SUMMARY
The legume *Clitoria ternatea* L. commonly known as butterfly pea is indigenous to India where it is adapted throughout the tropical regions in the rain fall range of 500 to 1500 mm. It is a perennial pasture legume highly productive during the rainy season. Its potential has not yet been fully exploited for upgrading the productivity and the nutritional value of the native pastures. One of the main reasons is a general lack of relevant information on the various aspects such as the extent of genetic diversity in the indigenous genotypes, factors related to its establishment in the pasture and its production behaviour under sole and mix crop situations against the different native grasses.

The present study was therefore carried out to (i) Assess the genetic diversity present in the germplasm collected from different parts of the country as well as characterization and cataloguing (ii) Factors affecting the establishment of *Clitoria ternatea* in pastures viz. effect of various factors such as sowing depth, soil types, temperature and light colours on the germination of polymorphic seeds (iii) Assessment of variability in important forage yielding attributes (iv) Genotypic stability and (v) Compatibility of *Clitoria* with native grasses and tree component and its effect on quality and productivity.

The basic material of the present study comprises of 92 germplasm collected from major areas of its distribution such as Rajasthan, Uttar Pradesh, Delhi State, Madhya Pradesh, Gujarat, Maharashtra, Tamil Nadu, Bihar and West Bengal. For the study of genetic diversity all the *Clitoria ternatea* genotypes were grown in replicated trial and the data on various plant attributes and productivity was recorded for three consecutive years at the peak period of the plant growth, i.e. at 50% flowering stage.

The seed of the *Clitoria* genotypes collected from the different parts of the country manifested considerable diversity in the seed coat colour patterns. The basic seed coat colours in *Clitoria* comprised of various shades of light brown to black colour and the different patterns developed through a uniform sprinkling of fine dots or speckles of various colour and sizes over the basic seed coat colour. The grey speckled seed coat colour types occurred most frequently followed by shining black and dark brown types with or without dottings or speckling.

*Clitoria* is a profusely flowering plant and the flower petals (wing, keel and standard) particularly its wings conspicuously showed various colours. The deep blue colour was the most frequent followed by white or various shades of pink against white or light blue.
Under climatic conditions at Jhansi the flowering response of *Clitoria* genotypes was day neutral. Both vegetative and reproductive growth phases continued simultaneously till late September, afterwards the growth activity progressively ceased with the increase in self defoliation and pods bearing by the end of November. A majority of the genotypes flowered in the medium range (43-46 days) followed by late and early flowering types. Due to day neutral behaviour of *Clitoria* plants the discernible genotypic coefficient of variations in flowering were rather low.

*Clitoria* plants being a creeper show indeterminate growth and the growth occurs from the growing tips of the main stem and the auxiliary branches. Significant differences among the genotypes were observed for all the ten characters in each individual year of the study. The genetic diversity amongst the genotypes was widest for green fodder yield followed by leaf number/plant and was comparatively low for branch number/plant and days to flower. The genotypes showed medium genetic diversity for the characters of elongation such as plant height and length of the branch.

The important forage yielding attribute in *Clitoria ternatea* is the leafiness as determined by leaf number/plant and the leaf/stem ratio in the forage yield along with branch number and branch length. The studies reveal that there is considerable amount of genetic diversity in these forage yielding attributes and there is wide scope for selecting high forage yielding types in *Clitoria* on the basis of profuse leafiness and branching attributes.

The results indicated that the pure stands of *Clitoria* plants in the establishment year had the highest leaf/stem ratio and the longest branch as compared to its regrowth performance in the following years. The second year of regrowth was characterized by an overall increase in size of the plants including branching behaviour, leafiness and maximum realization of yield potential, (both GY and DMY) as compared to any other year of growth. The aggressive vigour of the *Clitoria* plants in the second year appears to be linked with the maximum foliage entailing largest surface area available for photosynthetic activity. The unique feature of the *Clitoria* plant in pure stand is that its protein content continues to increase from the first year to the third year of growth.

The classification of the *Clitoria* genotypes in the present study was based on the index score method developed by Anderson (1957). The sum of the indices for all the 10 characters provided a multi-character expression data for each genotype separately. Based on the total index values the genotypes were classified into 15 divergent groups irrespective of their geographical origin, indicating thereby existence of considerable genetic diversity within the.
major geographic areas of distribution of Clitoria ternatea in this country. The group of genotypes with low total index values were the less vigorous growth types than those with higher values. A majority of the genotypes were represented in the high and very high index score groups. One of the important factors in the creation of considerable amount of genetic diversity in the localised populations is the prevalence of occasional outcrossing which create a spectrum of segregating progenies over the generations. When these segregating populations are subject to long term natural selection pressure, the result is the evolution of extremely divergent growth forms along with several intermediate growth forms. Presence of divergent growth forms in the materials from the same region may as well indicate that the different plant types may have occurred due to an exchange of genetic material at different periods between the different regions.

Since, major interest of the plant breeders lies in the identification of elite plant types with important agronomic traits, a concise key to the identification of such genotypes have been developed based on five economic traits such as plant height, branch number/plant, dry matter yield/plant, leaf-stem ratio and protein contents (%). The study revealed 70 different plant type groups, of which 53 were represented by a single genotype each followed by 14 groups with two genotypes and the remaining three groups by three genotypes each. The technique helped in identifying eight elite lines with the most favoured combination of high grades of all the five economic traits.

A proper characterization, cataloging and documentation of germplasm in the Clitoria ternatea based on twelve morphological traits have been prepared to depict the extent of genetic diversity available within the indigenous material. This catalogue would be useful as a ready reference to the researchers and help them identify suitable types for use in the crop improvement programmes.

Differential response of various treatments viz. sowing depth, soil types, temperature and colour of light illumination was observed on germination of different category of Clitoria seeds. It infers that different groups of Clitoria seeds have genetic differences among themselves. The seed germination decreased progressively from a maximum at 2 cm soil depth to a minimum at 8 cm. The different seed types had a differential response to the sowing depth, but the types showing maximum germination at shallow depth were the most adversely affected at greater depth of sowing. Amongst the soil types studied mixed type of soil was most conducive to seed germination followed by organic soil, red soil and the least in the black soils.

The studies indicated that for Clitoria seed germination 35°C was most conducive closely followed by 25°C and minimum at the lowest temperature 5°C. The optimal temperature requirement for the maximum seed germination varied significantly with the different kinds of
The effect of different colours of light on seed germination was significant on the different types of seed. While maximum germination in six out of eight seed types was observed in the total darkness, next in promoting germinability was violet colour for grey seeded, red colour for bluish grey and brown seeded types.

A highly stable genotype with high yield potential is a prerequisite for the release of a cultivar for wide scale cultivation. In the present study, the stability analysis on eight selected genotypes was made using Fberhart and Russel (1966) model. The components of the stability worked out are, the varietal means and the general mean of all the varieties for each location, linear regression (b1) of the varietal means with the general mean for each location, and deviation from the regression for each variety (S2 di). The varietal differences due to *Clitoria* genotypes were significant for dry fodder yield (DFY t/h), crude protein yield (CPY t/h) and seed yield (t/h). All these characters along with green fodder yield (GFY t/h) also showed significant linear environmental effect, indicating a favourable response of environment on the expression of these traits. A significant effect of the variety x environment on the dry matter yield (t/h), crude protein (t/h) yield and leaf/stem ratio also indicated differential response of the varieties to environment on the expression of these traits. The varietal differences for plant height, branch number/plant, GFY/plant and leaf-stem ratio was not significant. The environmental influence both linear and non-linear as well as variety x environment interaction effects on all these characters were highly significant. These studies suggest that the forage attributes in the species *Clitoria ternatea* which shows indeterminate vegetative (trailing type) growth with no clear cut difference between the vegetative and reproductive growth phases are predominantly influenced by the environmental effects rather than by genetic effect. The results indicated that only two characters namely DMY (t/h) and CPY (t/h), for which the varietal differences as well as variety x environment effects were significant appeared to be the most important for the stability analysis of the genotypes. Out of eight genotypes only two namely IICT 249 and IICT 278 had very high mean dry fodder and crude protein yield, and with regression coefficient in the range of 1.08-1.46 along with insignificant standard deviation qualify to be the most stable variety.

Relative growth rate (RGR) is an index of the plant's potential to accumulate dry matter over a given period of time. An aggressive growth form is the preferred type for mix crop situation where the legume is to compete for the available resources of moisture, nutrients and light. The RGR studies were conducted on eight elite selections of *Clitoria* at two stages of growth, i.e., 40-50 days and 51-60 days. The result indicated considerable genotypic variation in the whole plant growth rate and the growth of its components such as leaf and stem at both the stages of plant growth. During the first growth phase (40-50 days) the stem part of the
plant showed almost twice as much RGR as the leaf component, but at the later stages such differences were not as much clearly marked. In general the RGR of the whole plant and its components was considerably reduced with age of the plants. The results indicated that high RGR at the first stage of plant growth was accompanied by a relatively higher leaf/stem ratio than at the later stages of growth. The leaf/stem ratio was strongly associated character with the RGR of the stem component at both the stages of plant growth. Plants with low initial dry matter yield tended to grow more aggressively than the ones with high initial dry matter yield. The results indicated that the selection for aggressive growth types could be based on high leafiness of the plants. Very high values of coefficient of variation for each RGR value at both the phases of plant growth indicated ample scope of selection of aggressive growth types in *Clitoria*. This legume by virtue of its fast growth habit and trailing nature could be recommended for mix cropping with tall growing grasses for increasing the nutritional value of the mixed swards.

The results of various grass-legume combination treatments on productivity and nutritional quality involving three native grasses viz. *Chrysopogon fulvus*, *Heteropogon contortus* and *Cenchrus ciliaris* and two legumes viz. *Clitoria ternatea* and *Leucaena leucocephalla* (subabul) have been reported in the present study.

Under the sole crop situation all the grass species except *Heteropogon* produced significantly higher dry matter yield than *Clitoria*. The percentage CP in the *Clitoria* forage (19.7%) was nearly three times to that of the grasses (4.6 - 7.4%). As a result of very high crude protein content of *Clitoria* forage its CP yield in the pure stand was also significantly higher than the grasses. Amongst the grasses *Cenchrus* as a sole crop produced maximum CPY followed by *Chrysopogon* and *Heteropogon*.

The legume *Clitoria* as a companion crop of the grasses helped to increase the dry matter and crude protein yield of the mixture (*Clitoria* + grass) by a significant margin over the sole stands and of the grass. But when compared with the CPY of the pure crop of *Clitoria*, the only beneficial combination was *Clitoria* + *Cenchrus* where a gain of 17.6% CPY was obtained. The grass *Heteropogon* despite being the lowest producer of DM and CP yield in pure stand was most benefitted by its association with *Clitoria*.

All the combinations of the Subabul with the different grasses produced significantly higher DMY and CPY as compared to the pure crop of the grasses and also to all the *Clitoria* + grass combinations. When two legumes viz. *Clitoria* and Subabul together were mix cropped with the different grass species the percentage increase in yield of the mixture was 159% to 276% in DM and 69 to 118% CP yield over the sole crop of *Clitoria* and 68% to 131% DM and 205 to 548% CP yield over the sole crop of the grass species. The three species combinations
also resulted in an increase of 54 to 76 % DMY and 76 to 137 % CPY over Clitoria + grass. As compared to the pure crop of the grasses the CP yield of the Clitoria + grass plots increased by a margin of 73 to 174 %. Subabul + grass 150 to 300 %

In all the combination treatments of grass + Clitoria the proportion of the grass component of the mixture was 52 to 67 % for DM and 30 to 51 % CPY. In all the combinations of grass + Subabul the proportion of the grass component to the total DMY and CPY of the mixture was 43 to 60 % for DMY and 20 to 41 % for CPY. When Clitoria and Subabul together were intercropped with different grasses the relative contribution of the different components to the total biomass ranged from 20 to 27 % for Clitoria, 34 to 45 % for Subabul and 28 to 46 % for the grasses.

The studies indicated that the most beneficial combination in terms of crude protein yield was Clitoria + Subabul followed by three species combination, Clitoria + Cenchrus + Subabul. The later combination also produced the highest DMY amongst all the treatments.

The positive response of the grass-legume combinations over the pure stands increase progressively over the years. The average productivity of biomass from the grass-legume mixture increased from 4.60 t/h in the establishment year to 7.72 t/h in the third year of growth, an increase of 68%.

The result is of considerable significance because it reveals special adaptation/preference of the fast trailing legume Clitoria for the tree legume Subabul. In natural pasture conditions interstend with wild bushes Clitoria may be the ideal legume forming a thick canopy of its trailing branches over the shorter growing bushes/trees which could easily be browsed by all types of wild and domesticated animals.

One of the characteristic feature of all the grass-legume mixture is that the companion grasses are enriched by higher protein content in the forage at the expense of the legume components. Protein enrichment of grass through the association of legume was inversely related to the inherent value of the grass proteins under sole crop situations. The percentage proportion of protein in the Clitoria forage was reduced from a level of 19.69 % as a pure crop to a level of 14 to 16.6 % when intercropped with the different grasses. The crude protein content of the grass species increased from sole crop situation to crop mix situation with the different legumes. This increase was from 5.7 to 6.1 % in Chrysopogon, 4.57 to 5.32 % in Heteropogon and 7.4 to 7.6 % in Cenchrus.

In all the three years of the study the first cut yield of Clitoria in all the treatments was significantly higher than the second cut yield. The first cut yield of the Clitoria and the mean
yield of all the years was significantly higher in the pure stand and in combination with subabul than in any other grass - legume combination treatments.

Environment in the different years had a profound effect on the dry matter yield and its crude protein content (%) in *Clitoria*. The dry matter and crude protein content in forage decreased progressively, often significantly, from first year to the third year of growth. Only in case of *Clitoria* + *Cenchrus* + Subabul treatment there was a significant improvement in the crude protein content of the *Clitoria* forage from the first year to the third year of growth.