	230.98(50)
160.10(35)	251.52(12)	208.69(12)	195.00(07)	231.40(07)
197.45(22)	251.98(01)	211.04(50)	195.24(45)	260.09(29)
204.99(43)	255.09(16)	228.65(02)	197.09(47)	263.98(45)
228.30(23)	288.20(07)	240.57(20)	199.78(16)	265.76(19)
252.10(21)	313.35(45)	252.92(23)	229.38(01)	273.57(18)
256.29(26)	329.87(48)	265.14(41)	266.05(43)	280.54(26)
275.66(48)	344.10(29)	266.89(46)	268.48(48)	289.46(21)
322.34(42)	370.52(19)	277.95(26)	330.72(18)	320.87(48)
359.15(18)	419.69(42)	279.05(05)	380.99(08)	370.84(42)
399.25(34)	504.34(34)	312.49(27)	428.82(42)	428.24(44)
417.76(44)	515.70(20)	321.24(19)	504.71(20)	434.98(34)
440.18(08)	536.25(44)	390.77(29)	519.76(44)	474.92(20)
448.94(20)	571.99(08)	412.00(07)	578.24(09)	535.30(08)
514.40(46)	612.83(46)	842.62(08)	580.40(34)	548.26(46)
708.14(09)	869.62(09)	1185.23(09)	697.38(46)	844.23(09)

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Combination with EC 26646	Combination with IC 49700	Combination with EC 42960	Combination with EC 44747	Combination with EC 44744
000.00(41)	000.00(42)	000.00(43)	000.00(44)	000.00(45)
061.97(25)	039.85(34)	030.02(35)	042.35(42)	020.08(16)
068.38(04)	042.35(44)	038.50(47)	046.15(20)	024.94(35)
073.73(05)	045.21(43)	045.21(42)	060.44(34)	052.87(14)
076.86(12)	051.84(46)	045.23(38)	073.01(46)	063.95(04)
077.65(06)	059.17(35)	045.37(14)	083.88(43)	073.43(01)
079.22(15)	059.79(20)	051.40(16)	117.59(48)	078.09(48)
083.59(50)	078.83(16)	059.52(17)	134.03(35)	085.87(47)
087.20(49)	092.60(48)	071.76(13)	146.25(16)	088.51(13)
087.92(39)	101.22(47)	078.52(34)	176.30(14)	089.59(06)
103.70(31)	104.75(45)	083.88(44)	179.28(47)	089.68(43)
107.41(03)	123.46(14)	089.68(45)	183.98(45)	095.51(49)
110.56(29)	141.82(38)	092.84(24)	191.04(17)	096.27(17)
111.38(02)	155.90(17)	093.30(48)	201.07(38)	104.75(42)
112.70(32)	159.35(13)	109.73(20)	237.40(24)	106.52(32)
113.24(27)	177.12(21)	113.97(22)	239.26(13)	109.02(24)
113.67(26)	179.61(24)	115.47(46)	290.71(21)	113.71(21)
120.42(10)	184.76(01)	135.63(21)	298.82(22)	114.60(12)
124.43(28)	207.75(22)	148.06(01)	316.31(01)	121.21(50)
126.82(36)	236.98(04)	149.07(18)	333.91(18)	122.76(15)
132.34(30)	248.04(18)	153.99(32)	342.04(04)	129.25(25)
138.97(19)	254.06(32)	161.80(49)	357.03(32)	134.17(38)
139.00(07)	263.63(49)	163.78(04)	370.22(10)	138.37(03)
139.87(33)	287.53(10)	172.36(11)	380.05(49)	149.75(22)
145.90(11)	300.15(06)	176.16(15)	384.24(06)	150.94(36)
169.49(13)	300.96(15)	179.78(10)	393.22(03)	154.38(10)
173.92(01)	319.30(31)	186.35(03)	394.48(15)	170.85(20)
175.53(37)	322.34(36)	188.46(31)	417.76(36)	180.02(11)
196.13(45)	326.68(03)	192.37(06)	428.24(40)	180.58(31)
199.76(40)	328.00(11)	192.99(40)	431.69(11)	183.98(44)
201.43(14)	333.95(25)	204.99(36)	437.14(31)	186.87(19)
208.88(16)	354.26(12)	208.21(28)	449.82(28)	195.24(39)
212.31(47)	360.58(28)	222.32(25)	454.59(12)	196.00(34)
213.42(24)	370.84(40)	244.26(37)	478.05(25)	196.13(41)
221.31(21)	372.09(50)	259.83(30)	517.58(50)	199.65(28)
232.86(17)	419.69(37)	266.05(39)	518.89(30)	214.13(05)
242.53(35)	428.82(39)	274.17(12)	519.76(39)	247.97(46)
258.88(22)	435.18(30)	276.87(50)	536.25(37)	260.34(30)
265.14(38)	474.12(41)	350.33(41)	562.30(19)	263.98(40)
284.41(48)	476.46(19)	355.90(33)	615.94(41)	283.25(26)
294.81(23)	513.97(26)	380.64(26)	646.66(26)	288.73(02)
350.33(43)	520.03(05)	391.81(02)	653.19(05)	295.55(29)
386.11(08)	566.97(33)	398.25(05)	670.00(33)	301.34(27)
474.12(42)	578.25(02)	401.80(19)	697.02(02)	306.02(33)
504.19(18)	637.49(27)	455.18(23)	775.30(29)	313.35(37)
530.28(20)	664.53(29)	460.56(27)	794.53(27)	326.84(18)
589.46(09)	707.74(23)	525.20(29)	854.20(23)	415.41(07)
614.70(34)	779.99(07)	597.33(07)	932.57(07)	485.46(23)
615.94(44)	1430.99(08)	1141.81(08)	1612.30(08)	878.92(08)
724.37(46)	1825.43(09)	1510.71(09)	2033.46(09)	1153.04(09)

Chapter Opener Page

VITA

VITA

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